Agromyzid Flies of Some Native Legume Crops in Java

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Preface

Among all insect pests that attack grain legumes in tropical to subtropical Asia, Africa, Australia, and Oceania, tiny flies belonging to family Agromyzidae (Diptera), commonly known as "beanflies", are probably the most destructive. The insects have a wide host range among cultivated legumes and infest plants from emergence until harvest. The infestation, especially in seedling stage, can result in total crop destruction.

Pioneering research on beanflies was done early in this century in Indonesia where these insects cause considerable damage, especially to soybean. Dr. P. van der Goot, a Dutch entomologist, made detailed observations of these pests and published a bulletin "De Agromyza - Vliegjes der inlandsche katjang-gewassen of Java" in 1930. This publication contains a wealth of information on the biology and control of agromyzid flies in Java. However, this information remained inaccessible to non-Dutch speaking researchers. In fact, scores of research papers and theses have been published on beanfly pests without referring to this pioneering work.

At the Asian Vegetable Research and Development Center (AVRDC), intensive research is carried out to improve the yield potential of soybean and mungbean, two of the principal hosts of beanflies. A major portion of our entomological research activity is, therefore, devoted to their control. Besides developing new pest control technology, we consider it important that, as a principal research institute working on soybean and mungbean, that we make available to national programs and concerned scientists maximum information on these crops. It is with this purpose in mind that we decided to translate the original Dutch publication into English.

I would like to acknowledge the special efforts made by Mr. Tobias van Hameren, Agricultural University, Wageningen, The Netherlands, who did the translation during his tenure as a research scholar at AVRDC during summer 1983. I wish to thank Dr. G. W. Selleck, Director General and Dr. R. T. Opena, plant breeder, Mr. E. W. Sulzberger, Information Officer, AVRDC, and Dr. J. A. Litsinger, Entomologist, IRRI, for reading through the manuscript and making valuable suggestions, and Mr. Omar O. Hidayat, plant breeder, Sukamandi Research Institute for Food Crops, Sukamandi, West Java, Indonesia, for providing names and Indonesian spellings for the places and crops mentioned in the text. Typing was done by Miss Angela Chen.

In translation, I have changed old Latin names of crops to currently accepted ones. I have retained the old name of one beanfly species, *Melanagromyza phaseoli* Coq., throughout the text but have indicated the recent change in nomenclature to *Ophiomyia phaseoli* Tryon in the introductory chapter.

Shanhua,
5 November 1984.

N. S. Talekar
Entomologist, AVRDC

Agromyzid Flies of Some Native Legume Crops in Java

Introduction

The disease and insect pest problems of the indigenous secondary crops have not received adequate attention from the point of view of research. While the insect pests of rice in Java have been extensively investigated, and their economic importance, biology and control methods studied, our knowledge of pests of secondary crops remains poor. Koningsberger (1903), in his book "Diseases of Secondary Crops", gives few details on the pests of secondary crops, and in later years these gaps have been filled only slighly. Only the information on vertebrate pests of cassava has been updated by the experiments of Leefmans (1915).

Since 1919, the writer of this article has initiated research on various pests of indigenous legumes. The research showed that soybean (*Glycine max*) in particular is severely damaged by various insect pests. A consice summary of various soybean pests will be published separately. This publication brings together information on some of the important insect pests of soybeans, namely Agromyzid flies.

Little information is available in the literature on the *Agromyza* of soybean in the tropics and the information gathered during the course of this investigation is still inadequate. Zehntner (1900) was the first researcher to pay attention to these pests, and wrote in "De Indische Natuur" a consice description of this insect and gave a scientific name *Agromyza soya* Zehntner. In subsequent years nothing has been added to our knowledge of this fly.

As with every pioneering work, either in entomology or other fields, the work of Zenhtner had some inaccuracies, and it seemed advisable to investigate the subject once again. Further research also brought new facts to light. One of them was that with soybean we deal not only with one, but with three *Agromyza* species each with its characteristic damage. Further, it was found that these species also attack other legumes and in one of them, common bean, it is a serious pest. We will distinguish these species and discuss the details in the next chapter.

1. Soybean fly (*Melanagromyza phaseoli* Coquillett)[1], is a pest of soybean and several other legume species in the early growth stages. Its larvae bore into the cortex near the root collar and its damage can result in the death of many plants.
2. Soybean stemborer (*Melanagromyza sojae* Zehntner) infests older soybean plants. The larva bores into the pith of the stem and seldom causes plant mortality.
3. Soybean topborer (*Melanagromyza dolichostigma* De Meijere) is a pest of older soybean plants. It also infests rice bean (*Vigna umbellata*). The larvae bore into the top and the plants consequently look stunted.

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[1]This insect is now classified as *Ophiomyia phaseoli* Tryon.

SOYBEAN FLY

Melanagromyza phaseoli

Introductory Remarks

Although the soybean fly has yet to be recorded in the literature in Java, there are indications that this insect has been observed there as a damaging pest. For example, if we read the old description of *Agromyza sojae* by Zehntner (1900), then we see from the description and the drawing on page 122 (Zehntner 1900), that he undoubtedly encountered *M. phaseoli*. Zehntner thought this insect to be the same as soybean stemborer because he found the larvae in the pith of older plants. The name *Agromyza sojae* Zehntner, therefore, can be assigned to the latter species after Zehntner. In Indonesian literature (van Hall 1923) there are casual reports of *Agromyza* larvae being harmful to beans and other legumes. Further details are rarely given. It is nearly certain that in most cases one is dealing with *Melanagromyza phaseoli*.

Our research showed that this fly is found all over Java, and in some areas it is quite serious. It is an especially an important pest of various bean species such as common bean (grain and vegetable type) and all other varieties of *Phaseolus vulgaris* which are frequently grown by farmers in Java at elevations from 400 to 1,200 meters. In the lowland, this insect is serious on young soybean plants, especially in those areas where the crop is sown in tilled soil rather than in rice stubble.

In terms of geographical distribution, Java is the only area where *M. phaseoli* damages crops. The insect was first recorded and described by Coquillett (1899) from Australia (New South Wales and Queensland) where it was reported as a serious pest of beans (*Phaseolus vulgaris*). It is also reported in the Philippines, various parts of our archipelago, Malaysia, Ceylon (Sri Lanka) and also, although it is not yet determined with certainty, from various parts of India (Pusa, Bengal, Madras), Mauritius, and southern China. It is also suspected to be present in Manchuria and Japan, two areas where soybean is grown extensively, but so far no definite information is available. According to Professor S. Kuwaka's oral information in 1929, this insect is not found in Japan.

In North America, the insect probably does not occur. On the other hand, there is high probability that the *Agromyza* species recorded in Rhodesia (Zimbabwe), *Agromyza fabalis* Coq. in common bean and cowpea is identical to our fly.

In all countries where *M. phaseoli* was reported, it was considered as a serious pest, especially on beans and other legumes. A detailed investigation of the life history of our fly was conducted in the Philippines by Otanes in 1918. A good publication by Otanes (1918) gives detailed information which is important to us in Java and to which we will refer several times.

For comparison to the situation in Java, the reports of damage caused by *M. phaseoli* Coq. in foreign countries are summarized below:

Australia: Especially harmful to bean species (French bean) and cowpea (*vigna unguiculata* ssp *unguiculata* cv. gr. *unguiculata*) in Queensland and New South Wales.

Philippines: Very harmful to cowpea and kidney bean.

Ceylon (Sri Lanka): Very harmful to common bean, cowpea, pea, *Vigna mungo*, and chick pea (*Cicer aerietinum*).

India: Very damaging to bean, cowpea, hyacinth bean (*Dolichos lablab*), and *Vigna mungo*.

Straits Settlements (Penang, Singapore, and Mallaca): Damaging to lima bean (*Phaseolus lunatus*).

China (Canton): Harmful to *Phaseolus vulgaris* and lima bean.

Mauritius: Damaging to mungbean (*Vigna radiata*) and common bean.

Rhodesia (Zimbabwe): Recorded as *Agromyza fabilis*, it is very damaging to cowpea and bean.

The scientific name of our beanfly, *Agromyza* (*Melanagromyza*) *phaseoli* Coq. was given to us by the specialist, Malloch (Urbana, Illinois, USA) who identified our Javanian specimen with types from Australia and the Philippines. The same identification was received from Professor De Meijere in Amsterdam.

Although the insect damage was known to local farmers, they apparently have not given it any special name. Only in Lembang dialect, do the people speak of hamagingsir[1] to describe *Melanagromyza* injury.

In English speaking countries, *Melanagromyza* is usually given the name "beanfly". For our condition, the name "Katjang Vliegje" (soybean fly) seems to be the most desirable one.

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[1] According to A. J. Koens (Alg. Landbouwweekbld V. Ned-Indie dl. 7, No. 47, 1923, bldz 2367), word "gingsir" would mean "untimely planting". The literal translation of the word is "shift, remove, change".

2

Morphology

The description of various developmental stages given in this chapter is concise and, for practical purposes, adequate to identify the species. For further details, readers are referred to systematic literature[1].

Egg:

The eggs are transluscent, short and oval; on both ends they are identically truncated. The surface is completely smooth. The length is generally 0.31 mm and width 0.13 mm.

Larva:

The larva is oblong, curved at the end of the head, acuminate towards the mouth, and round at the anal end. The newly emerged larva is nearly transparent but the color changes to transluscent or yellowish white before pupation. The mouth hooks are always black; and prothoracic and anal stigma are always grey white. The fully grown larvae are 2.82 to 2.97 mm long, 0.56 mm wide. Length of anal horns is 0.10 mm.

A fully grown larva of *M. phaseoli* can easily and accurately be distinguished from other *Melanagromyza* larvae in some plants even with a simple magnifying lens. In *M. phaseoli*, the prothoracic stigmata are slightly projecting out and have little hornlets, while the anal stigmata are very clearly stalked and have a widened comb-shaped (pectinate) structure. With *M. sojae*, the prothoracic stigmata do not stalk out, while the anal stigmata have black and hardened protruberant discs. With *M. dolichostigma*, both prothoracic and anal stigmata are long, sometimes curved like horns, and are not widened at the top.

In doubtful cases, higher magnification offers additional morphological characters. The head shows a peculiar, nonchitinous, worm-like protruberance on the top which is lacking in other *Melanagromyza* species. The mouth hooks have one big and one small downward directed tooth. The body has clear transverse striations. Prothoracic stigmata jut out with a short stalk ending in a comb-shaped top with 5 round button-like structures. Anal stigmata have a short clearcut stalk and at the top, on both sides, have a branched comb-shaped structure with 4 to 5 round buttons. For further details see Figure 1, a and b.

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[1]Systematic description of the fly can be found in Proc. Entomol. Soc. Washington 18:93, 1916. There it is eroneously called *Agromyza destructor* Malloch. A detailed description was further given by Prof. De. Meijere (Bijdragen tot de Dierkunde 22:17, 1922).

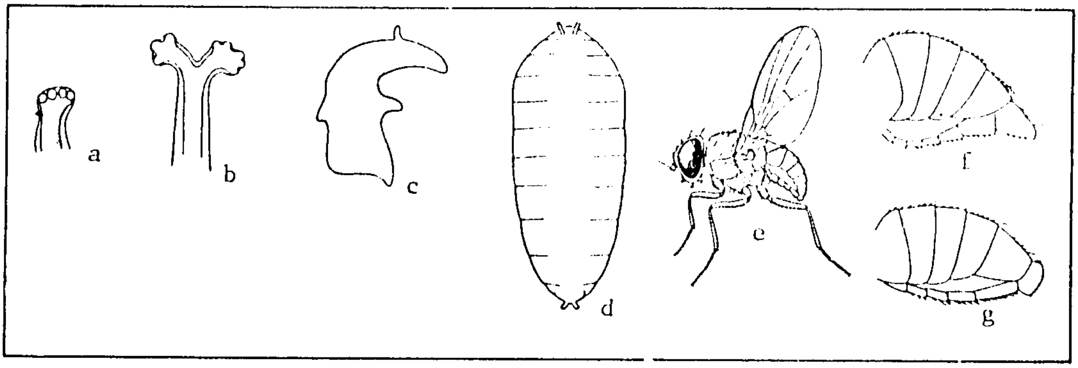

Figure 1. *Melanagromyza phaseoli*: a. prothoracic stigma of larva, b. anal stigma of larva, c. mouth hook of larva, d. pupa, e. adult, f. side view of the abdomen of an adult female, and, g. that of an adult male.

Puparium:

The puparium, initally yellow colored, changes to yellowish-brown. The stigmata hornlets at both head and anal ends are similar to those found in the larva. The margins of the body segments can be seen clearly with a magnifying lens. The puparium size varies from 2.25 to 2.30 mm long and 0.95 to 1.05 mm wide.

Adult:

The adult fly, which is grey-balck immediately after emergence becomes black, especially on the abdomen. The eyes are dark brown, antinnae and legs completely black, wings clear, and the halters black with light brown stalklets.

Both sexes can be clearly distinguished. The female is bigger than the male. The end of the abdomen is rounded off in the male, whereas it is longer with a short and clearcut ovipositor in the female (Figure 1, f and g).

The females are 1.88 to 2.16 mm long, 0.70 mm wide at the thorax and have a wing expanse of 4.45 mm. In the male, body length is 1.60 to 1.84 mm, width at the thorax 0.60 mm and wing expanse 3.80 mm.

For further details, please refer to Figure le.

3

General Biology

For the description of biology, we will restrict ourselves to those crops such as common bean which suffer most from soybean fly.

The information was collected in the Bogor area during 1919 to 1923. Since the pest is more serious in mountain areas, studies were also made at Lembang (elevation 1,200 m) during 1921-1922 on the biology of the pest in the highlands. Data on the biology of the pest in lowland areas are lacking. However, such data will not differ much from the information obtained at Bogor as demonstrated by similar observations for *Epilachna* and rice borer.

Oviposition:

The small black *Melanagromyza* flies, which are observed on the top and underside of the leaves, deposit eggs in the leaves, never in the petioles or stems. For this purpose, the fly bores a hole on the upper side of the leaf and deposits a whitish oval egg between the upper and lower epidermis. The egg is not visible from the outside, but it is seen if one holds the leaf against the light or clears it with alcohol. The eggs, sometimes a large number of them, are dispersed throughout the leaf lamina. However, the majority are located near the base of the leaf. The egg incubation time is very short and the larvae emerge within 40 hours. In mountain areas, the egg stage is noticeably longer; in Lembang, eggs hatch after three to four days. The emergence of larvae from the eggs occurs at any time of the day.

Larva:

The newly emerged larva, although a transparent greenish-yellow, can be noticed without difficulty in the green leaves, because the black mouth hooks, by their regular movement, are clearly seen through the leaf epidermis. Soon after emergence, with the help of mouth hooks, the larva starts digging a long small tunnel in the mesophyll, usually just under the epidermis of the under side of the leaf. At times, these tunnels can be seen on the upper side of the leaf. Initially the direction of the mining tunnel is always towards the top, then irregualr, and later towards the leaf base.

In approximately two days, through the irregular tunnels, the larva reaches the leaf base from where it continues its downward movement through the petiole, remaining just below the epidermis. The larva eats its way nearly straight downwards through the stem cortex tissue upto the root collar. At this point it restricts itself to eating the deeper cortex tissue in surrounding area. At this stage, the full grown larva pupates in the spongy tissue, usually below the epidermis and just under the soil surface. The puparium cannot be observed from the outside.

Because of the hidden mode of life, development time for the larva cannot be determined accurately. In Bogor, the larval stage took an average of 10 days. In 100 rearing experiments, the minimun time for larval development was 7 days and the maximum 11 days. In the mountain area (Lembang), the larval stage lasted from 17 to 22 days.

Puparium:

The yellow brown pupa ("tubelet") is usually found at the root collar, and always beneath the soil surface. This location of the pupa could be related to favorable moisture conditions. In the most preferred host, such as common bean, one can find several pupae in one plant. A maximum of 30 pupae were found in one bean plant.

Since the pupa is hidden from the view, the length of the pupal period is difficult to determine. In 100 rearing experiments at Bogor, the pupal stage, on an average, lasted 9 days, ranging from a maximum of 13 days to a minimum of 7 days. When full grown larvae ready for pupation in infested plants were removed, the pupal period lasted for nine days. In the mountain area (Lembang), the pupal stage took noticeably longer, from 13 to 20 days.

The total time for development of *M. phaseoli* from oviposition to adult emergence, based on 90 observations at Bogor, varied from 17 to 26 days with an average of 21 days. In mountain areas like Lembang, due to lower temperatures, the total development time from egg to fly was strikingly longer. Based on 20 observations, it was 39 to 47 days, with an average of 43 days in cooler months (14°C to 23°C) and only 30 days in normal months (18°C to 25°C)[1].

Adult:

After emergence from the pupae, the black flies work their way to the outside through cracks in the epidermis and then through thin layer of soil in their search for a susceptible host plant. One can observe them, often in the early morning, sitting on the upper or lower surface of leaves.

Soon after emergence, copulation takes place, at times within two days, but on an average of five days. Copulation always occurs in the morning between 7 and 10 AM. One can find only rare cases of copulation after this time, as Otanes has observed in the Philippines. Only on overcast days one can observe more copulation at odd hours (later than usual). It is possible that the time of copulation depends on temperature. In Lembang, I never observed copulation in the

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[1]The day temperature at Bogor during the experimenral period varied from 24°C to 31°C.

open field before 8.30 to 9.00 in the morning. At the same time, the copulating couples could be commonly found until 12 noon to 1 PM. The duration of copulation is rather long, 1 to 2 hours, and the place of copulation is usually on the upper side of the leaves. Soon after insemination, females start egg production.

The deposition of eggs occurs only in the leaves of the host plant, never in the petiole or in the stem. The earlier opinion that the eggs could be deposited near or in the root collar is incorrect. In some crops, oviposition takes place in all leaves, while in others this occurs only in unifoliate leaves. During egg laying, with the help of ovipositor, the fly bores a hole from the top end sloping downwards into the mesophyll, and deposits one egg in the hole. On the upper side of the leaf, a round egg hole can be seen encircled within a light-colored oblong and oval lesion. The egg itself is not clearly visible from the outside.

Not all egg holes contain an egg. The female makes many holes and sucks the plant juice oozing out of the holes for sustenance. Such food holes cannot be distinguished from egg holes. Only after a few days, small perforations (mainly in cowpea) occur in the leaf tissue with food holes, whereas such perforations are never obseved with egg holes.

The food holes of *M. phaseoli* in soybean can easily be distinguished from those of *M. sojae*. The food holes of the latter are always long and stripe shaped. The egg holes of *M. sojae* which are always round, as we shall later see, are always found on the underside of the leaves. The total number of eggs that one female can produce has not been accurately determined. Otanes, from five observations, reports a total of 113 to 330 eggs per female. The flies live from 9 to 21 days. In our study, the flies lived for much shorter period and thus the total number of eggs laid was less. From 12 observations, we found on an average of 94 eggs per female, with a maximum of 183 and a minium of 16. The flies deposited 49 eggs per day. Such egg production figures donot give a true picture of fly multiplication in nature. Only a small percentage of these eggs develop fully. Indeed, the percentage of eggs that donot hatch is practically nil, however, the number of pupae seldon exceed four or five per plant. Thus a considerable number of larvae are killed due to "over production".

Some information on the multiplication of fly population was recorded from six observations, each consisting of 11 to 125 flies. The average number of flies that emerged from each group was 56. Based on this figure, the direct muliplication of this insect is not very high. The number of generations in the lowland, however, is considerable; up to 14 per year. Thus, in just a short time, there is a considerable increase in population.

The adult life span of this insect in confinement could be consicerable, given ideal conditions such as feeding honey and water. In 100 observations, with males and females separated immediately after copulation and maintained in glass tubes, the females could live up to 45 days, with an average of 19 days, and males upto 43 days, with an average of 18 days. In other studies, flies were kept alive for 49 days, and in studies at Lembang their maximum life span was 29 days.

Presumably, in nature, their longevity is considerably shorter. In our experiments with small net cages, flies died much earlier, usually within 8 to 13 days. In a laboratory trial with glass tubes, humidity most likely had a favorable impact on fly longevity.

As pointed out earlier, the food of the flies consists of plant sap oozing out of the wounds made by the females with ovipositors in the leaves. The males rely on the moisture droplets on the leaves for food. Like the females, the males also seem to have a great need for the water droplets.

4

Susceptible and Immune Host Plants

As far as is known, *Melanagromyza* only attacks plants belonging to the Legume family. Of these, however, only a small number of species serve as host plants and among them, only a few suffer serious damage.

It is important to know which crop plants are attacked and which green manure and wild legumes serve as sources of reinfestation. The search of literature published to date provides the following available information.

Susceptible hosts:

A. Cultivated plants
- Soybean (*Glycine max*)
- Common bean (*Phaseolus vulgaris*)
- Lima bean (*P. lunatus*)
- Cowpea (*Vigna unguiculata* ssp *unguiculata* cv. gr. *unguiculata*)
- Mungbean (*V. radiata*)
- Rice bean (*V. umbellata*)
- Pigeon pea (*Cajanus cajan*)

B. Green manure crops
- *Crotalaria juncea*
- *Vigna hosei*
- *V. mungo*
- *V. umbellata* (var. "*trinervis*")
- *V. radiata*(var. "*sepiara*")

C. Herbs
- *V. trilobata*
- *P. semierectus*

Immune hosts:

A. Cultivated plants
- Peanut (*Arachis hypogaea*)
- Yam bean (*Pachyrrhizus erosus*)
- Peas (*Pisum sativum*)
- Winged bean (*Psophocarpus tetragonolobus*)
- Kacang kowas (*Macuna utilis*)

B. Green manure crops
- *Tephrosia candida*
- *Crotalaria usaramoensis*
- *C. anagyroides*
- *Sesbania aegyptica*
- *Indigofera suffruticosa*
- *Lupinus angustifolius*
- *Mimosa invisa*
- *Colopogonium mucunoides*
- *Centrosema plumieri*
- *Desmodium gyroides*
- *D. stipulaceum*

Leucena glauca

C. Herbs:

Crotalaria striata
Flemingia sp.
Cassia leschenaultiana
V. sublobata

This list of host plants does not quite agree with observations in other countries. For example, in the Philippines, soybean is regarded as a non-preferred host, whereas in Java this crop is heavily damaged. In India, it is damaged by an *Agromyza* species. In the Philippines, *Cajanus cajan* is regarded as a non-preferred host, whereas in Java it suffers some insect damage. Other differences, especially in the Philippines, will be reviewed later.

5

Nature of Damage in Different Crops

The nature of *M. phaseoli* damage to different hosts and the reaction of the hosts to attack varies from one crop to another. In general, the plants are more heavily damaged when they are young. It is thus considered a seedling pest problem. However, its consequences are also manifested in older plants.

The nature of damage in various crops is described below:

Common bean *(Phaseolus vulgaris)*:

On common bean and other varieties of *P. vulgaris*, flies are seen on plants before the unifoliate leaves are barely developed[1]. With further growth, however, the number of flies decreases, and after the development of the fifth leaf flies are rarely seen. At this time, the bean plant starts bearing pods. Thus, not only seedlings but also slightly older plants suffer damage from this pest.

Nature of damage: The most serious damage undoubtedly occurs at the unifoliate leaf stage. In fact, almost all bean plants show a large number of egg holes. Oviposition can take place even in upper leaves. This frequently occurs on the third leaf (the first trifoliate leaf). The fourth leaf shows some egg holes, but the leaves situated above it are usually undamaged.

Some information on the differences in damage to different leaves was collected in 1919 at our experimental station at Bogor. Based on 12 observations involving 4,400 plants, the average injury to the unifoliate leaf amounted to 92.7% and to the second trifoliate leaf, 1%.

In the case of injury to the unifoliate leaves (see Figure 2a), we see numerous small egg holes on the upper side with corresponding light yellow spots, especially on the basal portion of the leaf. The larval mines are more visible on the under side of the leaves and appear as numerous silvery curved stripes just under the epidermis. On the upper side, we usually see only a few tunnels which are not very complex, and these tunnels continue on to the under side of the leaf where they appear as wide white stripes. Later, the egg holes and larval mines become dark brown and are clearly visible. Through the petioles and stems, larval mines can be easily seen under the epidermis as wide, straight, white stripes.

On upper leaves the egg holes are made in a fashion similar to lower leaves, but there are few corresponding larval mines.

On common bean, infestation is very common and nearly

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[1]By this, I mean the first pair of leaves that always have different shape.

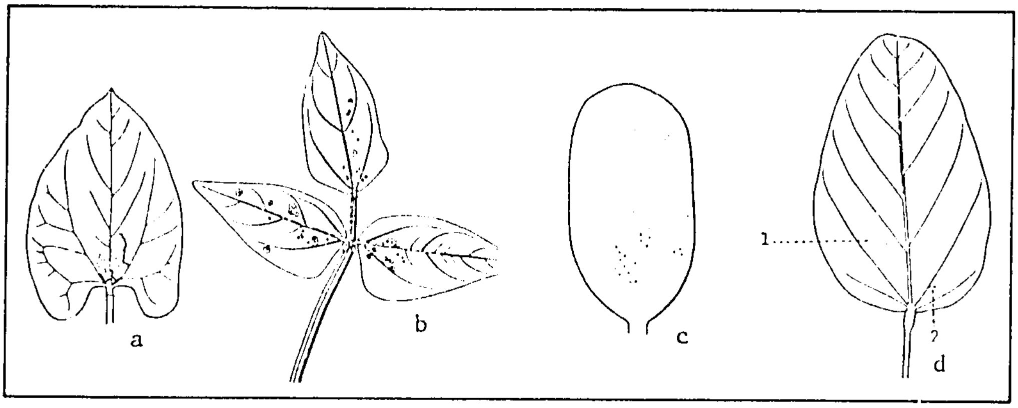

Figure 2. *Melanagromyza phaseoli*: a. egg holes and larval tunnels in the leaf of common bean, b. food holes in the top leaf of yard long bean, c. egg holes and larval tunnels in the cotyledon of soybean, and d. larval tunnels of *M. phaseoli* (1) and *M. sojae* (2) on the underside of unifoliate leaf of soybean.

every plant in the later growth stages contains *Melanagromyza* pupae. In our experiment, 15 observations showed this trend.

Among 2,000 plants at the first true leaf stage, none was undamaged, 6.3% showed some brown coloring at the root collar, and 63.7% contained pupae inside. The number of pupae within a plant can be considerable, especially in a vigorous plant that can "grow through" the infestation. A maximum of 30 pupae were found in one plant. Usually, the numbers ranged from 7 to 10, with an average of 4 pupae/plant.

Reports in foreign literature indicate that the larvae feed and pupate in the petioles of top leaves. I observed similar damage only in the laboratory under abnormally heavy infestations which severely affected plant growth. In the open field, as well as in our experimental plots in mountain areas, I never encountered pupae in older petioles. No more than a mere swelling of petioles was observed. Such swellings, according to other researchers, is abundant when *M. phaseoli* infests the plants. In common bean at harvest time, I often found fresh pupae of *Melanagromyza* remaining in the root collar. In this manner, I once counted 554 empty pupae and 375 that were still intact. This led me to conclude that despite infestation of older leaves, pupation still takes place at the root collar.

Response of host plant: The infestation of common bean by beanfly is usually total. The developing larvae eat and tunnel rapidly downwards until they arrive at the root collar. The cortex tissue at this point is severely damaged. As there are several larvae in a localized area, the cortex tissue is often devoured around the root collar. Hence there is severe disturbance in the transport of nutrients.

If the cortex tissue is almost completely destroyed, the result is fatal to the plant. The plant that continues to "grow through" (tolerate) the infestation suddenly starts to fade, the first true leaves wilt, and within a few days, the plant dies. The first occurrence of this symptom is usually at the age of three to four weeks. In many cases, the dying off caused by southern blight or *Sclerotium rolfsii*, occurs faster and earlier.

If part of cortex tissue remains intact, as usually is the case, the plant continues to grow for the time being. In the case of heavily infested plants, a clear thickening of the stem is usually accompanied by abnormal growth above the root collar.

The plant tries to develop a new root system above the point of injury by forming adventitious roots. These roots can develop in one or more rows on the stem from the place of injury. In wet weather, the lowest adventitious roots can reach considerable length and indeed can compensate the loss of much of the root system (Figure 3).

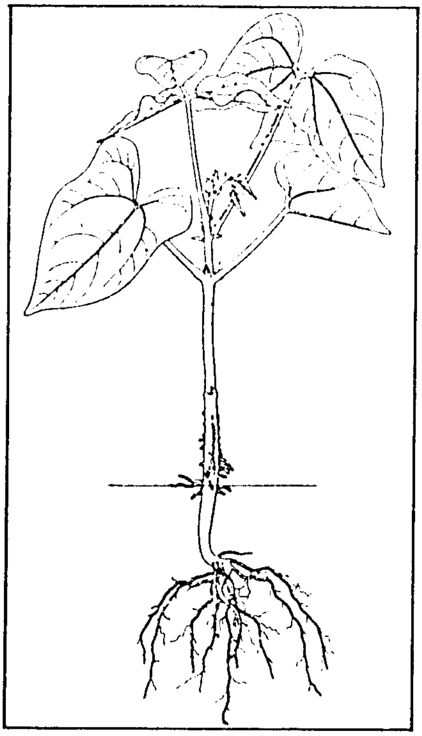

Figure 3. *Melanagromyza phaseoli* damage and resultant adventitious roots in common bean.

Extent of damage: Depending upon the severity of the infestation and the amount of rainfall and fertility status of the soil, the plant can grow through the infestation and still produce adequate yield, or grow slowly and die. The death of the plants occurs usually during the dry season, or if the crop is planted in less fertile soil where beans are grown year after year. In such soil, the plants die one by one, which results in considerable yield loss. The die-off starts with light discoloring of the trifoliate leaves which can be seen from a distance. Soon after, the unifoliate leaves fall, followed by the trifoliates. Stunted plants rarely survive.

The die-off of unifoliate and trifoliate leaves is caused less by the mining of mesophyll tissue than by the tunneling of petioles by the larvae. When the damage is serious, the plant tissue is discolored by brownish larval tunnels inside the petiole. The transport of nutrients to the leaves becomes impeded, resulting in premature death of the leaves.

Those leaves in which the beanfly adult makes only feeding holes are not significantly damaged by this type of infestation. The small holes enlarge, and damaged unifoliate leaves yellow prematurely and usually drop off.

Soybean *(Glycine max)*:

Soybean distinguishes itself from other legume species in that *Melanagromyza* uses the cotyledons for egg deposition. In most susceptible bean species, such as common bean, cowpea, and mungbean, after germination the cotyledons emerge as shriveled structures or soon drop off. As such they are the least suitable for egg laying. With soybean, however, the cotyledons are large, green, fleshy, and become yellow only after 12-14 days. This provides ample opportunity for egg laying.

Nature of damage: In common bean, even the oldest leaves are damaged but in soybean, *Melanagromyza* is predominantly a seedling pest. The cotyledons are always heavily damaged. The unifoliate and trifoliate leaves show egg holes, but none of the upper leaves are damaged[1]. In our experiment, 50 observations involving 36,000 plants showed that on an average, 80% of the cotyledons, 79.7% of the unifoliate leaves, and only 12% of the trifoliate leaves were damaged.

As soon as the soybean cotyledons emerge from the soil, which in the lowlands is usually five days after sowing, we see *Melanagromyza* flies boring on the upper side of the fresh cotyledons. Egg holes and larval mines are also found there. Initially, the mines are shining and light-colored, but later change to brown. Initially the mines move upwards, but then form a closed irregular loop (Figure 2c). Further burrowing down the stem usually remains invisible from the outside.

In the case of damage to the unifoliate leaves, we usually see a rather wide, curved tunnel in the mesophyll on the upper side. This tunnel is not continuous as it usually ends at the upper side of the leaf. Initial color of the tunnel is white, which later turns to brown.

On trifoliate leaves, the tunnels always seem to occur on the underside of the leaflets. The tunnels of *M. sojae* and *M. phaseoli* are similar. They are very short and always

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[1]Damaged leaves were considered those in which the larvae bore tunnels indicating thereby that, besides feeding holes, these leaves had egg holes.

go straight to the veins without doing much feeding in the mesophyll tissue. Tunnels from the injury to unifoliate or trifoliate leaves and along the stems are visible as black stripes. These tunnels, however, are not visible when *M. sojae* damages common bean.

The insect can infest soybean successfully, and in the later growth stages one or more well developed pupae can be found in the plants. In 20 observations involving 4,000 six-week old soybean plants, none was undamaged, 44.4% showed brown discoloring of the root collar, and 55.6% contained pupae. On average, there were two pupae per plant with a maximum of five pupae each.

These figures reflect not only the infestation of the cotyledons, but also oviposition in the unifoliate and trifoliate leaves, all of which succeed in infestation. In a separate study on the mode of infestation via different plant parts, infestation was successful in 32.1%, 28%, and 34.4% cases, respectively, via cotyledon, unifoliate, and trifoliate leaves. There was little difference among these figures.

Reaction of the plant: In the underground part of the root collar, *M. phaseoli* larva bores through soybean and common bean plants in a similar fashion. As a result, a number of plants wilt and die immediately. This usually takes place at an age of 3 to 4 weeks at the second trifoliate leaf stage. The stronger plants can form new roots above the damaged parts, while slightly damaged plants usually grow through the infestation without noticeable differences. In the rainy season, adventitious roots form above the soil surface in many damaged plants. These roots are initiated from the stems at the cotyledons and sometimes at the unifoliate leaves, but remain short. Additional growth or thickening of the root collar never occurs.

Cowpea:

Different cultivars of cowpea, especially dwarf types (which are widely cultivated), are damaged in nearly the same manner as common beans.

Nature of damage: In cowpea, we also find a large number of flies on young unifoliate leaves where egg holes are commonly on the basal parts of the leaves. The mining of young larvae is visible on the underside of the leaves where they are seen as transparent twisted lines which attract attention only when the leaves are in a favorable position. Short, interrupted, white-colored tunnels do occur on the top side, but these are not common. When the larvae are actively feeding, the tunnels are visible, otherwise the color of the tunnel is little different from the surrounding tissue.

As in common bean, the upper leaves of cowpea (dwarf type) are damaged by *Melanagromyza*, yet the injury to the unifoliate leaves is always the heaviest. Observations at our experimental farm in Bogor showed that, on average, damage to the unifoliate leaves was 63.6% compared with 42.3% to trifoliate leaves. The mining of upper leaves is similar to that of the unifoliate leaves except that it is sporadic.

It was observed that the larvae from infested unifoliate leaves are not well developed, while those feeding on upper leaves are much stronger. The tunnelled area behind the progressively feeding larvae is empty. At times, especially in rapid growing cultivars, the top areas of the stems just under the epidermis contains a bladder-like structure which usually holds one or more pupae. A wide, short tunnel leads them to one of the top leaves. Otanes (1918) and others report that with injury to the older leaves, *Melanagromyza* larvae generally stay in the petioles. Damaged petioles are swollen and break off easily. I never observed these symptoms in Java.

Like egg holes, the feeding holes are also important in cowpeas (dwarf type). The feeding holes can be distinguished from the egg holes in that their wounds contain small galls. In the case of the top leaves, which are usually damaged just before they are full grown, feeding holes expand to form white marginal perforated structures throughout the plant. This form of injury is important.

Extent of damage: As in common bean or soybean, the larva causes damage when it tunnels its way down the stem and into the root collar. It is remarkable that the destruction of *Vigna* plant tissue stops when the larvae reach the root collar. The cause of this remains unclear, but in cowpea the larvae often arrive at the root collar, bore only superficially, and then disappear or die without forming pupae. The cortex tissue is superficially black, but damage is rarely serious. We will discuss this subject later. In 20 observations involving 7,000 plants at our experimental station at Bogor, clear mining in the unifoliate leaves was found after one month. There were 53.6% undamaged root collars, 15.6% had slight damage, and 10.9% had deeper damage accompanied by the presence of pupae. On average, there were one to two pupae/plant with a maximum of eight found in one plant.

Based on these observations, damage caused by *Melanagromyza* to cowpea is not significant. After the damage, the plants grow normally, and there is no plant mortality. If we examine infested plants in the later growth stages, the root collar is mostly undamaged. As we will see later, this behavior is different in the Philippines where *Melanagromyza* causes severe damage to cowpea. Neither the abnormal growth on the root collar nor the formation of adventitious roots was ever observed as a result of fly injury.

Mungbean *(Vigna radiata)*:

In contrast with the crops studied so far, *Melanagromyza* injury to mungbean is probably restricted only to the oblong, narrow, unifoliate leaves and is thus considered a seedling pest.

Nature of damage: In mungbean, the flies make holes in the upper surface of the unifoliate leaves, close to the leaf base. The larval mines are found only on the underside of the leaves. These mines are short, initially silvery, and later turn brown. The tunnels along the stems are not visible.

Except for the unifoliate and the first trifoliate leaves, *Melanagromyza* damage was never observed in the top leaves. Efforts to obtain infestation on older leaves always failed under laboratory conditions.

As the young mungbean plants are small, it is understandable that in many cases the larva dies prematuraly due to insufficient food. Although larval mining is evident on most unifoliate leaves, a large number of these plants do not contain pupae. On our experimental field, six weeks after planting, 4,300 plants were observed for unifoliate leaf infestation. The infestation criterion was the presence of clear-cut mines on the lower side of the unifoliate leaves. On average, 5.2% of the plants were undamaged, 43.2% had brown root collar, and 51.6% contained pupae. The average was one pupae per plant, and a maximum of five pupae were found in some plants.

Extent of damage: Of the damaged plants, a part dies at an early stage; others continue to grow but remain stunted. Formation of a few adventitious roots on the stem rarely occurs in damaged plants.

Lima bean *(Phaseolus lunatus)*:

With the usual indigenous varieties, damage is restricted to the unifoliate leaves, and even then we find only a few conspicuous holes per leaf. The initial larval mining of leaves is not easily visible and attract attention only when the tunnels turn brown. The form and course of tunnels are similar to those in common bean and cowpea. The larval tunnels along the stems are clearly marked in both red and green stemmed varieties by the presence of wide, white stripes. The leaves in upper plant parts remain undamaged. This observation agrees with findings in foreign countries.

Nature of damage: The nature of damage is inconspicuous. Among the varieties grown by the people in West Java, only a small percentage of the plants on our experimental farm were infested, and the infestation was so minor that young plants seldom died. With white seeded varieties, the so-called "sebyari beans" (related to lima bean or "butter cup bean", imported from Surinam by Dr. van Hall), *M. phaseoli* caused considerable mortality among young plants. Slightly damaged plants grow through the infestation like common bean by forming adventitious roots up to the cotyledons. Thickening or abnormal growth never occurs at the root collar. Severely damaged plants do not form these roots, but rather wilt and later die.

At our experimental field, damage to cyanogen-containing local varieties ranged from 10 to 20%, while the mortality rate seldom exceeded 5%. The imported, completely white cyanogen-free lima-type varieties, like sebyari beans, were more susceptible to *Melanagromyza* injury. The damage rate of these varieties was at least 50%, while the mortality on our field amounted to 20 to 35%. A few sweet tasting (cyanogen free?) indigenous types like "roay kedelee" (see Chapter 7) were as susceptible as the foreign types (Table 8).

As a host of *Melanagromyza*, lima bean provides some meaningful information. According to observations on our field at Bogor, one finds in cyanogen-free varieties (Sebyari beans), on an average, 5 pupae with a maximum of 17 specimens per plant, whereas in cyanogen-containing local varieties a maximum of only 8 pupae/plant were found.

Vigna radiata var. "*sepiaria*"[1] :

This variety of mungbean is sometimes used as a green manure crop and is damaged damaged in a manner similar to mungbean, i.e. restricted to the unifoliate leaves. At our experimental field, during four observations involving 5,700 plants, 60-90% of the plants had beanfly damage. The plant mortality was rather low (maximum 2.5%).

Vigna mungo:

This green manure crop, classified by many as *Vigna radiata*, is damaged in a fashion similar to other mungbean varieties. Only the unifoliate leaves are damaged, and the mortality of young plants is not significant.

Rice bean *(Vigna umbellata)*:

In the seedling stage, this crop resembles mungbean. Damage is similar to that of mungbean, being restricted to unifoliate leaves.

Vigna umbellata var. "*trinervis*"[2]:

This late maturing variety of rice bean, sometimes used as a green manure, is damaged in a fashion similar to rice bean. At our experimental field in Bogor, observations on 1,000 plants showed 60 to 90% of them to be infested. Mortality averaged 28% with a maximum of 56%.

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[1] In botanical garden, formerly named *Vigna sepiaria*.
[2] In botanical garden, formerly named *Phaseolus trinervis*.

Pigeon Pea *(Cajanus cajan)*:

As in mungbean, damage is restricted to unifoliate leaves. The few mining tunnels become clearly visible only when the leaf turns yellow. Older plants are rarely damaged.

At Bogor, *Melanagromyza* rarely caused injury or mortality in pigeon pea. Based on 10 observations involving 2,100 plants, 25 to 45% were damaged, but the mortality rate averaged only 7%, with a maximum of 26%.

The crop is not very conducive to *Melanagromyza* development. According to our observations at the Bogor experimental field, larvae developed into pupae in only 25% of the infested plants. There was, on average, only one pupa/plant with a maximum of two.

Jack bean (*Canavalia ensiformis*):

Nature of damage: I have been unable to obtain reliable information on this crop. My search in leather-like unifoliate and top leaves for familiar *Melanagromyza* holes and corresponding mines have been unsuccessful. *Melanagromyza* damage was discovered only by the accidental uprooting of plants in our experimental field. Among them, 37% had *Melanagromyza* visible at root collar. The leather-like properties of the unifoliate leaves most likely conceal the damage.

Extent of damage: The damage seems to be very benign and is not visible from outside. Only when plants are uprooted does one notice a depression of the plant tissues at the root collar. There is no evidence of cancerous tissue.

Lablab bean *(Dolichos lablab)*:

The damage is restricted to the unifoliate leaves; the upper leaves are not damaged. Similar observations were made by Otanes in the Philippines. The nature of damage to the unifoliate leaves is similar to that in common bean and lima bean. Numerous holes are found at the base of leaf lamina. The holes and numerous mines in the mesophyll soon turn brown and are easily visible. With severe damage, the leaves are shriveled and the feeding tunnels along the stem are always apparent.

Among the upper leaves, numerous holes are often present in the first trifoliate leaf. In still higher leaves, holes may be present but larval tunnels are absent. Evidently, these are the food holes.

Nature of damage: The damage to lablab bean is predominant in the seedlings. This injury often kills the young seedlings because the infestation of unifoliate leaves can be severe. At our experimental farm in Bogor, many young plants died due to *Melanagromyza*, and the remainder, although damaged, grew through the infestation without forming adventitious roots, cancerous growth, or thickening near the root collar. At one location, all of the plants were damaged, and 20% of them died. On average, there were three pupae/plant with a maximum of six.

Vigna trilobata:

This local herb, called "hiris leuweung", according to laboratory trials, can also be damaged by *Melanagromyza*. A number of holes were found in the unifoliate leaves and in the first trifoliate leaf. In the open field on older plants, *Melanagromyza* damage was not encountered. Hence it is unlikely that this crop could serve as a natural host.

Phaseolus semierectus:

This wild[1] legume, sometimes used as a green manure crop, appears to be damaged in the field by *Melanagromyza*, and is presumably one of the wild hosts of this insect.
Nature of damage: *Melanagromyza* damages unifoliate leaves of this species. Whitish mines in the mesophyll cells can be clearly observed, but stem mines are not visible. Our observations at Bogor experimental field indicate that damage to the first trifoliate and upper leaves is restricted to food holes; egg holes and feeding tunnels are rare. In 2 to 3 week-old plants which produce flowers and tendrils, many flies and egg holes were present in the youngest top leaf. In some cases, short larval mines were visible but fully developed larvae were never found. *Melanagromyza* damage to *P. semierectus* is evidently confined mainly to the seedling stage.
Extent of damage: Instances of thin plant stands of *P. semierectus* used as a green manure crop might be attributed to *Melanagromyza*. In the case of unifoliate leaf damage, some plants grow through the infestation and, similar to common bean and soybean, put out small adventitious roots along the lower part of the stem up to the cotyledons. In our experimental field at Bogor, among 6,000 plants examined, *Melanagromyza* holes were visible in 50% of the unifoliate leaves resulting in 4% plant mortality. Among 171 dead plants, 52 contained one pupa/plant and the rest had traces of damage.

Vigna hosei:

This creeping leguminous crop is also damaged by beanfly, almost exclusively in the seedling stage. Only unifoliate leaves are infested, and trifoliates and new leaves which develop as a result of defoliation remain insect-free. The familiar undulating larval tunnels are

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[1] According to Heijne (De nuttige planten van Ned-Indie 2:838, 1927), the indigenous name of this crop would be "Katjang monjet"

visible on the top side of unifoliate leaves as white stripes.

At our experimental field in Bogor, 43% of the seedlings had obvious *Melanagromyza* feeding tunnels in the unifoliate leaves. The plant does not suffer much damage as infestation, in many cases, is not severe. In Bogor only 10% of the seedlings were killed by *Melanagromyza*, and a maximum of one pupa per plant was found in infested plants.

Crotalaria juncea:

This indigenous green manure crop (Heijne 1927), which has been studied more carefully than the familiar *Crotalaria* species (*C. anagyroides, C. usarnamoensis, C. striata, C. incana, C. alata*), was clearly infested by *M. phaseoli*.

Except at our experimental field in Bogor, two other wild *Crotalaria* species which have large, fleshy cotyledons, namely *C. quinquefolia* (Heijne's publication page 764) and *C. retusa* (Heijne's publication page 765), also show similar damage and thus can be regarded as original wild hosts.

Nature of damage: In *C. juncea*, the damage is restricted to cotyledons which are large, fleshy, and permanent, thus offering a good opportunity for infestation. This was similar to infestation of soybean cotyledons which had egg holes and larval tunnels.

Extent of damage: Although 40-50% of *C. juncea* plants had cotyledon damage at our experimental field in Bogor, plant mortality was not evident. Similarly, only 10% of *C. retusa* or *C. quinquefolia* were damaged, and there was no plant mortality.

Vigna aconitifolia:

This food legume is grown in the dry areas of India. It was imported here by the Garden Section as an annual crop for trial use. This crop was damaged so severely by *M. phaseoli* at Bogor that its cultivation became impossible.

6

Extent of Damage to Cultivated Plants

Earlier we described the nature of beanfly damage to various crops. However, this topic deserves further elaboration by providing additional data regarding the extent of the damage.

Soybean:

Soybean suffers from beanfly infestation only in certain areas. If we investigate beanfly injury in the most important soybean growing areas of Java, such as Sidoarjo, Nganjuk, the Madiun city area, Solo, Grobogan, Brebes, etc., where soybean is grown in rice stubble culture, the beanfly problem is hardly noticeable. Mortality in the seedling stage is non-existent. The presumed cause for this effect will be discussed in the chapter on "Protection".

However, where soybean is sown in tilled fields, for example in parts of Yogja and in the Bogor area on upland and on rice field dikes, the damage to young soybean is serious. In addition to the Selection Garden in Bogor, I observed similar injury in farmer's fields at Ciomas (Bogor), in soybean experimental fields in Yogja and Grobogan, and on dikes of paddy fields near Bandung. Further, beanfly infestation was recorded at the experimental field in Lawang. Beanfly infestation is probably more extensive than commonly believed.

In all of these locations, a large number of young plants die at an age of 3 to 5 weeks. The remaining plants grow, but poor stands considerably reduce the yields.

At our experimental fields in Bogor, we recorded data on damage and plant mortality at various times during the year. The data taken in 60 observations from average infestations are summarized in Table 1. The percentage of damaged plants can reach 70 to 90%. There is little difference in infestation rates at various times of the year, including the rainy season or the dry season. The flies appear to be unaffected by rains.

Despite consistently high damage, plant mortality varies considerably. At Bogor, the plants killed by beanflies range from 1 to 100%. In the rainy season mortality is very low. This is probably due to ideal growing conditions which enables the plant to grow through the infestation. In the dry season, mortality is very high on somewhat less fertile soil or if irrigation is not available.

Cowpea(dwarf type) and yardlong bean:

These two crops are the most commonly grown varieties of *Vigna unguiculata* in Java. Yardlong bean is grown mainly as a stubble crop following paddy rice and often on large

Table 1. Extent of beanfly damage in soybean.

Sowing date	Number of plants				
	total	damaged	dead	% damaged	% dead
2- 1-1919	806	772	335	97.0	41.5
10- 1-1919	481	441	58	91.6	12.0
11- 1-1919	972	674	22	69.3	2.2
21- 1-1919	628	623	43	99.2	6.8
28- 1-1919	768	654	31	85.1	4.0
10- 2-1919	1237	1084	89	87.6	7.2
19- 2-1919	997	781	136	78.3	13.6
22- 2-1919	1039	897	89	86.3	8.5
8- 3-1919	687	631	39	91.8	5.6
3- 4-1919	325	149	50	45.8	15.3
27- 4-1919	1110	792	141	71.3	12.7
9- 5-1919	1245	616	230	49.4	18.4
3- 6-1919	843	521	230	61.8	27.2
21- 7-1919	177	154	150	87.0	84.7
21- 7-1919	1246	1082	462	86.8	37.0
28- 8-1919	224	224	163	100.0	72.2
17- 9-1919	538	507	414	94.2	77.0
22-10-1919	192	192	61	100.0	31.7
7-11-1919	1087	961	61	88.4	5.6

areas like in Indramajoe. Yardlong bean is also planted on paddy field dikes and small dryland plots. Characteristic *Melanagromyza* damage for both crops almost always consists of punctures on the unifoliate leaves and holes in the upper leaves. Yet, plant mortality is rare. This phenomenon is not well understood and could be due to varietal differences. Similar results were obtained at our experimental field in Bogor[1].

The percent plant damage and mortality from 60 observations during different times of the year are summarized in Table 2. In most cases, the damage approaches 100% but mortality is rare. Damage is only slightly less in the rainy season than in the dry season.

As described above, yardlong bean suffers little damage from beanflies despite heavy infestation of the unifoliate leaves. This can be ascribed to the premature death of leaves. This is very peculiar, however, because in Australia, Ceylon (Sri Lanka), and the Philippines, where cowpea is grown, beanfly causes considerable plant mortality.

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[1] In 1923, in Lembang, I observed a poorly growing plot of young plants in which all leaves were full of *Melanagromyza* holes. A number of small plants were almost killed. A similar incidence was observed at our experimental farm in Bogor where plants developed very poorly in infertile soil.

Table 2. Extent of beanfly damage in cowpea (dwarf type).

Sowing date	Number of plants				
	total	dam-aged	dead	% dam-aged	% dead
2- 1-1919	284	266	0	93.8	0.0
10- 1-1919	211	211	0	100.0	0.0
20- 1-1919	152	130	0	85.5	0.0
3- 3-1919	112	96	0	85.7	0.0
3- 4-1919	1037	1023	0	98.6	0.0
9- 4-1919	54	54	0	100.0	0.0
9- 5-1919	30	30	0	100.0	0.0
3- 6-1919	839	836	0	99.6	0.0
14- 7-1919	469	469	7	100.0	1.5
7- 8-1919	79	61	2	77.2	2.5
26- 8-1919	569	561	0	98.6	0.0
17- 9-1919	95	95	0	100.0	0.0
12-10-1919	223	218	0	97.7	0.0
22-10-1919	184	173	0	94.0	0.0

Otanes (1918) presents a detailed account of cowpea damage in the Philippines. Good crops are often not possible in the dry season due to beanfly infestation; 40 to 60% or more plants die and the rest are stunted. In rainy season, mortality is reduced by vigorous plant development.

It is possible that the *V. unguiculata* varieties grown in Java are more resistant to this insect than varieties grown in the Philippines. This subject requires further investigation. It was recently found that a number of varieties imported from America, at present planted in the Selection Garden at Bogor, also survive *Melanagromyza* infestation. In any case, in Java, *M. phaseoli* is not a serious threat to dwarf type cowpea or yardlong bean.

Common bean:

This crop is cultivated mainly at elevations between 400 and 1,200 meters, or even higher. "Kacang djogo" or pod type dwarf variety of *P. vulgaris* is grown in upland fields, on paddy fields bunds, and after the harvest in paddy fields, often in large areas. Since the pods find a ready market among Europeans, its cultivation is expanding. "Kacang boontjies" or grain type-climbing varieties with white seeds are less popular.

One often hears reports of poor growth and mortality of this crop. Also the annual reviews of "Ziekten en Beschadigingen der Cultuurgewassen" often record damage symptoms. It seems that the crop suffers more damage during the dry season and as a result the plant is not vigorous enough to tolerate the infestation. Plant growth is better in upland areas during the rainy season but distinct damage to unifoliate leaves can nevertheless be observed. In seriously damaged fields, a large number of plants are killed, and even older plants routinely die off. The surviving plants are usually stunted, which results in significant yield loss.

At our experimental farm in Bogor, 30 observations were recorded on the damage and mortality of "Kacang djogo". The data are summarized in Table 3. The results show considerable damage, up to 100%, and very high mortality during various times of the year. Difference in damage between the rainy and dry seasons are minor but plant mortality is rare in the rainy season.

Table 3. Extent of beanfly damage in dwarf type common bean.

Sowing date	Number of plants				
	total	dam- aged	dead	% dam- daged	% dead
24-12-1918	570	427	302	74.9	53.0
11- 1-1919	464	464	400	100.0	86.2
20- 1-1919	67	63	26	94.0	38.8
12- 2-1919	342	304	194	88.9	56.7
25- 2-1919	407	398	258	97.8	63.4
3- 3-1919	77	36	56	46.7	72.7
9- 4-1919	70	70	23	100.0	32.8
11- 5-1919	46	28	8	60.9	17.4
2- 8-1919	102	102	20	100.0	19.6
7- 8-1919	176	161	113	91.5	64.2
23- 8-1919	302	290	45	96.0	14.9
28- 8-1919	153	152	13	99.3	8.5
17- 9-1919	46	46	0	100.0	0.0
12-10-1919	87	81	42	93.1	48.3

Mungbean:

Mungbean is an important crop in some areas, especially in N. Nganjuk where it is grown in stubble after rice. In other areas, it is grown in small plots, on paddy field bunds, and in upland areas.

We have not heard reports of seedling mortality due to *M. phaseoli*, but it is possible that the insect causes more damage than one cares to notice in tilled fields and on paddy field bunds. We have observed beanfly damage several times in farmers' crops grown in the Ciomas (Bogor) area.

Our most important data on damage comes from the experimental field in Bogor where *Melanagromyza* damage was very serious. A portion of the young plants died, and others remained stunted. The crop showed uneven growth and yields were low.

The data on *M. phaseoli* damage and mortality are presented in Table 4. Results showed that damage can be very

Table 4. Extent of beanfly damage in mungbean.

Sowing date	Number of plants				
	total	dam-aged	dead	% dam-aged	% dead
21- 1-1919	531	500	75	94	14.1
21- 1-1919	442	420	80	95	18.1
9- 4-1919	204	204	92	100	45.1
9- 4-1919	245	245	85	100	34.7
11- 5-1919	275	162	70	58.9	25.4
11- 5-1919	325	131	51	40.3	15.7
28- 8-1919	183	182	0	99	0
28- 8-1919	179	179	0	100	0
12-10-1919	265	262	18	99	6.8
3- 3-1920	210	101	85	48	40.5
3- 3-1920	296	168	29	57	9.8

serious, up to 100%, with mortality relatively low, usually 5 to 10%. The rainy season is the best season for the crop despite the fact that beanfly damage symptoms are relatively similar in all seasons.

7

Susceptibility of Various Varieties

In Chapter 4, we listed a number of cultivated and green manure crops which for all practical purposes, are immune to *M. phaseoli* damage. This shows that only a limited number of legumes are suitable hosts for the growth and development of beanflies. It is possible that within certain susceptible species, varieties may exist which are immune to *Melanagromyza*. Further observations of varieties representing soybean, lima bean, and yardlong bean suggest that this may occur.

Soybean:

Among different indigenous soybean varieties sown at our experimental field in Bogor, not one appeared to be immune or less susceptible to *Melanagromyza* damage. The same was true with different soybean types grown at the Selection Garden for Annual Crops. Hence, it is surprising to note in the literature that Otanes in the Philippines records soybean as a *Melanagromyza*-resistant host. The possibility that the Philippine varieties are indeed resistant to *Melanagromyza* cannot be ruled out. The late Professor Charles Fuller Baker was kind enough to send at our request seeds of common Philippines varieties, all of which had white seed coats. However, when sown at the Bogor experimental farm, all were damaged as heavily as indigenous varieties. These results are contrary to Otane's observations in the Philippines.

Table 5 gives damage data on some soybean varieties which were tested at our experiment station. It is evident

Table 5. Extent of beanfly damage in different soybean varieties.

Variety	Sowing date	Number of plants				
		total	dam-aged	dead	%dam-aged	% dead
Kedelee Philippijnen	3-1-19	329	319	184	96.9	55.9
Kedelee poetin (population)	"	806	772	335	97.0	41.5
Kedelee item (populatin)	10-1-19	879	661	100	75.1	11.3
Kedelee poetih (population)	"	820	625	5	75.9	0.6
Kedelee Philippijnen	"	365	354	138	96.9	37.8
Kedelee Formosa (white)	"	355	629	29	96.0	4.4
Kedelee Formosa (black)	"	975	757	1	77.6	0.01
Kedelee Formosa (black)	19-2-19	1234	1088	8	88.1	0.6
Kedelee Philippijnen	"	824	630	138	76.4	15.5
Kedelee Formosa (white)	"	684	587	94	85.8	13.7
Kedelee item (population)	"	997	781	139	78.3	13.6
Kedelee poetih (population)	"	1069	884	9	82.6	0.8

that there was little difference in susceptibility of these varieties. Similar experience in other years, together with observations at the Selection Garden for Annual Crops in Bogor confirms that no domestic or foreign soybean varieties, is immune to *Melanagromyza*. However, differences in resistance are apparent, a fact that was first pointed out by Mr. Koch of the Sub-Department for Annual Crops. Significant data on this subject was collected in 1928 at the experimental fields where numerous unselected native types were planted along with selected lines from the Selection Garden. Variations in susceptibility are summarized in Table 6.

Table 6. Response of various soybean varieties to beanfly.

Var.	Place of origin	Seed coat color	Number of plants		
			total	dead	% dead
16	Selectie-tuin	black	8725	165	1.9
28	Selectie-tuin	white	23510	956	4.1
36	Balapoelang	white	3987	165	4.1
45	Madjalengka	green	9702	135	1.4
67	Rambipoedji (Bes.)	white	3356	115	3.5
91	Gondanglegi (Pas.)	white	7100	369	5.2
94	Ardjawinangoen	white	4324	106	2.5
114	Leomadjang	white	2234	220	10.0
85	Boelang (S'baia)	black	3655	3322	91.0
106	Trenggalik (K.)	black	1846	1267	68.0
110	Bajeman (Pas.)	black	1262	1038	87.9
119	Boeleleng (Bali)	white	1165	1023	87.8

It is apparent from the data that soybean varieties vary in characteristic from extremely susceptible to highly resistant. In resistant varieties, damage reaches 100%, but they grow through the infestation without any adverse effect on growth or yield. This resistance, however, clearly depends on external influences, in this case on rainfall and soil fertility. This was evident at our experimental field where two lines, Nos. 28 and 16, which were very resistant during the 1928 dry season (only 2 to 5% dead plants), were planted on fertile soil (after *Crotalaria*) and less fertile soil. In the former case, only a few plants died; in the latter, the mortality rate was significant as shown in Table 7.

Lima bean:

There are a large number of varieties of *Phaseolus lunatus*, lima bean, with wide variation in hydrogen

Table 7. *M. phaseoli* infestation and plant mortality of selected soybean varieties planted in soils of different fertility status.

Variety	Kind of soil	Date of sowing	Number of plants		
			total	dead	% mortality
Ked No. 28	fertile	5/5/1928	228	35	15.4
	infertile	"	230	92	40
Ked No. 16	fertile	5/5/1928	202	15	7
	infertile	"	327	207	63.3

cyanide content. Certain imported foreign varieties, such as "Sebyari-boontjes" do not contain prussic acid.

In connection with continued serious *Melanagromyza* damage to young "Sebyari boontjes", some comparison trials with *P. lunatus* varieties were conducted at Bogor. Next to the sebyari beans, we planted some hydrogen cyanide-containing, bitter tasting lima bean (Kacang roay) that originated from Bogor and Lembang[1] area, and a non-bitter (hydrogen cyanide free?) "roary" variety which originated from Ciomas area. This last variety is called "roary kedelee" by local people because of its seed shape.

The results of the trial are summarized in Table 8. With the hydrogen cyanide-free "Sebyari boontjes", the damage was always heavy, 50 to 70%, with considerable mortality, 20 to 30%. With indigenous bitter varieties with lateral flattened seeds, all of which contained prussic acid, the damage totaled 15 to 30%, and there was practically no mortality.

The round-seeded, sweet-tasting, local variety "roary kedelee", was only slightly less damaged than "Sebyari boontjes". About 60% of the plants were infested and plant mortality was relatively low. From these data, I conclude that among various *P. lunatus* varieties, only those that contain hydrogen cyanide have some immunity. The cyanide-free ones, such as "Sebyari boontjes", are heavily damaged by beanflies.

Yardlong bean:

We include yardlong bean only for the sake of a complete discussion of the topic and not because differences in susceptibility to *Melanagromyza* were observed.

[1]According to the Chemical Laboratory of the General Research Station for Agriculture, seed samples of these contain prussic acid.

Table 8. Beanfly damage to various lima bean varieties.

Variety	Sowing date	Number of plants				
		total	dam-aged	de-ad	%dam-aged	% dead
Sebyari-boontjes	17- 6-21	196	90	43	46.0	21.0
Kratok v. Buitenzorg	"	66	14	1	21.2	1.5
Kratok v. Lembang.	"	76	13	3	17.1	3.9
Kratok met br. zaad.	"	206	18	3	9.0	1.4
Sebyari-boontjes	18- 8-21	216	123	0	57.0	0
Kratok met br.zaad.	"	220	36	0	16.4	0
Sebyari-boontjes	24- 1-23	76	56	27	73.7	35.5
Roay kedelee (black)	"	86	50	12	58.1	18.6
Roay pait	"	49	34	9	69.4	18.4
Roay kedelee (spotted)	"	92	65	4	70.7	4.3
Sebyari-boontjes	18- 7-25	63	55	11	87.3	17.5
Kratok Buitenzorg	"	15	6	8	40.0	53.0
Roay pait	"	27	20	16	74.1	59.3
Roay kedelee	"	41	26	18	63.5	43.9
Sebyari-boontjes	19- 9-23	343	280	37	81.6	17.9
Kratok Buitenzorg	"	311	93	10	30.0	3.5
Roay pait	"	307	194	19	63.2	6.2
Roay kedelee	"	294	199	5	67.7	1.7
Sebyari-boontjes	24-10-23	232	162	132	70.0	57.8
Kratok Buitenzorg	"	246	76	13	30.9	5.3
Roay pait	"	49	34	9	69.4	18.4
Roay kedelee	"	185	122	23	66.0	1.2

Information in the foreign literature, however, indicates that there are large differences in susceptibility to *Melanagromyza* among different varieties of this crop. In the earlier chapters, we have indicated that with the locally grown indigenous varieties of *V. unguiculata*, known as "Kacang panjang, Kacang tuenggak, Kacang dadap, Kacang mantri" etc., there is heavy damage but practically no mortality. Therefore, it is peculiar that in the Philippines, Australia, and Ceylon (Sri Lanka), cowpeas were reported to be heavily damaged along with serious mortality due to *Melanagromyza*. One would tend to conclude that *V. unguiculata* varieties used in foreign countries are particularly susceptible to damage. However, this has not occurred with various cowpea varieties planted at Cultural and Selection Gardens in Bogor. The varieties tested by the Selection Garden at Bogor, namely New Eva, Victor, Iron, Brabham, Taylor, all from North America, and several early and late maturing imported cowpea varieties were not killed by *Melanagromyza*. It is not appropriate to qualify the information from abroad as incorrect, however, we stand by the fact that to date severe mortality from *Melanagromyza* has not occurred in Java in a single cowpea variety. This subject is worthy of further investigation.

Common bean:

During the writeup of this manuscript (February 1930), the Horticultural Official Bange showed us, at his research station in Kabandjahe (Karo Highlands, Sumatra), numerous imported bean varieties. All were killed by *Melanagromyza*, except the snapbean Alpha which originated from Sluis en Groot in Enkhuizen in the Netherlands. This variety had the usual damage with the familiar feeding tunnels in unifoliate leaves and the cancerous tissue growth at the root collar, but the plants appeared to grow through the infestation and produce a large number of well-developed pods.

This is the first case that I have observed in which a variety of *P. vulgaris* showed measured resistance against *Melanagromyza*. Of the various varieties and types, such as grain-type common beans that are of major importance in this area, not a single variety has demonstrated an equivalent level of resistance.

8

Parasites of *Melanagromyza*

Although the beanfly egg, larval, and pupal stages are concealed inside the plant, *Melanagromyza* does not remain free of parasites. Ichneumon (braconid) wasps, in particular, play an important role in population regulation. We observed four types of ichneumon flies which are pupal parasites of *M. phaseoli*. Egg and larval parasites were not found.

The absence of egg parasites can be explained by the fact that the egg development period is very short and that the eggs are adequately hidden. This makes predation practically impossible. Further, we did not find any effective larval parasite.

It is possible that the pupal parasites initiate damage to the larvae, develop within the larvae, and that the adult parasite wasps emerge only during the pupal period of the host. The nature of the larval habitat, in which the insect is protected only by a thin plant epidermis above the soil surface, exposes them to easier infestation than pupae under the soil. With the exception of ichneumon fly, *Eurytoma* sp., it has not been demonstrated that these predators can be grown in large numbers from damaged plants.

The pupal parasite (a parasite which emerges from the pupa of *M. phaseoli*), plays a rather important role in beanfly control. Without their occurrence in large numbers, significant damage can be expected. In order to study the degree of parasitism of the pupae and the species of ichneumon flies that occur, we conducted 90 observations between 1919 and 1923 in Bogor and Lembang.

Our data indcate that the percent parasitism of *M. phaseoli* in Java is generally low, averaging only 5.1% with a maximum of 42.4%.

The ichneumon parasites obtained from a large number of pupae belong to the following species:

A. *Cynipoide* sp. - 271 specimens or 40.5%.
B. *Eurytoma poloni* Girault - 1 specimen or 0.2%.
C. *Trigonogastra agromyza* Dodd - 395 specimens or 59.1%.
D. *Eurytoma* sp. - 1 specimen or 0.2%.

A. *Cynipoide* sp.[1]

Description:

Female: Body black, abdomen somewhat dark brown, antennae brownish black. Legs yellowish brown. The wings are light grey with darker bases and dark-colored wing veins.

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[1] Identification by A. B. Gahan of U. S. National Museum, Washington (1929).

The antennae have 15 segments: 1st and 2nd roundish, the 3rd moderately elongated, while the remaining are rather short cylindrical of somewhat even length, except the uppermost segment which is round. All antennal segments have short dense hairs. Antennae are always peculiarly curved. The abdomen is curved, has somewhat flattened sides, with a stalk attachment to the thorax (Figure 4a).

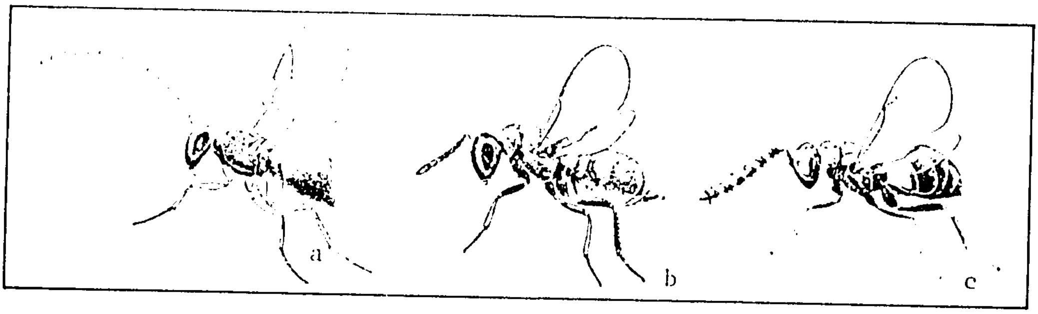

Figure 4. a. *Cynipoide* sp, female; b. *Eurytoma poloni* Girault, female; and c. male.

Body size: Length 1.70 mm, width at thorax 0.50 mm, antennae 2.05 mm long, wing expanse 3.55 mm.
Male: Still unknown.

Biology:

The life history was not studied in great detail. This ichneumon fly, according to our observations, is one of the more important parasites of *M. phaseoli*; 40% of ichneumon wasps raised from infested *Melanagromyza* pupae belonged to this species. In addition to beanfly, we also raised this wasp from pupae of *M. sojae* and *M. dolichostigma* (see later discussion),

Although the extent of parasitism varied greatly, it was not related to weather condition, as evidenced by ichneumon wasps being present in considerable number both at Bogor and Lembang.

B. *Eurytoma poloni* Girault[1]

Description:

Female: Head and thorax slightly black, abdomen shining black, antennae completely black except the first segment which is redish brown. Legs black, the shins of tibia brown, tarsae whitish, the pretarsus dark. Wings are translucent.

Head and thorax wide with granular surface, abdomen

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[1]Identification by A. B. Gahan of U. S. National Museum, Washington (1929). For original description of this species see Proc. U. S. Natl. Mus. 58:205, 1920.

smooth, flattened on the sides with an inconspicuous, small abdominal stalk. Antennae have 10 segments, the first segment moderately long, the second wide, round-cylindrical, the top three acuminate, cylindrical and without constriction (Figure 4b).

Body size: Length 2.15 mm, width at thorax 0.65 mm, antennae 0.65 mm long, wing expanse 3.55 mm.

Male: Body completely black, abdomen shining, antennae black shining with long white hairs, legs blackish brown, the joint between femur and tibia and top and base of tibia light brown, tarsi grey white with the top segment somewhat darker. Wings are colorless with black marginal veins.

Head and thorax with granular surface, abdomen smooth and flattened on both sides with a long stalk. Antennae have nine segments, the first segment moderately long, the second round, and the others with strong intersegmental constrictions; the top two segments are rather long and acuminate. All antennal segments have long bristle hairs (Figure 4c).

Body size: Length 1.75 mm, width at thorax 0.50 mm, antennal length 1.25 mm, wing expanse 3.05 mm.

Male: Body completely black, abdomen shining, antennae black shining with long white hairs, legs blackish brown, the joint between femur and tibia and top and base of tibia light brown, tarsi grey white with the top segment somewhat darker. Wings are colorless with black marginal veins.

Head and thorax with granular surface, abdomen smooth and flattened on the sides with a long stalk. Antennae have nine segments, the first segment moderately long, the second round and the others with strong intersegmental constrictions; the top two segments are rather long and acuminate. All antennal segments have long bristle hairs (Figure 4c).

Body size: Length 1.75 mm, width at thorax 0.50 mm, antennal length 1.25 mm, wing expanse 3.05 mm.

Biology:

The biology was not studied in great detail. The life span of this ichneumon wasp in captivity was 22 to 28 days.

The fly was found to parasitize *M. phaseoli* in only one case. It is generally a pupal parasite of *M. dolichostigma* (see later discussion).

C. *Trigonogastra agromyzae* Dodd[1]

Description:

Female: Body completely black, shining, thorax with a

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[1] Identification by A. B. Gahan of U. S. National Museum, Washington (1929). For original description of this species see Trans. Royal Soc. South Australia 41:347, 1917.

greenish metallic shine, eyes dark brown. Antennae black, the first segment yellowish brown. Legs yellowish brown, top segment of tarsus black, the rest whitish. Wings are colorless, transparent, with dark marginal veins.

Head and thorax rather wide, abdomen not flattened, acuminate with clear, long abdomenal stalk. Antennae with 13 segments, first segment long, second segment oblong, spherical, the third and fourth segments almost round and flat, the next segments wide and cylindrical, the top with not clearly defined oblong and acuminate three segments (Figure 5a).

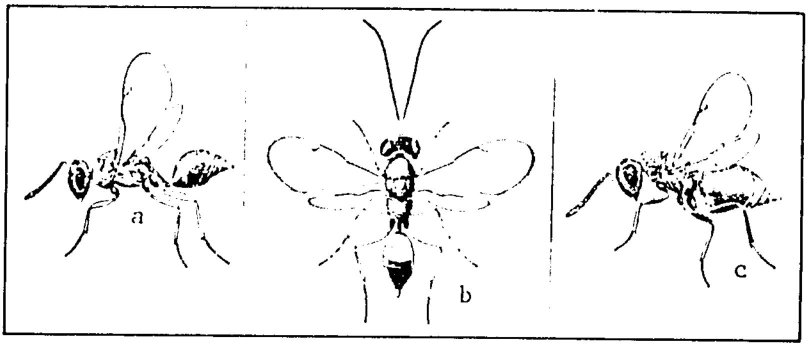

Figure 5. a. *Trigonogastra agromyzae* Dodd, female; b. male; and c. *Eurytoma* sp., female.

Body size: Length 2.05 mm, width at thorax 0.40 mm, antennae length 0.88 mm, wing expanse 3.15 mm.

Male: Head and thorax black, abdomen brownish black with yellow brown spot on the front part of the dorsal side. Antennae black, first segment brownish. Legs yellowish-brown, the lower two tarsae black. Wings light-grey with dark wing veins.

Abdomen with stalk-shaped attachment to thorax. Antennae have 11 segments, first segment rather long, the second spherical, third through ninth oblong, cylindrical. Top two segments acuminate, weakly constricted in the middle (Figure 5b).

Body size: Length 1.45 mm, width at thorax 0.35 mm, antennae 1.15 mm long, wing expanse 2.90 mm.

Biology:

Detailed information on the development of this important parasite of *M. phaseoli* still is lacking. Ichneumon wasps can be kept alive in captivity from 30 to 48 days.

This ichneumon appears to be the most important parasite of *M. phaseoli* in Bogor and Lembang. On average, 60% of the wasps raised from the infested pupae belonged to this species. It was also the most important parasite of *M. sojae*, and was raised several times on *M. dolichostigma* pupae.

This parasite is not the same as that recorded on *M. phaseoli* by Otanes in the Philippines under the name *Paratrogonogastra stella* Girault (Otanes' paper, page 24). That specimen was quite different.

D. *Eurytoma* Sp.[1]

Description :

Female: Body completely black, abdomen shining, thorax moderately black, antennae completely black, legs black, tarsi, except for the paratarsus, white, tibia light brown, front wings with a dark-brown spot.

Body with coarse granular-textured thorax and smooth abdomen. Abdomen slightly flat on both sides, without a stalk-like attachment at the thorax. Ovipositors protruding as an acuminate extension. Antennae with nine segments, first segment moderately long, second oblong cylindrical, top two segments acuminate, without strong constrictions; all antennal segments have short white hairs (Figure 5c).

Body size: Length 1.95 mm, width at thorax 0.5 mm, antennae 0.70 mm long, wing expanse 3.10 mm.

Male: Body color same as female. Forewings light grey with a dark spot in the middle.

Abdomen flattened on the sides with well developed abdominal stalk. Antennae nine segmented, first segment rather long and swollen, second cylindrical, other segments serrated with a very thin attachment stalk and long bristly hairs, top two segments without constrictions.

Body size: Length 1.75 mm, width at thorax 0.55 mm, antennae 1.20 mm long, wing expanse 2.90 mm.

Biology:

Detailed investigations were not carried out. In captivity the wasp remained alive for at least 10 days.

As a parasite of *M. phaseoli*, this insect was observed only once, but was raised several times from pupae of *M. sojae* and *M. dolichostigma*.

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[1]According to A. B. Gahan (in litt. 1929) this species is a variety of braconid fly *Eurotoma poloni* Girault; however, it has a clear dark spot on the front wings which suggest that it is a separate species.

9

Parasites of *M. Phaseoli* from Other Countries

From the discussion in earlier chapters, it is clear that the various parasites found in Java play only a minor role in the control of the beanfly. It is therefore important to assess the occurrence and importance of parasites in other countries because the parasites could be imported into Java. The following information was found in foreign literature.

Australia :

In an Australian publication, E. Jarvis (1913) mentions two parasites that were raised from *M. phaseoli* pupae. No names or data on the extent of parasitism are given.

A. P. Dodd (1917), in northern Queensland, described several parasites but did not furnish information on their economic importance. He recorded the following species: *Polycystomyia benificia* Dodd (seemingly more numerous), *Trigonogastra agromyzae* Dodd, *Pterasema subaenea* Dodd, *Neodimockia aggromyzae* Dodd, *Eupelmus* sp., *Eurytoma* spp. (three species), and *Achrysocharis* sp. (hyperparasite?). As mentioned earlier, information on the extent of parasitismof *M. phaseoli* observed in Australia is lacking. Since beanfly is still a serious pest in Australia, the role played by parasites in regulating the pest population seems unimportant. Therefore, importation of parasites from Australia will be given low priority.

Philippines:

Otanes (1918) records two indigenous parasites, *Paratrigonogastra stella* Girault and *Eurytoma poloni* Girault. The latter braconid is already present in Java. Average parasitism in the Philippines (17%) is somewhat higher than in Java. According to the available information, *Eurytoma* occurs somewhat more frequently than *Paratrigonogastra*. Despite the parasitism, *Melanagromyza* is a serious pest in the Philippines, hence these parasites will likely be of little use in Indonesia.

Ceylon (Sri Lanka):

According to Rutherford (1914), *Melanagromyza* in Ceylon is parasitized by various insects. However, accurate data are lacking. Two parasites, *Trigonogastra rugosa* Wat. and *Polycystres propinquus* Wat., were later recorded by Waterson (1915).

India:

Data concerning parasites are lacking in the superficial information presently available on this pest.

Mauritius:

Information about parasites of *M. phaseoli* is lacking.

Rhodesia: (Zimbabwe):

As mentioned earlier, it is now certain that *Agromyza fabalis* Coq., reported by Jack (1913) in Rhodesia, is identical to our beanfly. Jack (1913) also noted that the larvae (pupae?) are heavily parasitized by a kind of braconid (chalcidid?). At the same time, however, serious beanfly damage is prevalent in susceptible crops. These parasites, therefore, have little practical value, and their importation from Rhodesia should not be considered.

In summary, in countries where *Melanagromyza* is present, several parasites also occur. According to the available data, they do not play an important role in controlling the beanflies. It would therefore be impractical to import any of these parasites to Java for *Melanagromyza* control.

10

Direct Protection Methods

From the discussion of *M. phaseoli* in earlier chapters, it is clear that in Java, this insect is a serious pest of all bean species in mountain areas, and of soybean and imported lima bean varieties in lowland areas. Thus, protection of these crops must be considered. As with most insect pests in the tropics, plant protection can be accomplished either by using chemicals or cultural practices. If supply is adequate, local people prefer a chemical methods. This method will be discussed first.

It is well known that among the various insects that are harmful to cultivated plants, a group of Diptera flies is the most difficult to control. The inaccessability of the larvae and the unusual mobility of the adults are usually responsible for poor control of the pest with chemical sprays. I wish to point out equally poor control of fly pests of European cereals, e.g. the fritfly (*Chlorops frit*), the yellow culmfly (*Hylemya coarctata*), the Hessian fly (*Mayetiola destructor*), and fruit flies (*Ceratitis capitata*), *Dacus tryoni* etc.).

Initially, direct control methods seemed promising, but for reasons of safety other promising methods were also tested.

A. Control measures against larvae:

1. Removal of the unifoliate leaves of common bean and lima beans.
2. Spraying of the root collar (root neck) with mercuric chloride solution.
3. Spraying of the root collar with derris extract.
4. Spraying with Bordeaux mixture.

B. Control measures against adult flies

1. Spraying with lead arsenate.
2. Spraying with lime milk.
3. Spraying with a mercuric chloride solution.
4. Catching the flies with the "Australian fly catcher".
5. Various other methods recommended in foreign countries for flies.

The results of these methods are summarized below.

A. Control measures against the larvae:

1. Removal of the unifoliate leaves of common bean and lima bean:

This experiment was based on the observation that major infestation of common bean occurred in unifoliate leaves, and in lima bean, exclusively on the unifoliate leaves. With the removal of these plant parts, it appeared logical that the flies would be deprived of the opportunity of oviposition and serious infestations could thus be prevented.

The results showed that this treatment has a disastrous effect on the growth of both common bean and lima bean. In addition there was increased mortality in common bean due to bacterial diseases. In both crops it was found that where unifoliate leaves were absent, flies severely attacked the first trifoliate leaves. For this reason the trials were discontinued.

2. Spraying the root collar with mercuric chloride solution:

In Canada, treatment of the root necks with a mercuric chloride solution (1:1000) gave excellent control of cabbage fly (*Anthomyia brassicae*). The eggs and larvae were killed or dislodged without damage to the plant.

It seemed desirable to try this method for *M. phaseoli* control. With cabbage fly, the nature of the infestation of root neck is completely different. This insect deposits eggs directly at the root collar and the larvae eat superficial cavities into the plant tissue from the outside. Thus, it is always easy to reach the larvae with the poisonous liquid. With the beanfly, oviposition and initial damage takes place in the internal plant parts above the soil surface. Injury to the root neck is also internal and occurs only in the last larval instar. Spraying the root collar with contact or stomach poisons can succeed only if the liquid penetrates the cracks in the epidermis or moves by osmosis into the cortex.

As explained above, the theoretical chances of success were not good. In practice, the mercuric chloride solution did not have any influence on beanfly control. For this trial, we used two to three week old bean (*P. vulgaris*) plants. The larvae had already reached the root neck and feeding in the root collar had nearly ended. A similar experiment was done with soybean. A mercuric chloride solution was sprayed in the morning. The number of dead plants were recorded from treated and untreated plots. The results are summarized in Table 9. The mortality rate in untreated plots was as high as in the treated ones, and larvae and pupae found inside treated plants were all alive. This confirmed our earlier belief that treatents applied to the root necks would not reach the larvae in the infested tissue.

3. Spraying the root collar with derris extract:

Theoretically all liquid agents which are applied for protection against *M. phaseoli*, including mercuric chloride, will not be successful because *Melanagromyza* larvae are protected at the root neck. A small publication from Straits Settlements (Penang, Singapore, Malacca), abstracted in the

Table 9. Effect of mercuric chloride on beanfly control.

Crops	Treatment	Sowing date	Number of plants			
			total	dam-aged	dead	% dead
Soybean	drenched	4/4-1920	182	175	74	40.7
"	not drenched	"	550	523	187	33.4
"	not drenched	"	576	565	217	37.7
Common bean (dwarf type)	drenched	31/3-1920	185	151	19	10.5
"	not drenched	"	260	173	43	16.5
"	not drenched	"	114	104	28	24.6
Common bean	drenched	9/2-1922	27	?	22	81.5
"	not drenched	"	138	?	119	87.5

"Review of Applied Entomology" cites favorable results when lima bean (*P. lunatus*) root necks were sprayed with derris extract. Derris extract is often recommended as an insecticide. An overview of the literature shows, among others, an article in Teysmannia by Dr. van Hall (1920) which reports that derris extract works as a contact as well as a stomach poison[1].

In our experiment, three-week old common bean and lima bean plants were sprayed daily for 14 successive days at the root necks with 3% derris extract. The efficacy of the treatment was evaluated by comparing plant damage and mortality with untreated plants. The results are summarized in Table 10.

The data show that derris extract does not have any noticeable impact on beanfly. The plant mortality was normally high and the larvae and pupae inside sprayed plants were not affected. Hence the results were disappointing.

4. Spraying with Bordeaux mixture:

According to a recent experiment by De Long (1929), the success of Bordeaux mixture against hoppers (Cicadellidae) was attributed to probable absorption of the copper compound in the leaf, which poisoned the sucking insects. We decided to check this experimentally to determine the effect of Borduaux mixture spray on *M. phaseoli* larvae. The chances of success did not seem to be great since the critical level of copper absorption had to be reached during the two days that the larvae remain inside the leaves. Indeed, the results were completely negative. Trials were initiated in the

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[1] A detailed study of derris is published in Med. Deli. Profestation, Ze series No. 58, 1929.

Table 10. Effect of derris extract on beanfly control.

Crop	Treatment	Sowing date	Number of plants		
			total	dead	% dead
Common bean (dwarf type)	sprayed	3-2-1922	39	39	100
"	not sprayed	"	136	119	87.5
Common bean (dwarf type)	sprayed	30-1-1922	15	12	88
"	not sprayed	"	45	45	100
Lima bean	sprayed	30-1-1922	35	20	57.2
"	not sprayed	"	75	52	69.3

laboratory and were continued in the field. The most susceptible crops, common bean, soybean, mungbean, and cowpea were sprayed. The treatment was applied when young plants emerged and was repeated several times throughout the growing period. As the data in Table 11 show, plant mortality in the treated fields was hardly less than in the untreated fields. Spraying seemed to stimulate growth without decreasing plant mortality only in common bean. In laboratory tests, it was found that flies developed normally in sprayed plants with little likelihood of *Melanagromyza* larval mortality.

At the same time, in the former experiment, we checked whether or not the application of copper sulphate on soil would result in the uptake of copper in the plants similar to the so called "reclaiming pest" in Holland (Smith 1928), which would be toxic to *Melanagromyza*. These tests gave completely negative results both in the laboratory and in the field.

B. Control measures against adult flies:

1. Spraying with sugar-lead arsenate solution:

It is essential that one kills the flies before they can oviposit in the cotyledons or unifoliate leaves of beans, cowpea, or soybean. To achieve this Otanes recommends (but seemingly did not try) spraying a sugar solutions of lead arsenate or Paris green. Thirsty flies would presumably prefer the sweet solution, consume the poison, and die.

For the sake of a complete investigation, we also evaluated this control method. Only lead arsenate was used. Paris green, with its higher content of soluble arsenic acid, seemed less desirable because of its possible phytotoxic effects, and as experiments in America (List 1923) showed,

Table 11. Effect of Boardeaux mixture spray on beanfly control.

Crop	Treat-ment	Sowing date	Number of plants				
			total	dam-aged	dead	% dam-aged	% dead
Common bean	spray	17-8-29	114	78	53	68.3	46.4
(dwarf type)	no spray	17-8-29	91	71	46	78.0	50.5
"	spray	17-8-29	112	86	58	76.7	51.7
"	no spray	17-8-29	93	77	36	82.7	38.7
"	spray	22-8-29	147	93	40	63.2	27.2
"	no spray	22-8-29	136	76	48	55.8	35.2
"	spray	23-8-29	124	88	56	70.9	29.0
"	no spray	25-8-29	128	97	76	75.7	59.3
"	spray	4-9-29	151	99	83	65.5	54.9
"	no spray	4-9-29	180	101	63	56.1	35.0
"	spray	10-9-29	169	186	67	80.4	39.6
"	no spray	10-9-29	175	113	92	64.5	52.5
Soybean	spray	17-8-29	547	383	376	70.0	68.7
"	no spray	17-8-29	572	432	496	75.5	86.7
"	spray	17-8-29	192	98	86	51.0	44.7
"	no spray	17-8-29	194	163	174	84.0	89.6
"	spray	10-8-29	259	186	205	71.8	79.1
"	no spray	20-8-29	238	186	184	78.1	77.3
"	spray	22-8-29	386	238	296	61.6	76.6
"	no spray	22-8-29	319	298	283	93.4	88.7
"	spray	23-8-29	333	137	286	41.1	85.8
"	no spray	25-8-29	356	298	284	83.7	79.7
"	spray	4-9-29	432	273	358	63.1	82.8
"	no spray	4-9-29	360	299	310	83.0	86.1
Limba bean	spray	17-8-29	78	66	58	84.6	74.3
"	no spray	17-8-29	95	69	65	72.6	68.4
"	spray	17-8-29	87	62	60	72.4	68.9
"	no spray	17-8-29	99	80	59	80.4	59.5
"	spray	22-8-29	98	66	63	67.3	64.3
"	no spray	22-8-29	86	72	54	83.7	62.7
"	spray	23-8-29	196	165	161	84.1	82.1
"	no spray	23-8-29	213	138	198	64.7	92.9
".	spray	4-8-29	151	137	125	90.7	82.7
"	no spray	4-8-29	166	148	139	89.1	83.7

bean plants are particularly susceptible. Trials were conducted in the field on common bean and soybean. Spraying commenced as soon as the unifoliate leaves emerged from the unfolding cotyledons. Plants were sprayed regularly early in the morning with 1% lead arsenate plus sugar. The treatment, however, was disappointing. In practice, the droplets dried quickly, and shortly after spraying the poison was not available to the flies. The poisonous liquid itself was of little value in fly control. In a single laboratory experiment, flies were fed the poisonous liquid instead of sugar water. Mortality did not increase with feeding of the poison. This could be due to the fact that the heavier lead arsenate did not remain in suspension, but settled to the bottom of the container instead.

As a result of the lead arsenate spraying, one would still expect the poison layer on the leaves to mechanically hinder the flies. During the process of oviposition or feeding, the plant sap that comes out as a result of probing by ovipositors can get mixed with traces of lead arsenate, and, as a result of fly's licking habit, the poison finally can becomes active. The toxic effects must be rapid to prevent flies from making additional egg holes.

All theoretical expectations, however, were shattered by the results of the trials. As the data in Table 12 show, injury to the plants sprayed in this manner was no less than the untreated checks. However, the mortality of sprayed plants was lower than the check plants.

Table 12. Effect of 1% lead arsenate spray on beanfly control.

Crop	Treatment	Sowing date	Number of plants				
			total	dam-aged	dead	%dam-aged	% dead
Common bean (dwarf type)	spray	24-12-18	280	273	43	97.5	15.3
	no spray	"	570	427	302	74.9	52.8
Common bean (dwarf type)	spray	12- 2-19	279	?	158	?	56.6
	no spray	"	342	304	219	88.8	64.0
Common bean (pod type)	spray	22-12-18	507	489	99	96.4	19.5
	no spray	"	528	485	179	91.9	33.7
Soybean	spray	10- 1-19	843	?	12	?	1.4
	no spray	"	481	441	58	91.5	12.2
Soybean	spray	25- 2-19	1003	1003	2	100.0	0.1
	no spray	"	1039	897	89	86.3	9.5
Common bean (dwarf type)	spray	5- 9-23	208	198	90	95.2	43.3
	no spray	"	215	207	94	96.3	43.7

Spraying with lead arsenate caused severe damage to common beans and soybeans. Cotyledons were especially affected by the spraying. It therefore appears that Otanes' recommendations are not practical.

2. Spraying with chalk milk:

A single test was conducted simultaneously with lead arsenate trials to check whether or not covering leaves with a protective layer could produce a mechanical barrier for the flies. A 1% chalk milk solution was sprayed on young bean plants during early morning to test this hypothesis.

The results of the test were similar to those with lead arsenate. The data summarized in Table 13 show that damage to sprayed plants was only slightly less than that of the unsprayed plants. Chalk milk solution appeared to cause severe phytotoxicity.

Table 13. Effect of chalk milk spraying on the control of *M. phaseoli* on common bean.

Treatment	Number of plants				
	total	damaged	dead	%damaged	% dead
Sprayed	211	161	112	76.3	33.1
Not sprayed	215	207	94	96.3	43.7

3. Spraying with mercuric chloride:

Since spraying with insoluble poison (lead arsenate) suspended in water did not produce any meaningful results, experiments were conducted with a soluble poison. A 1% mercuric chloride solution was chosen for this trial. The choice of solution was based on the assumption that spraying at the root neck of the bean plant should cause no plant damage and the poisonous liquid, besides being consumed by the flies, might also penetrate the egg holes on the upper side of unifolite leaves and kill the eggs and young larvae.

For this trial, cowpea was chosen as a test plant. In cowpea, not only the injury to the unifoliate leaves is severe but the damage is also conspicuous. When the emerging cotyledons unfolded, the young plants were regularly sprayed during early morning hours with a mercuric chloride solution. After some days it was evident that sprayed plants grew slowly and remained stunted. Further, the spraying did not achieve desirable results since unifoliate leaves had visible egg holes. Because of this, and the adverse effect on plant growth, this test was discontinued.

4. Catching flies with an Australian flycatcher:

We found literature references to a specially designed flycatcher by an Australian. This was recommended as the best preventive measure for *Melanagromyza*, and probably was used on a large scale. Since their claims indicated very favorable results, it seemed desirable to construct such a trap and test it.

The construction of the trap was based on the observation that *Melanagromyza* flies are found primarily on young plants in the morning hours, and, when disturbed, fly straight up. This observation can be cleverly put to use in designing a large glass panel, the underside of which is moistened with petroleum. The panel is pulled close above the young plants in the field, while the cloth pieces, hanging on three sides serve to brush the plants and chase the flies. The insects fly perpendicularly, collide with the petroleum-layered glass, and die.

We tried this flycatcher several times at our experimental farm at Bogor, as well and in fields planted to common bean, soybean, and yardlong bean. The treatment was started as soon as the unifoliate leaves unfolded, and was continued until the plants were 4 to 5 weeks old. This operation was done at 7, 9, and 11 in the morning. The number of trapped flies as well as the number of plants showing *Melanagromyza* infestation in treated and untreated fields were recorded.

As the data below indicate, a large number of flies were caught in the flycatcher. It appeared that not only *Melanagromyza*, but also the ichneumon parasites of *Melanagromyza* remained stuck into the petroleum layer. This is a distinct disadvantage. However, these parasites have limited utility and their loss should not be rated as very important. The older the plants, the fewer the number of the number of flies that were caught. In six weeks, the total number of flies caught over 500 plants is as follows: common bean - 1,697; yardlong bean - 1,977; cowpea (dwarf type) - 1,840; black soybean - 1,840; and white soybean - 1,382.

Was this catching instrument satisfactory? The final analysis of this protection method leaves much to be desired. In the treated area, the damage was as severe as in untreated area (Table 14), namely between 75 and 90%. This indicates that fly catching has limited utility.

It must be borne in mind that these experiments were conducted on an experimentl field where numerous other legumes were also planted. A continuous external source of infestation was available, and, in this case, continuous catching of the flies were of no benefit. This control measure was like a drop in the ocean. It might make a difference in larger fields in the area; for example, common bean could be regularly treated. But there is always the possibility of infestation from neighboring legume fields. In Australia, the conditions for reinfestation are perhaps less favorable. In Java, this flycatcher appears to be of little use on small fields.

5. Various other methods recommended in other countries against *Melanagromyza*:

There are references in the foreign literature that cite various other control measures to prevent *Melanagromyza*

Table 14. Effect of the Australian flycatcher on the control of beanflies.

Crop	Planting date	Number of plants: total	dam-aged	dead	%dam-aged	% dead
Common bean (dwarf)	16-6-21	284	211	56	74.3	20.0
" (untreated)	"	265	198	32	84.7	12.1
Black soybean	"	589	524	451	88.9	76.6
" (untreated)	"	508	410	332	80.7	65.3
White soybean	"	586	496	436	84.6	74.4
" (untreated)	"	615	485	386	78.0	63.0
Yardlong bean	"	468	436	1	91.2	0.2
" (untreated)	"	473	443	10	93.7	2.1
Cowpea (dwarf type)	"	486	414	9	85.2	1.9
" (untreated)	"	740	585	2	79.0	0.3

damage. Nearly all of these recommendations are based on the erroneous idea that flies deposit eggs on the root collar[1] and that damage there can be prevented with chemical treatments. This is like the provision of "collars" with cabbage in order to prevent damage from cabbage fly in Europe

In Java, placement of ordinary ash around the base of plant is sometimes recommended and is sometimes successful. Possibly the ash works as fertilizer causing plants to grow through the infestation (see later discussion). Unfortunately, ash will not keep flies away from the root collar. It is also unlikely that this treatment will kill the larvae or pupae in the root collar. To be certain, we tried this method and the results summarized in Table 15 indicate zero control.

In Australia, tar water is recommended for treatment as soon as the unifoliate leaves unfold. This treatment is meant to prevent the flies (mechanically or by repelling them) from laying the eggs in the leaves. The latest information from Australia does not mention this treatment. It is assumed that the treatment has little practical value there. This treatment, therefore, was of no interest to us.

Another method recommended in Australia to repel the flies is spreading saw dust soaked with petroleum. This treatment derives from the use of petroleum as repellent

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[1]This is still mentioned in later literature, e. g. W. W. Froggat. French bean fly. Agric. Gaz. N. S. W. 33:522, 1923.

Table 15. Effect of placing ash around the root collar on *M. phaseoli* control.

Treatment	Sowing date	Number of plants				
		total	dam-aged	dead	%dead plants	Remarks
With ash	12/7/23	242	217	38	15.7	heavy rain
No ash	"	138	103	26	19.7	"
With ash	19/1/23	172	170	113	65.1	
No ash	"	151	148	118	78.1	
With ash	5/9/23	157	119	121	77.1	
No ash	"	215	207	94	43.7	

against other insects (flea beetle, etc.). We tried this method, and observed no significant long-term effects (Table 16).

Table 16. Effect of petroleum impregnated sawdust application on *M. phaseoli*.

Treatment	Sowing date	Number of plants				
		total	dam-aged	dead	% dam-aged	% dead
Petroleum + Sawdust	5/9/1923	133	97	82	73.0	61.6
Sawdust only	"	215	207	94	96.6	43.7

As there was no further mention of this treatment in the literature, it appears that this method was not satisfactory.

Conclusions:

From the experiments discussed above, it is clear that direct protection methods against *Melanagromyza* are not successful. Therefore, we assessed certain cultural methods in an attempt to provide more successful control. A summary of some of these methods is reported in the next chapter.

11

Cultural Control Methods

It is hard to imagine that cultural methods can reduce *Melanagromyza* damage. Further, methods must be adapted to the legume species grown. In the course of our research, we investigated the following methods:

A. Soybean:
1. Ridging of young plants
2. Fertilization
3. Paddy straw cover
4. Time of planting

B. Common bean:
1. Ridging of young plants
2. Fertilization
3. Time of planting
4. Intercropping with maize

C. Mungbean:
1. Paddy straw cover

D. Lima bean:
1. Fertilization

The results of the above methods are described below:

Cultural methods with soybean:

1. Ridging of young plants:

The production of adventitious rootlets on the stem above the root collar is one of the symptoms of *Melanagromyza* damage in soybean. When adventitious roots become visible on three-week old plants, we tried to cover them with soil.

This method of control is possible only when soybean is cultivated in loose soil. In stubble culture, this method is impractical since the soil is too hard for ridging.

We tried this method on loose soil at our experimental field in Bogor. In order to facilitate good coverage, soybean was planted in furrows instead of on flat beds and earthed-up after three weeks. As the data in Table 17 indicate, the results of this treatment were satisfactory. Mortality was less in earthed-up plants than in the control plants. It must be noted that the trials were conducted during the rainy season, which strongly encouraged the root system to develop. In the dry season, the results could be different. The method may be effective only on a small scale and in loose soil.

Table 17. Effect of ridging on beanfly control in soybean.

Treatment	Sowing date	Number of plants				
		total	dam-aged	dead	%dam-aged	% dead
Ridged	28-1-1919	595	492	42	82.6	7.0
Not ridged	"	610	464	85	76.0	13.9
Ridged	10-1-1919	910	644	0	72.9	0
Not ridged	"	481	441	58	91.6	12.0
Ridged	21-1-1919	642	636	3	99.0	0.4
Not ridged	"	636	630	81	99.0	12.7
Ridged	28-1-1919	786	648	0	82.4	0
Not ridged	"	768	654	31	85.0	4.0
Ridged	"	757	538	0	71.0	0
Ridged	28-1-1919	750	652	8	86.9	1.0
Not ridged	"	740	624	17	84.4	2.3
Ridged	"	735	519	2	70.6	0.2
Ridged	22-2-1919	993	751	6	75.6	0.6
Not ridged	"	1214	915	35	75.3	2.8
Ridged	"	1211	819	0	67.6	0
Ridged	8-3-1919	587	569	68	96.9	11.5
Not ridged	"	687	631	39	91.8	5.7

2. Fertilization:

Although we cannot prevent *Melanagromyza* damage in soybean, we can achieve the desired results by promoting vigorous growth which allows the plants to grow through the damage. This could be achieved by fertilization or by appropriate crop rotation (after legumes).

At our experimental field in Bogor, no noticeable differences in beanfly damage were observed in soybean as a result of fertilization (Table 18). As the trials were conducted in the dry season, the unfavorable results are probably due to climate.

The fact that soybean responds to soil fertility and suffers less damage from *Melanagromyza* mortality was shown in some trials conducted at the beginning of May 1928 at our experimental field. In less fertile plots (after paddy), plant mortality was considerable, but on more fertile plots (after *Crotalaria*), plant growth was luxuriant and mortality was reduced (Table 19).

Table 18. Effect of manure dressing of soybean on beanfly control.

Crop	Treatment (manure dressing)	Sowing date	Number of plants total	dam- aged[1]	dead	%dam- aged	% dead
Black soybean	yes	19- 6-21	589	516	519	87.6	88.1
"	no	"	508	420	271	82.6	53.1
Soyben Tjiomas	yes	19- 6-21	511	425	485	83.1	94.9
"	no	"	562	470	486	83.6	86.4
White soybean	yes	19- 6-21	516	404	51[illegible]	78.2	100.0
"	no	"	589	469	589	79.6	100.0
Soybean Tjiomas	yes	19- 6-21	570	316	484	55.4	84.9
"	no	"	596	325	533	54.5	89.4
Black soybean	yes	16- 6-21	589	524	444	88.6	75.3
"	no	"	495	384	328	77.6	66.3
Black soybean	yes	22- 6-21	589	433	474	73.5	90.4
"	no	"	572	462	496	80.8	86.7
Black soybean	yes	5-10-22	565	373	112	66.0	19.8
"	no	"	498	390	216	78.3	43.4

[1]Damage to cotyledons.

Table 19. Beanfly damage to soybean grown in fertile and non-fertile soils.

Variety	Soil type	Sowing date	Number of plants total	damaged cotelydons	dead	% dead
Soybean 1711	fertile	5/5-1928	425	91	62	14.6
"	not fertile	9/5-1928	84	34	68	80.9
Soybean No.28	fertile	5/5-1928	228	53	35	15.4
"	not fertile	9/5-1928	221	83	115	52.0
Soybean No.29	fertile	5/5-1928	210	79	10	4.8
"	not fertile	9/5-1928	413	165	182	44.1
Soybean No.16	fertile	5/5-1928	202	73	15	7.4
"	not fertile	9/5-1928	427	183	264	61.8
Soybean No.30	fertile	9/5-1928	442	205	158	35.8
"	not fertile	9/5-1928	42	20	41	97.6
Soybean white	fertile	5/5-1928	103	46	56	54.3
"	not fertile	5/5-1928	353	153	248	70.3

Planting in fertile soil, the use of fertilizer, and, in general, promoting favorable growing conditions may keep *Melanagromyza* related soybean mortality within acceptable limits.

3. Covering the plants with paddy straw:

Observations in various trials at our experimental field in Bogor often showed that volunteer soybean plants in a rather dense crop of cowpea remained free of *Melanagromyza* damage while all cowpea plants showed heavy damage. It was thought that cowpea could serve as a trap plant. A trial in which soybean was surrounded by wide strips of cowpea clearly demonstrated that cowpea did not serve as a host plant; soybean and cowpea were equally damaged.

It seemed as if the small volunteer soybean plants were protected against *Melanagromyza* by the broad leaves of cowpea. We tried to demonstrate this by mechanically covering the soybean plants. Immediately after sowing, the field was covered with a layer of paddy straw, a simulation of soybean in stubble culture following paddy rice.

The results of these trials were positive in terms of controlling beanflies. These experiments were, therefore, repeated at different times of the year. The results were consistent in all cases. Data on plant damage[1] and mortality caused by *Melanagromyza* with and without paddy straw cover are summarized in Table 20.

The data clearly demonstrate that damage in straw-covered field was less: 44% versus 66% in uncovered fields. Also, the severity of damage was much less in paddy straw-covered fields: 17% of the damaged plants died versus 38% on uncovered fields.

After further research, we found that the practice of covering soybean planted with rice straw was already practiced occasionally by local farmers. In the Ciomas area, for example, we found that soybean plots are rotated with *Pachyrrhizus erosus* or eggplant and are covered with paddy straw. This, according to the farmers, encourages luxuriant growth. These soybean fields yielded well, while uncovered fields were completely ruined by beanfly in the dry season. In the dry season at Bogor, soybean production was possible only when paddy straw cover was used.

It was thought that the paddy straw conserved soil moisture, thereby enabling the plants to grow vigorously. This concept, however, is not correct. As the data in Table 20 show, both plant mortality and insect infestation were reduced in paddy straw-covered soybean. However, the straw cover probably has a favorable effect on soybean growth, especially during the dry season. At our experimental station in Bogor, plants always grew more vigorously in straw

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[1] The damage to cotyledons only was recorded. In soybean, damage to unifoliate leaves is less important.

Table 20. Effect of straw mulch on beanfly control in soybean.

Treatment	Sowing date	Number of plants				
		total	damaged	dead	%damaged	% dead
With straw	27-4-1919	999	427	63	42.7	6.3
Without straw	27-4-1919	1110	792	141	21.3	13.6
With straw	9-5-1919	1217	594	140	48.8	11.5
Without straw	9-5-1919	1159	632	162	53.6	13.1
With straw	9-5-1919	1384	786	117	56.7	8.4
Without straw	9-5-1919	1245	616	230	49.4	18.4
With straw	9-6-1919	883	348	196	39.7	22.1
Without straw	9-6-1919	799	470	166	58.8	20.7
With straw	3-6-1919	1137	346	260	30.3	22.8
Without straw	3-6-1919	937	593	589	63.6	63.1
With straw	7-11-1919	1475	547	47	64.2	3.1
Without straw	7-11-1919	1087	961	61	88.4	5.6
With straw	11-5-1929	1861	726	103	39.0	5.5
Without straw	11-5-1929	1628	972	319	59.7	19.5
With straw	21-8-1920	675	441	524	65.3	77.6
Without straw	21-8-1920	1246	1082	462	86.8	37.1
With straw	2-7-1921	586	275	176	47.0	30.1
Without straw	2-7-1921	585	406	275	69.4	46.6
With straw	16-7-1921	615	123	?	20.0	?
Without straw	16-7-1921	570	316	?	55.4	?
With straw	18-8-1921	436	298	134	68.3	30.7
Without straw	18-8-1921	561	414	561	73.8	100
Leaves of uri[1]	16/10-1922	563	227	44	40.3	7.8
Roots of uri	16/10-1922	489	346	51	70.7	10.4
Without straw	16/10-1922	623	455	45	73.0	5.6

[1] *Imperata cylindrica*

covered plots than in uncovered plots. This was especially true in the dry season, but even in the rainy season straw covering always appeared to favor plant growth. This agrees with the practical experience of local soybean farmers in Bogor.

In Bogor, soybean is often planted in small plots or as an intercrop with eggplant (*Solanum melongena*) or yam bean (*Pachyrrhizus erosus*). In both cases, according to the farmers, the soybean must grow well. With eggplant, soybean is covered with paddy straw, hence the successful growth of the soybean crop. Straw is not used with yam bean. The yam bean seeds are sown two to three weeks ahead of the soybean planting. The successful growth of soybean in yam bean culture is similar to the cowpea trial, i.e. the yam bean plants cover the soybean and protect them from *Melanagromyza*.

The paddy straw cover probably protects the most susceptible plant parts, the cotyledons, which lift themselves slightly above the soil surface. Paddy straw, when applied carefully as a thick layer, can cover the cotyledons. Incomplete or delayed straw cover results in increased *Melanagromyza* damage.

Our experiments have proven the value of straw covering as a means of reducing *Melanagromyza* damage. This f'nding also explains why there is never serious damage to soybean by *Melanagromyza* in stubble culture after the paddy. Soybean is grown as a stubble crop just before or after paddy harvest, at which time paddy straw is trodden or pressed with banana stems and rolled or sometimes cut. In this way, the soybean seeds are covered. This not only helps to prevent soil desiccation, but also offers protection against *Melanagromyza*.

Since paddy straw is not always available, we checked whether covering the soil with other materials would give similar results. We tried grass (*Imperata cylindrica*) leaves which were obtained in quantity, and the results were equally good (Table 20).

4. Time of planting:

In Bogor, we learned that it was not possible to raise soybean during the dry season without certain precautionary measures (straw covering). Without exception, the crop was completely ruined by *Melanagromyza*. A similar incidence was observed at the Cultural Garden and at the Selection Garden for Annual Crops in Bogor.

It was observed, however, that soybean could be grown in this area if we waited until the rainy season. At that time, good yields were obtained in both the Selection Garden and at our experimental fields, both of which produce seed for other trials. Success was attributed more to vigorous soybean growth during the rainy season than to reduced *Melanagromyza* damage. The data presented in Table 1 clearly show that plant mortality is lower during the heavy rains, but *Melanagromyza* infestation of soybean and other crops is little affected. In upland areas, the rainy season, I think, is the right time for soybean planting.

Another factor that is sometimes important for soybean is the time of planting. This was demonstrated in a planting time experiment conducted by agricultural advisor Vink and his assistant Soewardjo in an upland area of Gorbogan (East Sajnarang). In this experiment, which involved four planting dates, a planting delayed for three weeks resulted in higher plant mortality than the first sowing. Delayed planting permitted the fly population to increase. Hence, delays in planting should be avoided.

Cultural methods for common beans:

1. Ridging of young plants:

Common bean forms even more adventitious roots than soybean. Otanes therefore recommends earthing up of common bean and lima bean in the Philippines as a way of permiting damaged plants to form a new root system and grow through the infestation. Although we did not achieve satisfactory control in soybean, for the sake of completeness, this method was tried again with common bean. The plants were ridged two and three weeks after planting. In the case of two-week old plants, root collar damage was scanty, but the damage to three-week old plants had already progressed to the point where the first set of adventitious roots were emerging.

The results of earthing-up of common bean plants are summarized in Table 21. As we can see, mortality decreased with ridging, but the method does not achieve complete control. However, it could be applied in a small garden.

Table 21. Effect of ridging common bean (dwarf type) on beanfly control.

Treatment	Sowing date	Number of plants				
		total	dam-aged	dead	%dam-aged	% dead
Ridged	24/12-1918	456	443	92	97.8	20.1
Not ridged	24/12-1918	570	427	302	74.9	52.8
Ridged	12/ 2-1919	322	283	95	87.8	29.5
Not ridged	12/ 2-1919	342	304	219	83.8	64.0
Ridged	24/12-1918	437	367	90	81.9	20.5
Not ridged	24/12-1918	428	485	179	91.8	33.7
Ridged	16/ 6-1921	258	210	1	81.2	0.3
Not ridged	16/ 6-1921	264	238	2	89.8	0.7

The plants that grew through the infestation always form new roots at the root collar, never higher, even with higher levels of earthing-up. Ridging, therefore, does not seem to encourage the development of roots at higher positions on the stem.

2. Fertilization:

The theory is often put forth that insects prefer to attack plants which are weak because of unfavorable growing conditions. Luxuriant plants would, according to this hypothesis, be free of damage or only slightly damaged. This is probably correct in special cases, but it is not universally true. In the case of common bean, vigorous and not very vigorous plants are damaged at approximately the same high levels. However, the implications of the damage vary according to crop growth. In the area surrounding Lembang, beanfly infestation of common beans planted on upper slopes resulted in 100% plant mortality following poor growth, whereas on lower slopes plants grew vigorously and normally. This indicates that better growing conditions probably reduce *Melanagromyza* damage. Hence, some common bean trials at Bogor were fertilized with ordinary farm yard manure. The results of fertilization on common bean mortality are recorded in Table 22. The trials were conducted at the most favorable time, early monsoon, and for the first time satisfactory yields were obtained at this location.

Table 22. Effect of manure dressing on beanfly control in common bean (dwarf type).

Treatment (manure dressing)	Sowing date	Number of plants					Remarks
		total	damaged	dead	%damaged	% dead	
Dressed	19-6-1921	265	189	12	71.3	4.5	
Not dressed	"	256	160	39	62.5	15.3	
Dressed	28-9-1921	324	186	19	57.4	5.9	
Not dressed	"	332	196	36	59.0	18.4	
Dressed	12-7-1923	247	230	162	93.1	65.6	very dry
Not dressed	"	213	186	165	87.3	72.8	

The manured plants grew much more luxuriantly than non-manured ones. As the data show, damage to manured plants was as high as the non-manured plants, but the mortality rate was much less, thus permitting normal maturity. Hence it is advisable, in order to tolerate *Melanagromyza* damage, that this crop be grown in fertile soil or be fertilized with farm yard manure. This is particularly important for light soils which have been under cultivation for a long time. Otherwise the bean crop will be a complete failure in the dry season.

3. Time of planting:

As with soybean, plant mortality in common bean is influenced by planting date. The data in Table 3 is misleading, presumably because of large differences in the severity of infestation at different times. In practice, the greatest mortality occurs during the early monsoon, while in the rainy season, although the infestation is still high, mortality is quite low. Experienced farmers guard against planting common bean at the height of the rainy season to avoid poor pod set and high mortality from bacterial diseases.

According to the experience of local growers, it is important not to sow common bean in the vicinity of earlier planted common bean fields. Such sowings could be ruined by "hamagingsir" (*Melanagromyza*). In contrast, isolated fields yield well. This may be true of fields where other host plants are absent in the surrounding area.

4. Intercropping with maize:

We have seen that by covering soybean fields with straw, the infestation of susceptible cotyledons decreases dramatically. On common bean, this treatment is not successful because the leaves are situated higher on the stem. However, positive results may also be obtained by planting common bean between rows of maize as is commonly done in Pujon. It was found in one experiment that the simultaneous planting of common bean and maize did not reduce *Melanagromyza* damage. This was presumed to be due to the slow initial growth of maize which led to inadequate protection of the young bean plants.

Cultural methods for mungbeans:

1. Covering with paddy straw:

Similar to soybean, mungbean is grown as a stubble crop after paddy. For the sake of completeness, it seemed desirable to check if the straw treatment which proved beneficial to soybean would also be useful for mungbean.

At our experimental station in Bogor, where mungbean is severely damaged by *Melanagromyza* on tilled fields, we checked whether the paddy straw treatment had any effect on the extent of damage. The results of these trials are recorded in Table 23. The data show that, as with soybean, the paddy straw reduced *Melanagromyza* damage in mungbean.

Table 23. Effect of straw mulching on beanfly control in mungbean.

Treatment	Sowing Date	Number of plants				
		total	dam-aged	dead	%dam-aged	% dead
With straw	11- 5-1919	2200	903	247	41.0	11.0
Without straw	11- 5-1919	1900	980	449	51.6	23.7
With straw	17- 9-1919	594	594	68	100	11.4
With straw	17- 9-1919	632	632	27	100	4.2
With straw	30-10-1920	1236	813	42	65.8	3.4
With straw	30-10-1920	2987	7848	20	95.4	0.7
With straw	24- 7-1923	558	265	193	47.5	34.6
With straw	24- 7-1923	662	496	212	73.4	32.0

Cultural methods for lima bean:

1. Fertilization:

In lima bean, mortality due to *Melanagromyza* occurs in only a few non-hydrogen cyanide-containing varieties such as white-seeded "sebyari-boontjes" or "butter cup beans". Because of favorable results with fertilization of common bean, it seemed desirable to assess this method for lima bean.

At our Bogor experimental station, farm yard manure trials were conducted on sebyari bean. The results are summarized in Table 24. The data show that farm yard manure reduced plant mortality compared with the check. Later fertilizer applications did not reduce sebyari bean mortality. We also did not succeed in reducing *Melanagromyza* damage in lima bean.

Table 24. Effect of manure dressing of lima bean on beanfly control.

Treatment (manure dressing)	Sowing date	Number of plants				
		total	dam-aged	dead	%dam-aged	% dead
Dressed	28/ 9-1921	360	306	9	85.0	2.9
Not dressed	28/ 9-1921	270	192	21	71.1	10.9
Dressed	24/ 1-1923	76	56	34	73.7	44.7
Not dressed	24/ 1-1923	232	162	142	70.0	60.9
Dressed	25/10-1923	251	225	119	90.0	47.4
Not dressed	25/10-1923	256	210	109	82.0	42.5
Dressed	10/ 4-1924	299	206	33	68.9	11.0
Not dressed	10/ 4-1924	276	238	49	86.2	17.7

Conclusions:

While we did not succeed in developing methods to adequately reduce *Melanagromyza* damage in certain bean crops, we succeeded in demonstrating cultural methods which can reduce serious *Melanagromyza* damage in two main crops, soybean and common bean.

The application of farm yard manure to common bean apparently promotes luxuriant growth and the ability of crops to grow through the infestation.

In soybean, covering with paddy straw immediately after sowing appeared to reduce damage and plant mortality. On upland fields, the rainy season is the most desirable time for planting soybean.

SOYBEAN STEMBORER

Melanagromyza sojae

1

Introductory Remarks

Among the three *Melanagromyza* species that attack beans, especially soybean, *Melanagromyza sojae* Zehnt., the so-called "soybean stemborer", is the most widespread but not the most important economically. A literature search revealed that this insect was first recorded and described in detail by Zehntner in "De Indische Natuur" in 1901. This publication was based on his work in East Java in 1896.

In our discussion of beanfly (*M. phaseoli*), we referred to Zehntner's publication which described two different varieties under the same name. According to the description of damage to young soybeans and Figures 1 a and c, 2 a and b, and 3 c and d in Zehntner's publication, the species he describes is undoubtedly *M. phaseoli*. His description of damage to older plants, in which he found larvae not boring under the epidermis but in the pith of stems, and Figures 2c, 3b, and 4a in his publication are in agreement with the description of the *Melanagromyza* species which is commonly found in soybean fields. According to the rules of nomenclature and systematics, we suggest the latter fly to be the soybean stemborer, *Melanagromyza sojae* Zehnt. In fact, Zehntner himself gave this name originally to the mixture of species, one that attacks young soybean plants and one that attacks older ones. The former species was already named *Agromyza phaseoli* by Coquillett in 1899. The name *Melanagromyza sojae*, therefore, refers to the latter species which is found in older plants.

The stemborer is widespread in Java, and can be found in large numbers in every lowland soybean field. Its distribution is restricted to certain altitudes or, more appropriately, by temperature. It is found in large numbers, for example, in areas around Maja (Cirebon, 500 m) and Bojong Salam (700 m), but at Lembang (1,200 m), Garut and surroundings, which are approximately at the same altitude, soybean plant damage by stemborer is quite rare. Among the *Melanagromyza* species that attack soybean, *M. sojae* is restricted to lowlands. This distribution, as will be discussed later, is also related to the absence of its original host plant, *Flemingia*, at higher altitudes.

Information on the geographical distribution of *M. sojae* outside Java is not available. The literature does not mention this pest in Japan, the Philippines, or India.

We will follow Zehntner's designation, soybean stemborer, to describe this insect. An indigenous name for this fly or its damage, as far as I know, does not exist. Its damage attracts little attention as it does not cause economic yield loss. Damaged plants are never killed by stemborer infestations. For the sake of completeness, however, we will give a brief summary of its biology.

2

Morphology

Eggs:

The egg is nearly crystal clear, short, oval, and rounded at both ends. The egg surface is smooth without markings. Average dimensions are 0.36 mm long and 0.13 mm wide.

Larvae:

The larva is oblong and cylindrical with an acuminate head end and truncated hind-part. The young larvae are translucent, but the older ones are often light yellow. Mouth hooks are shining black and anal stigmata are clear with a black button-like structure. The full grown larvae of *M. sojae* are easily distinguished from those of other soybean *Melanagromyza* not only because of their peculiar location within soybean stems, but also because their characteristic shape. The prothoracic stigmata are very long, as long as those of *M. dolichostigma*, with a clear protruberance similar to that of *M. phaseoli*. These structures are unstalked and are difficult to see even with a magnifying lens. Anal stigmata are long with a characteristic shape not found in the two other soybean *Melanagromyza*. These stigmata have small visible protruberances which appear as black platelets.

When observed under the microscope, the other structures become visible[1]. The head is without the small, tooth-shaped protruberance characteristic of *M. phaseoli* larvae. The prothoracic stigmata have seven unstalked buds. Anal stigmata protrude and usually consist of a ring of four short-stalked buds and a truncated, concave, chitinous cone in the center without soft pads or trachea (Figure 6b).

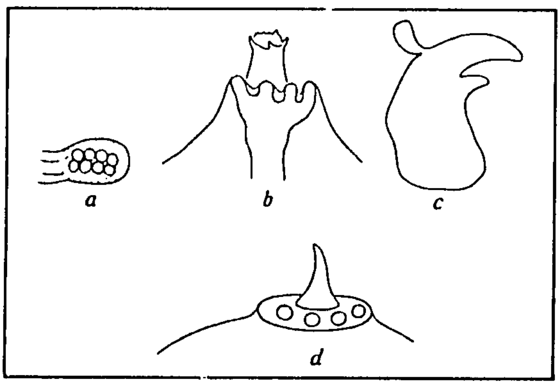

Figure 6. a. Prothoracic stigma, b. anal stigma, c. mouth hook of larva of *Melanagromyza sojae* and d. anal stigma of larva of *Melanagromyza* sp. in gynandropsis.

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[1]For a detailed description, see Prof. De Meijere, 1922 (page 19 in reference 25 listed under Literature Cited).

Pupa:

The pupa has a short oval shape and is usually light-yellow in color. Only the anal stigmata protrude like a small black button. The size is about 2.35 mm long and 0.80 mm wide.

Adult:

Superficially, the adult fly is not distinguishable from the *M. phaseoli* adult. Its color is black, with a metallic shiny abdomen. Antennae, legs, and bristles on head and thorax are all black. The wings are transparent.

As in the case of *M. phaseoli*, the males and females are clearly distinguishable. The females are larger and have tube-shaped abdomens.

Body size: Female - body length 1.88 mm, width at thorax 0.70 mm, wing expanse 4.45 mm; Male - body length 1.60 mm, width at thorax 0.50 mm, wing expanse 3.90 mm.

3

General Biology

Although *M. sojae* damages many crops, it infests soybean in greater numbers. Hence, we will discuss its development in soybean in greater detail.

Oviposition:

The adult soybean stemborer flies deposit eggs in a manner almost similar to that of *M. phaseoli*. They always oviposit in soybean leaves; never on petioles or stems. For oviposition, adult always chooses the undersides of leaves. With the help of forward-directed ovipositors, the adult makes small holes just under the epidermis in the mesophyll cells in which the eggs are deposited. The egg can be easily observed with the help of a magnifying lens. The egg is covered with only a thin epidermis and it shines faintly when observed through a magnifying lens. Often, the egg is protruding from a small hole or sometimes lies completely naked in a small groove when the egg laying fly is unable to bore completely through the epidermis.

The oviposition is normally at the basal part of the leaf lamina. Sometimes the oviposition holes are dispersed throughout the leaf but are usually found near the leaf veins.

The eggs usually hatch in two to three days. As the young larvae bore rapidly into leaf veins observation is not easy. Our development studies of stemborer, therefore, were less accurate than those of the beanfly.

Larva:

The young larva is nearly colorless and thus attracts very little attention. Immediately after emergence, with the help of black mouth hooks, it burrows through the mesophyll cells into the closest vein, disappearing downward in the leaf. The mesophyll cell tunnel, initially whitish, changes to brown, making it clearly distinguishable. The tunnel is usually short and rather straight, ending in the leaf vein. These tunnels are thus clearly distinguishable from the long bow-shaped wandering tunnels of *M. phaseoli*, which are often found in the same mesophyll cells.

The larva continues its way downwards into the stem through the leaf vein and then the petiole, eating and burrowing tunnels into the pith. In young as well as older plants, the larva quickly reaches the root collar. It bores a little further into the thickened main root, turns around, and moves upwards in the pith, thus widening the original tunnel. Before it reaches the top of the plant, and most often when half way, the larva is usually full grown. There, with the help of mouth hooks, it gnaws through xylem and phloem tissues to the epidermis, makes a hole to the outside, closes it with debris, and then pupates in the stem.

While the damaged plants are still young, the insect can easily reach the top of the plant before pupating. In this situation, due to the localized damage in the apical region, there is shoot necrosis similar to that caused by topborer (*M. dolichostigma*). After further research, it was revealed that the stemborer larvae can be easily distinguished morphologically from topborer larvae. In addition, stemborer damage is confined to the pith.

An accurate estimate of larval development time was difficult to determine due to the concealed nature of larval feeding and pupatation; however, it appeared to be between 9 and 11 days. Although several eggs may be deposited in one soybean plant, usually only one, and on rare occasions two larvae were found feeding in a single tunnel. Only in a large branched soybean plant would one find larvae in several separate tunnels. Zehntner's book (pages 119 and 121) describes two or more larvae and pupae in one tunnel. This was not found during my observations.

Pupa:

The light yellow pupa is always located in the pith tunnels, often at the level of the unifoliate leaf of the younger plants, and usually near the fly escape hole which appeared as a black depression.

Because the pupae are hidden in plant tissue, the duration of the pupal stage is difficult to determine precisely, but it usually ranged from 9 to 10 days.

Based on 35 rearing experiments in the laboratory at Bogor, total development time from egg to adult ranged from 16 to 26 days, with an average of 21 days. The development time for *M. sojae* at higher altitudes was not determined.

Adult:

Immediately after emergence from pupae, the weak, grey adult fly escapes through the fly hole gnawed earlier by fully grown larvae. The fly soon develops its metallic shining black color and seeks out soybean or other host plants.

Copulation occurs only five days after emergence. Similar to beanfly, the stemborer copulates only in the morning hours from 7 to 10 AM. The female starts laying eggs soon after copulation.

Oviposition, as pointed out earlier, occurs only on the underside of the leaves. In the case of egg-laying beanfly, cotyledon, unifoliate, and sometimes first trifoliate leaves are preferred. In the case of the stemborer, the reverse is true. *M. sojae* never laid eggs in the cotyledons. Unifoliate leaves had some egg holes wnile a large number of easily distinguishable holes were present in first trifoliate and upper leaves. The fly chooses the leaf underside, and with the aid of its forward directed-ovipositor, bores a hole just beneath the epidermis in which it lays only one egg. The hole is always superficial, and the discoloration of surrounding tissue that is common with beanfly is never evident. Hence, the holes are seen only upon careful observation.

Egg holes are normally short and oval shaped, 0.17 mm long and 0.11 mm wide, and are sometimes empty. The egg is inserted under the epidermis, sometimes only partially, with half or more of the egg exposed.

The insect also bores food holes in a fashion similar to beanfly. Unlike beanfly, the egg holes of soybean stemborer are distinguishable from its food holes. Most feeding holes are located on the upper sides of leaves and the shape of the holes is quite characteristic. Feeding holes are conspicuous shallow grooves, 1 to 1.5 mm long and 0.05 mm wide, injected into mesophyll cells with the help of the ovipositors. These holes never follow a straight downward path but are always more or less forward directed. The adult, similar to *M. phaseoli*, feeds on secretions.

Feeding holes of *M. sojae* do not damage plant tissue. Tissue tumors (abnormal growth) or holes in the leaf tissue commonly found in cowpea due to *M. phaseoli* attack, are absent in soybean infested by *M. sojae*.

Fecundity of the female was not determined. Most eggs were of little significance since the larvae were limited to a maximum of two per plant. Presumably, newly emerging larvae destroy those which emerge later.

The life span of the adult fly is rather long. In the laboratory, when fed on a diet of honey and water, in 20 observations, the female life span ranged from 15 to 36 days with an average of 23 days, and male life span ranged from 10 to 46 days with an average of 26 days. This is probably longer than the life span under natural conditions.

The adult stemborer flies feed on materials similar to those of beanfly adults: juices from food and egg holes in the leaf tissue, dew drops, and other moist materials.

4

Susceptible and Immune Plants

As with beanfly, *M. sojae* damages legumes exclusively. The number of host species is not large, and among them only soybean appears to be suitable for the growth and development of the insect. Apparently, the fly host range is restricted because of larval specialization as a pith feeder. Consequently, the insect can complete its life cycle only in those plants with well developed pith.

Susceptible hosts:

A. Cultivated plants:
  - Soybean (*Glycine max*)
  - Mungbean (*Vigna radiata*)
  - Pigeon pea (*Cajanus cajan*)
  - Rice bean (*Vigna umbellata*)

B. Green manure crops:
  - *Vigna radiata* var. *"sepiara"*
  - *Indigofera suffruticosa*

C. Herbs:
  - *Flemingia* sp.
  - *Aeschynomene indica*
  - *Vigna radiata* var. *sublobata*

Immune plants:

A. Cultivated plants:
  - Peanut (*Arachis hypogaea*)
  - Common bean (*Phaseolus vulgaris*)
  - Lima bean (*P. lunatus*)
  - Peas (*Pisum sativum*)
  - Yam bean (*Pachyrrhizus erosus*)
  - Winged bean (*Psophocarpus tetragonolobus*)
  - Cowpea (*Vigna unguiculata* ssp. *unguiculata* sp. gr. *unguiculata*)
  - Lablab bean (*Dolichos lablab*)
  - Jack bean (*Canavalia ensiformis*)

B. Green manures:
  - *Tephrosia candida*
  - *Crotalaria striata*
  - *C. usaramoensis*
  - *C. anagyroides*
  - *Mimosa invisa*
  - *Vigna hosei*
  - *Desmodium gyroides*
  - *D. stipulacaeum*
  - *Cassia patellaria*

C. Herbs:
  - All others.

5

Nature of Damage in Different Crops

The nature of damage will be discussed first in the two most important host plants mentioned in Chapter 4, soybean and indigo.

Soybean *(Glycine max)*:

In contrast to observations of beanfly, *M. sojae* does not damage plants immediately after emergence. The cotyledons remain free of any damage; few eggs are laid in the unifoliate leaves, and only in the first trifoliate and higher leaves do we find substantial numbers of eggs. Hence, the damage by *M. sojae* occurs in the flowering and podding stages of soybean plants. While beanfly infestation is serious in the seedling stage, stemborer infestation occurs in the later stages of growth.

There is no special characteristic associated with stemborer damage. The first feeding tunnels and egg holes are noticeable in the field only when the first trifoliate leaves are well developed, which takes about three weeks in lowland areas. External symptoms are thus seldom visible on damaged plants in later growth stages. The tops die in plants that are damaged early. Because of insufficient pith, the borer larvae are forced to feed upwards. This results in hollow topped plants which develop lateral shoots.

Infested plants do not show damage symptoms. Serious mortality in older crops, which Zehntner attributes to stemborer damage (or beanfly?, see page 113 of Zehntner's book) was not observed during my investigation.

In flowering or pod-bearing plants, the pith usually contains two separate feeding tunnels. The first tunnel, which is somewhat darkened, usually occupies the lower half of the stem and ends in a fly hole and pupa from which an insect has emerged and escaped to the outside. A more recent second tunnel usually starts below the plant top, extends half way, and contain a large larva or pupa. If the lower tunnel is absent, the top one extends downward.

In most older infested soybean plants, a major portion of the pith is perforated or destroyed, but without visible symptoms. Since pith tissues are of minor importance in supplying water and mineral nutrients to the plant, and as phloem and xylem tissues remain perfectly intact, there is no reduction in plant growth. Reduced soybean yields have not been recorded as a result of stemborer damage.

We studied the extent of stemborer damage in field plots at our experimental farm at Bogor. Damage varied from 70 to 100% in the 21,000 plants observed. On average, only 3.5% plants appeared to be damage-free, while 55% plants contained pupae. Among more mature plants, hardly a single specimen was left undamaged.

Indigo *(Indigofera suffruticosa)*:

Second to soybean, indigo is the most important host plant of soybean stemborer. This plant, besides being cultivated, grows wild in open fields.

Our information on indigo damage is rather sketchy. The first indication of damage occurs when plants have developed second or third unfolded pinnate leaves. The damage is characterized by the presence of long feeding holes of *M. sojae* on leaf undersides. From this stage, until the plants are fully grown, these characteristic stripes are often in such large numbers that the leaves appear completely destroyed when viewed from the underside. But the damage does not retard plant growth (Figure 7c). Unlike soybean, indigo appears to have a complete tolerance to *M. sojae* damage.

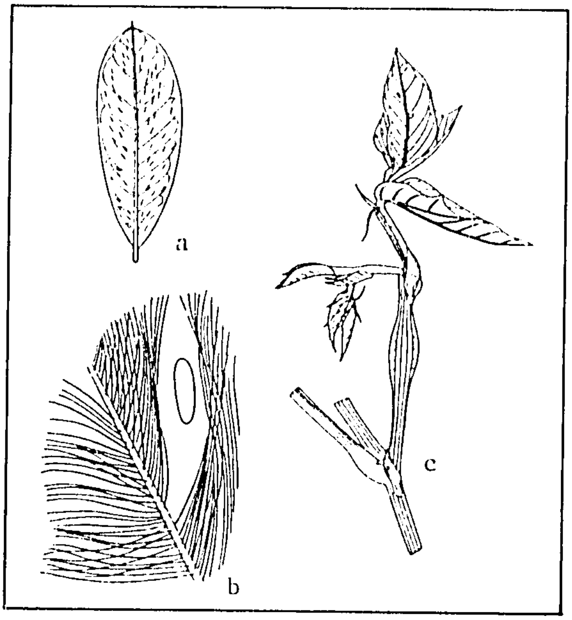

Figure 7. a. Underside of indigo leaf with food holes of *Melanagromyza sojae*. b. Egg of *M. dolichostigma* on the underside of rice bean leaf. c. Gall in rice bean top portion caused by *M. dolichostigma* damage.

So far, I have been unsuccessful in discovering eggs or egg holes in indigo. It is possible that the egg holes are camouflaged by the presence of numerous feeding stripes.

Feeding tunnels in the pith can be easily found by splitting open the older indigo stems. The tunnels occur from the lowest part of the stem up to the top; in the latter, they are more numerous and often united. In a full grown indigo plant stem, six to ten separate pith tunnels may be situated one above the other. The higher tunnels are the result of later infestation.

Only a small portion of the pith in the tunnel path is consumed. Most of the remaining pith turns brown or black. Often the tunnels are short and deserted, leading one to conclude that many larvae died prematurely in the indigo pith. The parasitization of larvae by an ichneumon fly, *Secodella*, is also common.

In indigo, the feeding tunnels in the pith do not cause visible external symptoms. However, in the warm afternoons infested plants show temporary wilting; undamaged plants do not exhibit these symptoms.

Under field condition, indigo was regularly damaged by stemborer. Damage data collected at our experimental field in Bogor are summarized in Table 25. Damage levels varied from 28 to 100%.

It is interesting to note that a related plant species, *Indigofera sumatrana*, is practiclly immune to *M. sojae* (Table 25). An explanation for this resistance has not been determined.

Table 25. Extent of *M. sojae* damage in *Indigofera*.

Crops	Sowing date	Number of plants				Remarks
		total	dam-aged	Heal-thy	%dam-aged	
I. suffruticosa	29-1-1920	100	28	72	28.0	Young
I. sumatrana	"	100	16	84	16.0	plants
I. suffruticosa	25-6-1920	100	35	65	35.0	"
I. sumatrana	"	100	8	92	8.0	"
I. suffruticosa	11-6-1920	100	76	24	76.0	Old
I. sumatrana	"	100	13	87	13.0	plants
I. suffruticosa	16-2-1921	100	99	1	99.0	"
I. sumatrana	"	100	2	98	2.0	"

Mungbean, Rice bean, and Pigeon pea:

Since the damage symptoms in these cultivated plants are similar, they will be discussed together.

Whereas *M. sojae* infests older soybean and indigo plants, in mungbean, rice bean, and pigeon pea the pest infests seedlings. Damage is found exclusively in the unifoliate and first trifoliate leaves; in older plants, feeding tunnels are absent in the upper stems. A significant proportion of younger plants are damaged by this insect (Table 26).

Most eggs are deposited exclusively on the undersides of unifoliate leaves, whereas very few are deposited in the first trifoliate leaves. In mungbean and rice bean, the short, straight mines in mesophyll tissues are often conspicuous, but in pigeon pea they are not.

Stripe-shaped feeding holes frequently appear on the topside of the unifoliate leaves in mungbean and rice bean.

Young damaged plants usually do not die, but death can occur from combined damage with beanfly.

Table 26. Extent of *M. sojae* damage in mungbean and related crops.

Crop	Sowing date	Number of plants				% undamaged
		total	undamaged	damaged	with pupae	
Mungbean	3- 6-19	172	0	136	36	0.0
(*Vigna radiata*)	7- 8-19	872	0	713	159	0.0
	7- 8-19	1901	64	995	922	3.4
	21- 8-19	206	25	104	77	12.1
	26- 8-19	1814	98	833	783	5.4
	17- 9-19	472	47	194	231	9.9
	17- 9-19	562	35	200	327	6.2
	30-10-19	1036	126	503	407	12.2
	30-10-19	2762	123	903	1736	4.4
V. radiata var.	8- 2-19	472	0	472	0	0.0
sepiara	7- 8-19	260	0	198	62	0.0
	29-10-19	31	0	15	16	0.0
V. umbellata	7- 8-19	49	1	25	23	2.0
	28- 8-19	52	3	27	22	5.8
Pigeon pea	28- 8-19	186	29	117	40	15.6
	28- 8-19	189	24	145	30	12.7
	28-10-19	28	0	16	12	0.0
Flemingia	10- 3-21	110	7	101	2	6.4
	14- 3-21	60	52	8	0	86.7

Fully grown larvae or pupae are present in only about half of the feeding tunnels in the pith of damaged plants. Apparently, most of the larvae die prematurely because of a lack of suitable food.

Vigna radiata var. *sepiaria:*

This little used green manure crop is also damaged by stemborer. As with mungbean, infestation is restricted to younger plants; in more mature plants feeding tunnels are absent in the upper parts. The damage is again restricted to unifoliate and first trifoliate leaves. Mesophyll tunnels on leaf undersides and feeding stripes on leaf uppersides are always distinct.

In this crop, the extent of damage is quite significant. At our experimental field in Bogor, we found 100% plant damage (Table 26). There was, however, no mortality in young plants due to stemborer infestation.

Apa-apa (*Flemingia* sp.):

This herb, which generally grows in the lowlands along roads and dikes or at dry sites, appears to be the original host of *M. sojae*. That it is not the most suitable host plant was revealed during our investigation. These plants are sometimes significantly damaged, for example up to 90%, in Indramayu. Many of the feeding tunnels, however, were empty, presumably due to larval mortality because of lack of suitable food.

We were not able to thoroughly study the nature of stemborer damage, but it is believed to be similar to that of soybean. The upper leaves are damaged and contain feeding tunnels.

The movement from *Flemingia* to soybean suggests an improvement in the environment for the fly. For example, at Indramayu, soybean is never planted; "apa apa" is common everywhere and is invariably damaged by *M. sojae*. At our experimental fields, from 1919 to 1921, newly planted soybeans were free of infestation, while those planted earlier were severely damaged by stemborer. Hence the migration from *Flemingia* to soybean was a gradual process.

Vigna sublobate (Kacang monjet):

At our experiment station at Bogor, it appeared that this herb (common at higher elevation area of Priangan) can also be damaged by stemborer. Based on observations at our experimental station, of the 100 plants sampled, 28 were damaged, of which only 6% contained living larvae. Presumably, at higher elevations, where wild host *Flemingia* is not common, kacang monjet takes over the role of host. The damage to this host is restricted mainly to the seedling stage, with feeding tunnels found principally in lower stems and the typical short larval tunnels in some unifoliate leaves.

Aeschynomene indica:

This thin profusely branching herb, which is prevalent in dry lowlands areas and dry rice fields, also appears to be the host of soybean stemborer. At Indramayu, as well as around Bogor, all plants sampled were found to be damaged by stemborer.

The nature of damage is identical to that of indigo. On older plants, the characteristic feeding tunnels are found one above the other inside the main stem and lateral shoots, while tunnels containing young larvae are usually found in apical portion of the plant.

We were not able to determine the nature of the insect damage since egg holes and stripe-shaped food holes could not be found. The morphological characters of the fly larvae, however, are identical to those of soybean stemborer larvae, thereby confirming its identity.

Phaseolus semierectus:

At our experimental field in Bogor, damage by stemborer was established only once, and appears to be rare in *P. semierectus*.

Gynandropsis sp. (family Capparidae):

We often found a fly larva identical to soybean stemborer in the pith of this garden plant. Initially, we thought that this insect also damaged non-legume plants. However, detailed microscopic observations of the larvae revealed some important morphological differences. The anal stigmata of the larva found in *Gynandropsis* have a typical central chitinous cone. This cone is not blunt as in the case of soybean stemborer, but ends in a somewhat curved, thornish point (Figure 6d). Thus, the difference between two species is sufficiently clear.

6

Natural Enemies

Despite its concealed mode of life, *M. sojae* is attacked by as many parasites as the beanfly. These parasites are also ichneumon flies. As in *M. phaseoli*, there are apparently no egg parasites in *M. sojae*. The beanly lacks larval parasites, but the stemborer has a rather important parasite tentatively identified as *Secodella* sp. by A. B. Gahan (1929). Pupal parasites that infest beanfly also attacks temborer. To date, ichneumon flies, *Cynipoide* sp., *Trigonogastra agromyzae* Dodd, and *Eurytoma* sp., have been identified from *M. sojae* pupae. The ratio of insects parasitized by various species of insects varies considerably. *Trigonogastra agromyzae* appears to be the most dominant parasite, while *Eurytoma* sp. was observed on only one occasion.

The extent of parasitism is rather important. Presumably, parasites can easily reach the pupae via exit holes through which adults escape.. In 500 pupal observations, the average parasitism was 30.3%, with a maximum of 56%.

A concise description of the larval parasite *Secodella* sp., is given in the following paragraphs.

Secodella sp.

Morphology:

Female: Body completely black with a blue metallic luster, elongate and narrow with distinct protruberant ovipositor and relatively short, stubby, protruberant wings. Antennae black. Legs black, tarsi, except for pretarsi, white. Wings colorless, marginal vein light brown (Figure 8).

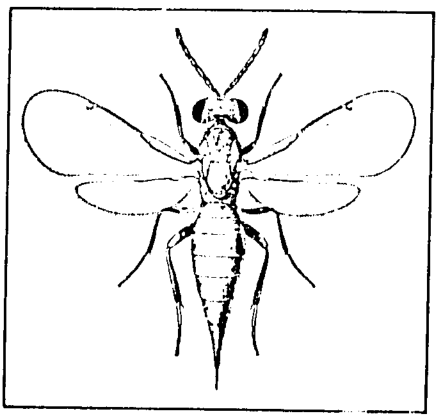

Figure 8. Female of *Secodella* sp.

Antennae eight-segmented, first segment quite long, other segments short and cylindrical, the top segment tapering. The ovipositors are dis inctly located along the abdomen, protruding beyond the length of the body.

Body length 2.20 to 2.65 mm, antennal length 0.85 mm, wing expanse 3.25 mm.

Male: Body black with bluish metallic luster, antennae black, legs black, tarsi except for pretarsi, white. Wings colorless.

Antennae nine-segmented, first segment rather long, second roundish, third through sixth segments oblong and cylindrical, the top three segments without constrictions. All antennal segments have thick bristles.

Body length 1.62 mm, antennal length 0.68 mm, wing expanse 2.65 mm.

Biology:

We did not thoroughly study the life history of this useful parasite. It is a larval parasite of soybean stemborer and soybean topborer, but was never found on beanfly.

The oblong, tapering, off-white larvae are found in feeding tunnels of *M. sojae* consuming *M. sojae* larvae. Later, in the same feeding tunnel, small black ichneumon pupae are also found. We did not determine the precise development time for the parasite. The pupal stage appeared to last for six days and the full grown wasp remained alive in the laboratory from 23 to 33 days.

The extent of parasitism could not be evaluated, since the young larvae were often lost when the stems were cut. But it is possible that the ichneumon wasps restrict the stemborer larval popultion. In indigo stems, 21 parsite and 67 *M. sojae* larvae were found, indicating a 24% level of parasitism.

7

Protection

From the preceeding discussion, it is clear that the soybean stemborer (*M. sojae*), although occurring commonly in the lowlands, does not cause significant damage to soybean. Protection measures that effectively control this pest are not necessary or economical.

The destruction of *Flemingia* plants in the vicinity of soybean fields could assist in reducing infestation, but probably would not justify the labor cost.

SOYBEAN TOPBORER

Melanagromyza dolichostigma

1

Introductory Remarks

While the previous two *Melanagromyza* species, *M. phaseoli* and *M. sojae*, are certainly recognized as important soybean pests in Java, the third species, *M. dolichostigma*, is not considered serious. Zehntner, in his publication on *M. sojae*, reports of epidermis tunneling and dessication of lateral shoots, damage characteristic of *M. dolichostigma*. However, it is difficult to believe that Zehntner would have confused the very conspicuous larvae with those of *M. sojae*. His concise remarks concerning an *Agromyza* sp., which causes abnormal stem thickening in cowpea, indicates the presence of *M. dolichostigma*, but his drawing of anal stigmata raise doubts that this particular *Agromyza* was present.

In any case, *M. dolichostigma* is widespread in Java, both in the lowlands and in the highlands, although it is seldom so numerous as to cause perceptible damage. In the lowlands, this insect is found sporadically in the top shoots of luxuriously growing older soybean plants in which plant tips die, but without visible reduction in pod set. In mountain areas, *M. dolichostigma* infests all soybeans including those grown on rice field bunds. The often-grown rice bean is also damaged. Although the damage is conspicuous, yield loss is not heavy.

Little information is available on this fly outside Java. As local people are not aware of the pest, it does not have a local name.

2

Morphology

Egg:

The eggs are greyish-white, almost transparent, oblong, cylindrical with rounded off ends. The egg surface has clear longitudinal grooves. Eggs measure 0.38 mm long by 0.15 mm wide.

Larva:

The full grown larva is oblong with sharp tapering, somewhat curved head, and a slightly rounded posterior end. The larva is non-translucent white, and at times light-yellow in color. The mouth hooks are black, stigmata white or colorless. The size of the full grown larva is 3.30 to 3.76 mm long, 0.7 mm wide, with anal horns 0.23 mm long and prothoracic horns 0.33 mm long.

The larva can be easily distinguished by the presence of conspicuous, long and somewhat curved protruberant prothoracic stigmata. The anal stigmata is also conspicuously long and stalked.

Under the microscope, the following details were visible. The head lacks a bud-shaped protruberance, mouth hooks with two moderately large, equal size dents, and one similar dent at the backsid of the hook.

The body has clear, crosswise protruberant stripes and pointed spinelets. The prothoracic stigmata are conspicuously large and stalked. The stalk is somewhat curved and uniformly thick. There is a thickening with 15 round bulbs at the top end. Anal stigmata are long and divided into two separate conical tubes. Each tube carries one row of eight bulbs on the top half and six at the topmost part (Figure 9 a, b, c)[1].

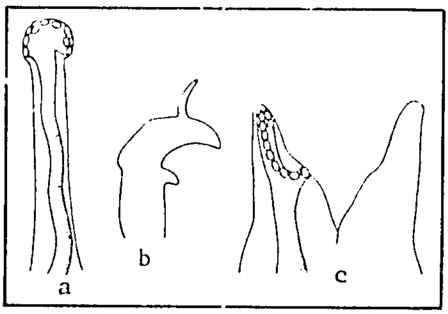

Figure 9. *Melanagromyza dolichostigma* larva: a. prothoracic stigma, b. mouth hook, and c. anal stigma.

Pupa:

The pupa is initially yellowish-brown and later turns

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[1]For a detailed description, see Prof. De Meijere, 1922 (page 19 in reference No. 25 listed under Literature Cited).

to reddish-brown at the anal end. The two pairs of stigmata are reddish brown. Pupal shape is a broad oval with clearly stalked prothoracic and anal stigmata. The prothoracic stigmata are long and somewhat curved.

Pupal size: length 2.35 to 2.55 mm, width 2.94 mm, and anal horns 0.19 mm and prothoracic horns o.42 mm.

Adult:

The body is completely black with a distinct, green metallic luster. Wings are translucent, veins light brown. Halters are commonly black. Tegula is white. Antennae and legs are black. The long bristle hairs on the sclerite (scutellum) are white; the other smaller hairs on head and thorax are darker.

Abdomen in the female terminates in a well developed anal tube with a rounded end.

Body size:- female: length 2.25 mm, width at thorax 0.64 mm, wing expanse 5.65 mm. Male: body length 1.95 mm, width at thorax 0.66 mm, wing expanse 5.15 mm.

3

General Biology

We will describe the life history of the soybean topborer in soybean, its most common host.

Egg:

The thick-walled eggs of soybean topborer are present in the leaves only when the plants are three to four weeks old, a stage of growth suitable to topborer oviposition. Whereas other species of *Melanagromyza* lay eggs in the leaves, the topborer lays eggs on the leaves. Well developed, rough, leaf hairs are necessary to ensure firm attachment of eggs to the leaf surface. Cotyledons and unifoliate leaves of soybean do not meet this requirements, as glabrous surfaces will not permit attachment of the eggs. The emergence of the first trifoliate leaves usually fulfills this requirement. This leaf, even before it unfolds, is sufficiently pubescent for attachment of superficially deposited eggs, while the coarse hairs on the underside offer further support. Among the top leaves, the newly folded ones are preferred for egg deposition.

The fly makes a superficial hole on the wrinkled leaf and lays one egg. The hole allows firm attachment of the eggs. The incubation period was not determined exactly but is estimated to be about two to three days,.

Larva:

The emergence of young larva was not observed. It appears that the larva bores immediately into the plant tissue since there is always a distinct hole in the leaf under the hatched empty egg. The tunnel extends into the leaf vein and downwards through the petiole into the stem. Once there, the larva bores between the cortex tissue and the xylem bundles, even downwards through the lowest layer of cortex for about 2 cm. Then the larva bores transversly through the stem, damaging xylem tissue and, ultimately, the pith. Gradually working in all direction, an oblong cavity is created in which only the xylem tissue remains undamaged. The cavity is concealed by undamaged cortex tissue and the stem epidermis.

The cavity usually contains several larvae; in soybean, it varies from two to six. In slow growing soybeans, the full grown larvae consume the remaining cortex tissue, resulting in necrosis. When the plants are growing luxuriantly and the apical meristem continues development, an abnormal thickening commonly occurs at the location of the cavity, as in *Vigna umbellata* var. *trinervis*.

In both cases, the full grown larva finally gnaw a small exit hole in the cavity wall and pupates surrounded by remnants of xylem vessels and debris.

Because the larva feeds within plant tissue and is thus concealed, the duration of the larval period was not precisely determined, but based on insect rearing experiments it appears to last nine to ten days.

Pupa:

The yellowish-brown pupa is always found near the apex of the plant, either in the dead top or in the thickened stem. At times, pupae are located in the thickened petioles of the apical leaves.

The pupal period lasts 9 to 12 days, after which the fly emerges.

Based on 18 insect-rearing experiments in the laboratory at Bogor, the time required for the insect to grow from egg to adult ranged from 17 to 21 days, with an average of 18 days in the lowlands. Similar studies were not conducted in mountain areas.

Adult:

The fly emerges from the plant through the exit hole made by the larva in the apical portion of the stem. Soon after emergence, the fly searches for the soybean plants.

Copulation usually occurs two to six days after the adult emergence. In this species, copulation also takes place in the early morning; at Bogor usually from 7 to 10 AM. In mountain areas, copulation takes place later in the day as it does with beanfly.

Oviposition starts soon after copulation. As mentioned earlier, the insect prefers folded leaves for attachment of eggs; in soybean these are the trifoliates. The first eggs are deposited when soybean plants are two to six weeks old.

The female lays eggs singly on the underside of the folded leaves which (at that time) function as top leaves. The eggs are either attached on leaf undersides or, as it occurs more often in soybean, are inserted into the mesophyll with the help of the ovipositor. Three to four such eggs may be deposited together on one leaf. The fly seldom uses the unfolded top leaves for egg laying.

Similar to *M. phaseoli* and *M. sojae*, *M. dolichostigma* also bores feeding holes in the leaves. These occur only on the top side of older leaves and are characterized by long shallow notches similar to but longer than those of *M. sojae*.

Few eggs are laid - a maximum of two per day - in one breeding cycle. Premature desication or predation by ants prevented adequate data collection in our experiment.

The life span of the adult is rather long. When fed in the laboratory on a mixture of honey and water, females lived from 11 to 44 days, with an average of 22 days; the males survived 9 to 46 days with an average of 24 days.

The adults feed on dew drops and plant juices obtained by females piercing leaves with their ovipositors.

4

Susceptible and Immune Plants

Similar to the previous two species, *M. dolichostigma* infests only legume plants. Hosts are few, partly due to special requirements for oviposition.

Susceptible hosts:

A. Cultivated plants:
- Soybean (*Glycine max*)
- Rice bean (*Vigna umbellata*)
- Common bean, Kacang buncis (*Phaseolus vulgaris*)

B. Green manure crops:
- *Vigna mungo*
- *V. umbellata* var. *trinervis*
- *V. radiata* var. *sepiaria*
- *Calopogonium mucunoides*
- *Puraria javanica*
- *Crotalaria juncea*

C. Herbs:
- *Vigna radiata* var. *sublobata*

Immune hosts:

A. Cultivated plants:
- Mungbean (*Vigna radiata*)
- Common bean, Kacang jogo (*Phaseolus vulgaris*)
- Lima bean (*Phaseolus lunatus*)
- Peanut (*Arachis hypogaea*)
- Pigeon pea (*Cajanus cajan*)
- Yam bean (*Pachyrrhyzus erosus*)
- Winged bean (*Psophocarpus tetragonolobus*)
- Cowpea (*V. unguiculata* ssp *unguiculata* cv. gr. *unguiculata*)
- Jack bean (*Canavalia ensiformis*)

B. Green manure crops:
- *Tephrosia candida*
- *Indigofera suffruticosa*
- *Crotalaria usaramoensis*
- *Centrosema plumieri*
- *Vigna hosei*

C. Herbs:
- *Vigna trilobata*
- *Phaseolus semierectus*
- *Phynchosia minima* etc.

5

Nature of Damage in Different Crops

The external symptoms of topborer damage vary considerably according to host species. Hence, the nature of the damage is described separately for different crops.

Soybean *(Glycine max)*:

The nature of damage in soybean is as follows. The damage occurs only when the plants are about three weeks old, a period when the first folded trifoliate leaf emerges and offers the fly a suitable site for egg laying. As long as the soybean plant is growing and unfolded leaves appear, *M. dolichostigma* damage can occur even up to flowering.

The young top leaves of soybean are ideal for superficially deposited eggs, as long as pubescence is adequate. The nature and extent of soybean damage depends upon the development stage during which the eggs are laid. If the eggs are deposited on a small, folded apical leaf, the larva reaches the apex via the petiole. The destruction of tissue results in brown discoloration, necrosis, and leaf drop. Usually, the apical shoot dies back up to a the distance of a few centimeters.

If the leaves are half unfolded during egg laying, wilting and die-off occurs only when the stem has formed new top leaves. Sometimes the larva does not reach the stem, but gnaws a cavity when halfway through the shoot. This cavity can be identified by light yellow and slightly thickened tissue.

Within the stem, the injury usually causes top die off a few centimeters from the next top leaf. In luxuriant plants, the top may continue growing and develop a swelling on the stem below the growing point. The swelling is usually small, initially yellow, and later bulbous with a greenish hue. It is here that fly excavates a cavity.

The conspicuous symptoms of *M. dolichostigma* damage thus consists of a brown discoloration and die-back of the apical meristem. These symptoms are usually visible when plants are 4 to 6 weeks old. Dead parts later drop and damage becomes inconspicuous.

The injury to soybean by the topborer is generally of little importance at or before flowering, a period when vegetative growth has virtually ceased. When the damage occurs at three to four week stage, stunted plants are rarely compensated by lateral shoots. Pod set and yield are seriously reduced, as observed at Lembang in 1921.

We collected only limited data on the rate of damage. In the lowlands, minor damage to soybean by *M. dolichostigma* could be attributed to soybean grown in stubble, which resulted in less luxuriant plant growth. However, on some luxuriant soybean fields near Ciwaringin (Cirebon) there was also little damge. Similarly at our experimental field in

Bogor, the damage was common but nerver serious, only 1 to 2%. Only in Lembang (altitude 1,200 m), was the damage serious, comprising at least half of the plant population.

The susceptibility of soybeans to topborer damage varies with the growth status of the plant. It is evident that plants with luxuriant growth are more damaged than slow growing ones. Also, the damage varies according to variety. For example, at our experimental field at Bogor in 1919, damage differed between a black lowland variety from Nganjuk, another black, large-seeded variety from Ciomas (Bogor), and a black seeded soybean from the Philippines. At first, the Nganjuk variety grows rather poorly, while the other two have luxuriant growth. Topborer damage occurred only in the latter two. At an experimental field in Lembang in 1921, we also observed much higher damage to the luxurious Ciomas soybean than the black-seeded Nganjuk variety or the white-seeded mountain variety.

Rice bean, *Vigna umbellata* var. *trinervis*, and *V. mungo:*

We shall treat these three crops together as the damage by *M. dolichostigma* is practically identical for the three species.

Rice bean is a cultivated climbing legume plant, which in mountain areas is often planted on the bunds of paddy fields. *V. umbellata* var. *trinervis* and *V. mungo* are sometimes used as green manure crops. Rice bean matures early and dies off within three months. *V. umbellata* var. *trinervis* and *V. mungo* often live for 12 months. All three are strongly pubescent on the undersides of the leaves and stems.

The nature of damage in these three crops differ only slightly from that of soybean. The eggs are deposited on the first trifoliate leaves and successively upon unfolded top leaves as they appear. The long, dense hairs offer excellent support for the deposition of eggs. The subsequent external symptoms on young top leaves are similar to those in soybean, except that the leaves remain intact on the plant for a longer period. Often, such leaves grow through the damage. Many times the fly larva excavate a cavity in the petiole.

Apical shoot damage in these three crops is often less serious than in soybean. In less luxuriant rice bean plants, several shoot tops or tendrils die back a few centimeters. With these three crops, tendrils generally continue to grow despite internal injury. A small, light-yellow, approximately one centimeter long thickening suggests the presence of larval activity. The thickening gradually develops into a gall on the stem above which normal growth occurs. Apical leaves are often damaged by *M. dolichostigma* and this results in additional gall formation. On the older stems of *V. umbellats* var. *trinervis*, numerous galls are situated one above the other beneath the growing tendrils. In these galls, the exit holes through which adults emerge are often visible. The external symptoms of topborer injury to three crops are tendril necrosis; roundish, gall-shaped thickening on the stems; apical leaf necrosis; or petiole thickening of apical leaves.

The topborer damage in these three crops is not very important. In rice bean, the frequent necrosis of the tendrils can retard growth and reduce pod set. The green manure crops, typified by luxuriant growth and long growing periods, produce lateral shoots which compensate for the damage.

In practice, the damage by topborer is rather general on all three crops, but was severe on rice bean at our experimental field in Bogor and in Maja Cultural Garden (Cirebon).

Common bean *(Phaseolus vulgaris):*

Only once did I notice *M. dolichostigma* damage on this crop. It was observed on full grown plants of white-seeded common beans grown by Dr. van Hall in his garden at Bogor. The tendril showed abnormal swelling and the galls contained larvae identical to those of *M. dolichostigma*. Presumably, the folded top leaves offer an appropriate site for egg laying. Topborer damage was never observed on the commonly grown dwarf varieties of *P. vulgaris*.

Vigna radiata var. *sepiaria*

That this green manure crop is damaged by *M. dolichostigma* appears to be due mainly to the slow unfolding of its young leaves which offers the fly an opportunity for egg laying on a virtually glabrous surface. The eggs are probably deposited on folded apical leaves of well developed plants. Wilting of damaged shoots occurs after a considerable delay. Apparently the fly larva is confined to the petiole and its feeding activity stimulates a small swelling. Later, the leaf wilts but the petiole remains intact until the fly has emerged. Larvae seldom reach the stem and apical necrosis has not been observed in this crop.

It should be pointed out that in a related species, mungbean (*Vigna radiata*), topborer damage was never observed in the luxuriant growth of either small-seeded or large-seeded plants. On one occasion, however, a few *M. dolichostigma* larvae were found in green pods of mungbean. On *V. radiata* var. *sepiaria*, the larvae of *M. weberi* De Meijere were found in the pods. This species is also known to feed in the pods of *Cajanus* and *Flemingia*.

Crotalaria juncea:

In early 1928, van der Elst noticed scattered topborer damage in Lamajang and later on older plants at Bogor. The injury resulted in wilting and apical necrosis without evidence of thickening of stem or gall formation.

Calopogonium mucunoides:

Based on observations at Bogor, this creeping legume, which is used for green manure, is always severely damaged by topborer. The damage symptoms are characterized by tendril necrosis.

Rather hairy tendrils at the apex of the plant apparently offer the topborer an opportunity for oviposition. However, larvae were absent in many of the dead tendrils, possibly indicating a somewhat unfavorable environment for larval development.

Pueraria javanica:

In the Cultural Garden at Bogor some tendrils of this green manure crop were always damaged. However, the crop is not a suitable host plant for this fly.

Vigna radiata var. *sublobata:*

This common herb, which is indigenous to the mountain areas of Priangan, was damaged considerably at our experimental field in Bogor. Gall-shaped thickening was restricted to young tendrils which died. A living larva was found in only one tendril. Apparently, this crop is not a suitable host for topborer.

6

Natural Enemies

Topborer is infested by a large number of ichneumon parasites. Most of them also parasitize beanfly, while a larval parasite of *M. sojae* also parasitizes topborer larva.

The following parasites were observed:

Egg parasites: none
Larval parasites: *Secodella* sp.
Pupal parasites: *Cynipoide* sp., *Eurytoma poloni* Girault, *Trigonogastra agromyzae* Dodd, and *Eurytoma* sp.

A brief accout concerning the parasites is summarized below.

The larval parasite, *Secodella* sp. developed from topborer galls plays an important role in *M. dolichostigma* biology. On *Vigna umbellata*, the parasitism reached 12%.

For pupal parasites, based on 40 observations involving 2,500 plants, an average of 10.5% and a maximum of 47% of the pupae were infested by parasites. The most important parasite was *Eurytoma poloni* Girault. *Eurytoma* sp. was more prevalent on *M. dolichostigma* than on either *M. sojae* or *M. phaseoli*.

7

Protection

The damage caused by topborer is often so insignificant that protection measures are impractical. Where the damage is more serious, such as in mountain areas or on certain perennial crops such as *Vigna mungo*, timely cutting and destruction of wilting tops is a practical means of control. In this way, further infestation can be prevented from spreading, thus limiting further damage.

Further, a system of crop rotation which would avoid infestation from the previous crop, as well as from a contiguous susceptible crop, is desirable.

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