Chapter 21

INSECTS AND OTHER PESTS IN AFRICA

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Introduction

One of the most important bean-production constraints in tropical and subtropical Africa is the wide range of insect pests. Insects attack every part of the bean plant from roots to pods and seeds and cause heavy losses (Karel et al., 1981). Pests infest beans not only in the field, but also in storage. However, for various reasons, few subsistence farmers control insect pests with chemicals; nor do they use insect-resistant cultivars or clean seed.

A substantial proportion of common beans are lost to pest damage every year in Africa. The losses in beans vary from slight to 100%, depending on area, season, cultivar, planting date, and cultural practices. Although accurate and reliable data on bean losses from insect pests are not available in various parts of Africa, estimates are available of losses from some pests (Table 1). Karel (1984a) and A.K. Karel and Ashimogo (unpublished data) recorded as much as 70% seed yield loss in Tanzania. Storage bean losses in eastern Africa are estimated to be between 30% and 73% (Karel, n.d.; Khamala, 1978).

Mixed cropping is practiced by 75%-90% of farmers in Africa (Leakey, 1970). There are many advantages in associated cropping such as reduced pest incidence and damage, erosion control, lower economic risk, and optimization of crop productivity (Desir and Pinchinat, 1976). Although mixed cropping reduces the pest population of some species, it must be combined with other protective

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Table 1. Yield losses in common beans from insect pests in Africa.

Pest	Country	Yield loss (%)	Source
Foliage beetle	Tanzania	18-31	Karel and Rweyemamu, 1984
Aphid	Uganda	90	Nyiira, 1978
	Tanzania	37	Swaine, 1969
	Burundi	50	Autrique et al., 1985
Bean fly	Kenya	30-100	De Lima, 1983
	Tanzania	33-100	Karel and Matee, 1986 Wallace, 1939
	Burundi	50	Autrique, 1985
	Central Africa	50	Autrique, 1985
	Uganda	100	Greathead, 1968
	Zimbabwe	50-100	Taylor, 1958
Thrips	Uganda	27	Ingram, 1969b
Pod borers	Kenya	15-25	De Lima, 1983
	Tanzania	33-53	Karel, 1985d
Bruchids	Kenya	73	Khamala, 1978
	Tanzania	30	Karel, n.d.
	Uganda	23	Rubaihayo et al., 1981

measures to optimize yields. Literature from many studies in several African countries suggest that large yield increases can be obtained with effective insect control (Karel and Ndunguru, 1980). Use of cultural control methods and resistant cultivars will further reduce losses caused by insects.

Insect pests are often found in complexes (Figure A) and such complexes are often responsible for severe damage and reduction in bean yields. However, insect complexes vary greatly throughout Africa (Table 2) and in most cases are not well documented. So far, only listings have been made: Hill (1975) listed over 60 insect species that attack beans; more recently, Karel (1984b) identified more than 80 insect species associated with beans in eastern Africa. These attack every part of the bean plant (Figure B) from the root to the pods and seeds, and seeds in storage (Table 3) (Karel et al., 1981).

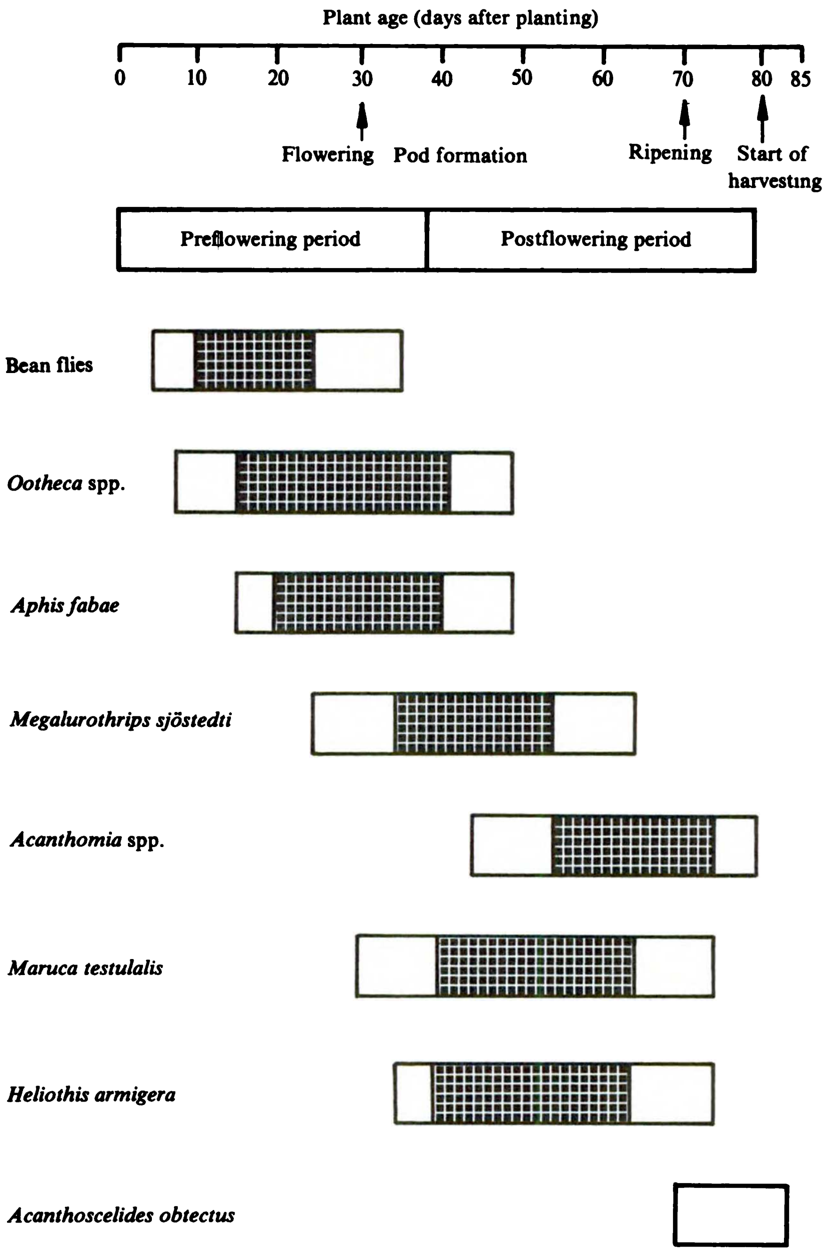

Figure A. The time of occurrence and peak activity of important insect pests of common bean (*Phaseolus vulgaris* L.) in Tanzania (Karel, 1982). ▦ = Peak activity; ▭ = Occurrence.

Table 2. Economic importance[a] of bean insect pests in major bean-producing countries of Africa.

Insect species	North Africa		East Africa					Southern Africa		
	Egypt	Ethiopia	Kenya	Tanzania	Uganda	Burundi	Rwanda	Malawi	Zambia	Zimbabwe
Ophiomyia phaseoli	I	I	I	I	I	I	I	I	I	I
Aphis fabae	M, L	M, L	I, M	M	I	I, M	M	M	L	L
Empoasca spp.	M	A	M, L	L	L	L	L	A	A	L
Ootheca spp.	A	A	M, L	I, M	L	M, L	A	M	A	A
Megalurothrips sjöstedti	A	A	M, L	M	M, L	L	L	A	M	L
Maruca testulalis	A	A	M, L	I, M	I	M	L	A	M, L	L
Heliothis armigera	M	I	I	I, M	M	L	M, L	M	M, L	M
Acanthoscelides obtectus and *Zabrotes subfasciatus*	A	A	I	I	I	I, M	I	I	M, L	M

a. Economic importance of pest: I = important; M = moderately important; L = less important; A = absent or not reported.

SOURCES: Adams, 1984; Dieudonné, 1981; Edje et al., 1981; Karel et al., 1981; Nyabenda et al., 1981; Rubaihayo et al., 1981.

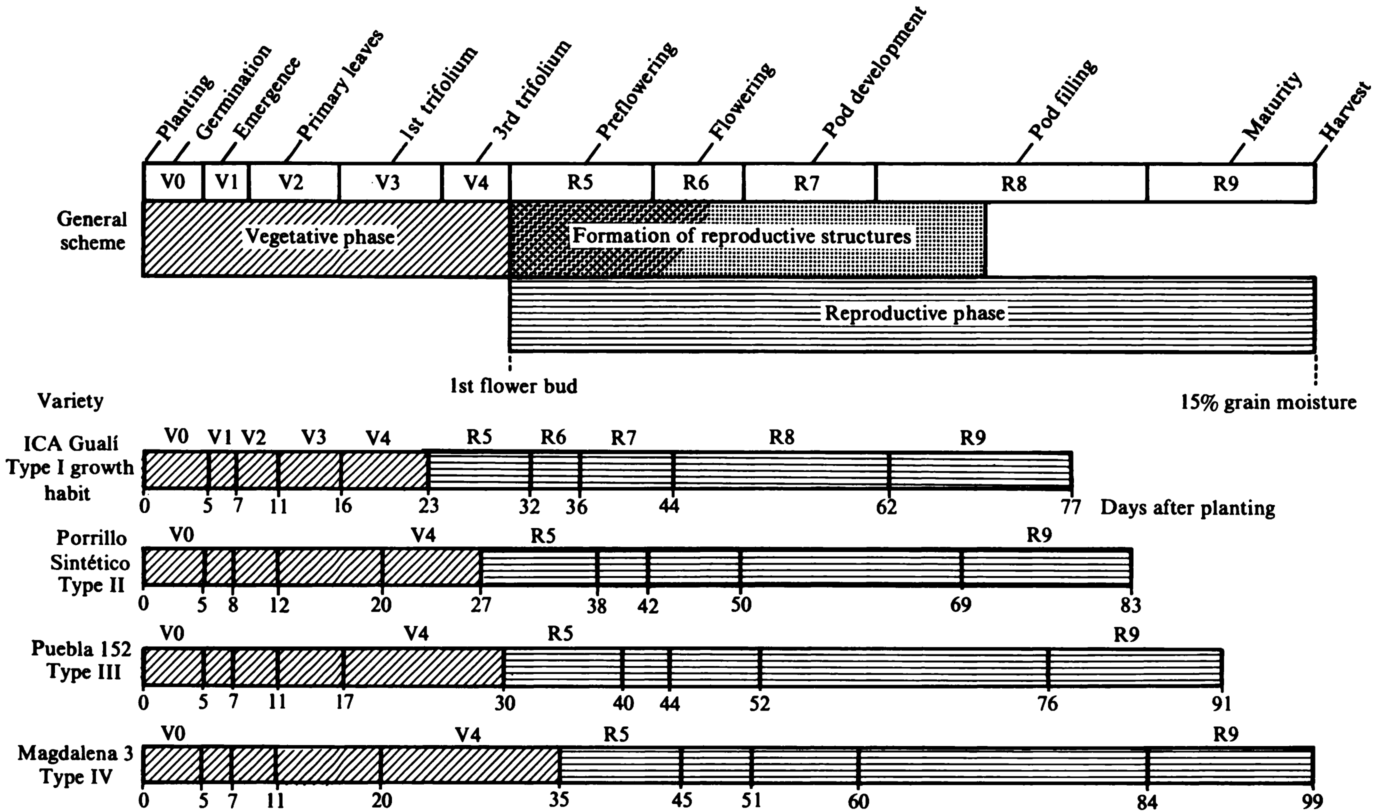

Figure B. Phases and stages of development of the common bean at the Centro Internacional de Agricultura Tropical (CIAT), Palmira, Colombia, at 24 °C and 1000 m.a.s.l. (Adapted from Fernández et al., 1982.)

Table 3. Major insect pests of common beans in Africa.

Common name	Scientific name	Pest status[a]	Damage
Bean fly	*Ophiomyia phaseoli* Tryon *O. centrosematis* de Meijere *Melanagromyza spencerella* Greathead	1	Feed on stem during preflowering period, especially at seedling stage
Leafminer	*Liriomyza trifolii* Burgess	2, 3	Maggots damage leaves by making serpentine tunnels while feeding on leaf palisade tissues
Black bean aphid	*Aphis fabae* Scopoli	1	Sucks plant sap from leaves and stem at seedling stage and from pods; virus vector
Cowpea aphid	*Aphis craccivora* Koch	2	Sucks plant sap from leaves and stem at seedling stage and from pods; virus vector
Leafhopper	*Empoasca lybica* Le Berg *E. dolichi* Paoli	2 2	Suck sap from leaves during preflowering period
Common whitefly	*Bemisia tabaci* (Gennadius)	2	Sucks plant sap from the underside of leaves
Foliage beetle	*Ootheca mutabilis* Sahlberg *O. bennigsenni* Weise	1, 3 1, 3	Feed on leaves during preflowering period; virus vector
Blister beetle	*Coryna kersteni* Gerstaecker *C. apicicornis* Guerin	3 3	Feed on pollen (and destroy anthers) and other flower parts
Blister beetle	*Mylabris amplectens* Gerstaecker *M. dicincta Bertoloni* *M. tristigma* Gerstaecker	3 3 3	Feed on flower parts, destroying them
Striped bean weevil	*Alcidodes leucogrammus* Erichson	2	Larvae feed inside stem, causing cankerous swellings; adults make holes in leaves during feeding

(Continued)

Table 3. (Continued).

Common name	Scientific name	Pest status[a]	Damage
Striped foliage beetle	*Luperodes quaternus* Fairmaire	2	Feeds on leaves at seedling stage
Flower thrips	*Megalurothrips sjöstedti* Trybom	1, 3	Damages flower buds and flowers by sucking sap
Legume pod borer	*Maruca testulalis* (Geyer)	1, 2	Feeds on flower buds, flowers, and green pods
American bollworm	*Heliothis armigera* Hubner	3	Feeds on flowers, pods, and sometimes foliage
Spiny bug	*Clavigralla schadabi* Dolling *C. tomentosicollis* Stål *C. hystricodes* Germar	2, 3	Suck sap from green pods and cause their premature drying and shrivelling
Giant coreid bug	*Anoplocnemis curvipes* Fabricius	2, 3	Sucks sap from green pods and cause their premature drying and shrivelling
Coreid bug	*Riptortus dentipes* Fabricius	2	Sucks sap from green pods and cause their premature drying and shrivelling
Green stink bug	*Nezara viridula* (Linnaeus)	2	Sucks sap from green pods and cause their premature drying and shrivelling; feeding punctures cause necrosis
Bean weevil	*Acanthoscelides obtectus* (Say)	1	Damages seeds in storage; infests dry seeds in field
Mexican bean weevil	*Zabrotes subfasciatus* (Boheman)	1	Damages seeds in storage

a. Pest status: 1 = major pest; 2 = minor (secondary) pest; and 3 = sporadic in occurrence.

Bean Fly (Diptera: Agromyzidae)

Bean fly, *Ophiomyia phaseoli* Tryon (earlier described as *Melanagromyza phaseoli*) is a widely distributed pest of seedling beans in eastern, central, and southern Africa, Asia, and Australia. It has not yet been recorded on beans in the Americas. It is the most important pest of common beans in Africa (Dieudonné, 1981; Edje et al., 1981; Greathead, 1968; Hassan, 1947; Jack, 1913; Karel, 1985a; Le Pelley, 1959; Moutia, 1944; Nyabenda et al., 1981; Ohlander, 1980; Wallace, 1939). It was recently reported on beans in Nigeria (Deeming, 1979). Two other species of bean fly, *Ophiomyia centrosematis* de Meijere and *Melanagromyza spencerella* Greathead, have also been recorded in eastern Africa (Greathead, 1968; N. S. Irving, unpublished data; Karel, 1985a). Spencer (1973) considers the *M. sojae* reported from Uganda to be synonymous with *O. phaseoli*. Species of *Ophiomyia* and *Melanagromyza* such as *O. centrosematis*, *M. spencerella*, and *M. dolichostigma* de Meijere, may have been considered as *O. phaseoli* in some literature. For example, the cases of bean-fly oviposition on stems reported by Walker (1960) were probably of *M. spencerella* (described in 1968 by Greathead) and not of *O. phaseoli*.

Bean flies are known by several common names such as stem fly, bean stem maggot, stemborer, pea stemborer, stem miner, bean stem miner, snap bean fly, and soybean leafminer. Karel (1985a) has summarized the literature on bean flies on beans with a detailed bibliography.

Life cycle

Bean flies are minute insects measuring 1.9 to 2.2 mm in length, with a wing span of 4.9 mm. The flies are shiny metallic black (Figure 160). The female is usually a little bigger than the male and can be recognized by her bluntly pointed abdominal tip. *Ophiomyia phaseoli* can be distinguished from all other species, except *M. spencerella*, by its unusually elongated shiny ocellar triangle that reaches to or beyond the lower orbital setulae. It is readily distinguished from *M. spencerella* in males by the form of the aedeagus; and in females, although with more difficulty, by the shape and serration of the ovipositor blade. *Ophiomyia centrosematis* can be distinguished from the other two species by its ocellar triangle and genitalia (Greathead, 1968).

Oviposition in *O. phaseoli* is peculiar. It consists of a series of actions carried out by the female fly: after alighting on a leaf, the female walks about on the leaf surface for a while. Once she has located a suitable site she raises her abdomen so that the ovipositor is perpendicular to the leaf surface. She then makes a series of downward movements with her abdomen to pierce the leaf surface with the ovipositor. She makes several elliptical cavities (ovipunctures) (Karel, 1985a), after which she moves backward and feeds on the exudate that has oozed from the ovipunctures. For oviposition, the female aligns the ovipositor, at an ovipuncture, with the leaf axis so that an opening leads toward the base of the leaf. This has the effect of directing the larva, when hatched, down the stem.

The female *O. phaseoli* oviposits on the upper surface of the leaves (Karel 1985a), although a few eggs are also laid on the lower leaf surface (Abul-Nasr, 1977; van der Goot, 1930; Greathead, 1968). However, Agarwal and Pandey (1961), Ali (1957), and Manohar and Balsubramanian (1980) observed greater oviposition on the lower leaf surface in beans. Davis (1969) reported that oviposition on the lower surface of the leaves usually occurs during rainy weather. The favorite site for oviposition is near the midrib, at the base of recently unfolded trifoliolate leaves (Davis, 1969; van der Goot, 1930; Greathead, 1968; Ho, 1967; Rogers, 1979). Karel (1985a) reported that the majority of ovipunctures are made in the basal one-third of the leaf. Many more ovipunctures are usually made than are used for oviposition and some are used for adult feeding only (Davis, 1969; Greathead, 1968; Ho, 1967; Swaine, 1969). Karel (1985a) reported that eggs are laid in only 10%-15% of the ovipunctures made.

Although the female of *M. spencerella* scarifies leaf tissue in the same way as does *O. phaseoli*, presumably for feeding purposes, it rarely oviposits on leaves. *Ophiomyia centrosematis*, unlike the other two species, causes no damage to leaves. Eggs of *Ophiomyia centrosematis* and *M. spencerella* are laid in the stem and hypocotyl. The bulk of the oviposition by *M. spencerella* occurs on the hypocotyl at ground level, two to three days after seedling emergence, whereas *O. centrosematis* does not prefer hypocotyl oviposition as much. However, because *M. spencerella* also deposits eggs in young stem tissue above the cotyledon, the ovipositional sites of the two species are indistinguishable (Greathead, 1968). *Melanagromyza spencerella* also lays its eggs in pockets beneath the epidermis, as does *O. phaseoli*. In *O. centrosematis* and *M. spencerella* stem oviposition is usually oriented with the opening on the lower side and egg situated above the opening (Greathead, 1968). Eggs are not visible from the outside, but can be seen if the leaf or hypocotyl is held up against light or is cleared with alcohol (van der Goot, 1930).

The eggs of the three species of bean fly are smooth, white, oval, and measure about 0.3 mm in length and 0.1 mm in diameter. They are laid singly in the ovipunctures. In her life time, a female lays about 70 eggs (Karel, 1985a). Agarwal and Pandey (1961) found an average of 33 eggs, while Otanes y Quesales (1918) recorded an average of 200 eggs.

The larva hatches from its egg in two to four days. The newly emerged larva, transparent to yellowish white in color, can be easily seen among the green leaves because of its black mouth hooks and body movement. Soon after hatching, the larva tunnels through the leaf tissue, beneath the epidermis, to a nearby main vein or directly to the midrib. The larval tunnels can be seen on the underside of the leaf as silvery mines. The larva then feeds and tunnels through the midrib to the petiole (leaf stalk) where it molts into a second instar. The larva then mines to a branch or upper part of the stem and molts again. The third-instar larva bores down the stem of the plant.

The mines of *O. phaseoli* and *O. centrosematis* can be seen below the epidermis with the help of a hand lens. However, the *M. spencerella* larva feeds and tunnels within the stem and therefore its tunnels are not apparent from the outside. The larva continues to feed down the stem into the root. It returns to pupate in the stem just above the soil surface (Greathead, 1968) or sometimes it pupates in the root (Ho, 1967). The larva changes its direction if it meets necrotic or previously mined tissue and progresses farther up the stem before pupating. The *O. centrosematis* and *M. spencerella* larvae mine downward, feeding extensively in the hypocotyl and taproot before returning to ground level or above to the nearest healthy tissue to pupate.

Fully grown larvae are 2.5 mm long with black rasping hooks (mouth parts), and yellow-white prothoracic and posterior (anal) spiracles (Ho, 1967; Karel, 1985a). The average number of pores in posterior spiracles of the larva of *O. phaseoli* is 8±1, while *M. spencerella* has an average of 10±1. The number of pores in the posterior spiracle of *O. centrosematis* larva average only three (Greathead, 1968). The total larval period lasts eight to ten days in warm climate (Karel, 1985a).

The fully grown larva pupates below the stem epidermis (Figure 161), although in older plants pupation may also occur at the base of a petiole. The puparium is found beneath the epidermis, with the head pointed upward and the ventral surface toward the axis of the stem. Before pupation, the area at the front end of the puparium is thinned to a semitransparent window which aids the emergence of the adult. The *M. spencerella* larva pupates in the same position as does *O. phaseoli* after preparing a window. The *O. centrosematis* larva pupates in the same way as *O. phaseoli*, but a window is not prepared. Instead, the anterior spiracles pierce the dry epidermis and project from it (Greathead, 1968).

The pupae of bean flies are barrel-shaped, about 5.5 mm by 2.2 mm in size. The pupae of *O. phaseoli* are usually translucent yellow-brown, while those of *O. centrosematis* are translucent red and yellow-brown. The pupae of *M. spencerella*, however, are opaque and shiny black (Greathead, 1968; Karel 1985a). The number of openings (pores) on posterior spiracles average 8±1 and 10±1 for *O. phaseoli* and *M. spencerella*, respectively. However, the posterior spiracles of *O. centrosematis* have only three openings (Figure C) (Greathead, 1968). The pupal period lasts seven to nine days in warm climates (Karel, 1985a; Swaine, 1969).

After emergence, adults are light brown before they turn shiny black. Adults usually emerge from the puparium in the morning. The total life cycle from egg to adult emergence varies with environmental conditions: in warm weather, it averages 20 days (17-23 days); in cool weather, it averages 42 days (Karel, 1985a). Greathead (1968) reported, for *O. phaseoli*, a life cycle from egg to

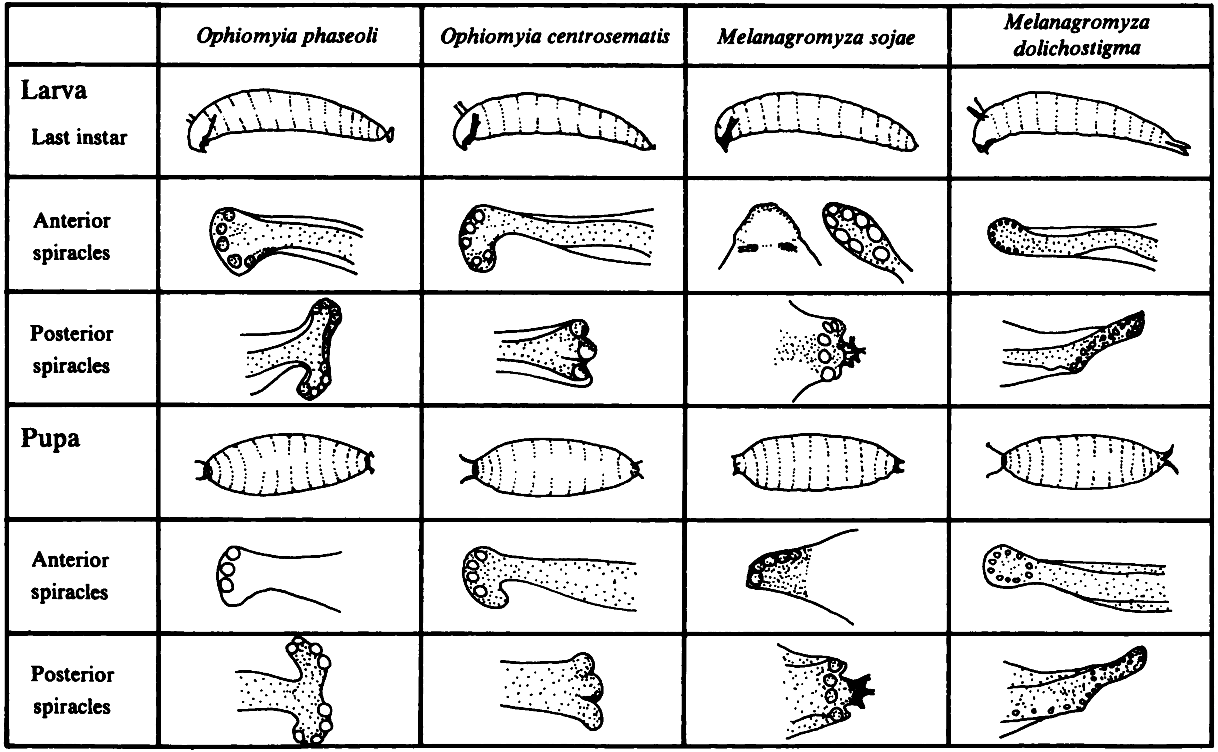

Figure C. Morphological characteristics of four bean fly species, including *Ophiomyia centrosematis*. (Taken from Talekar and Chen, 1986.)

adult emergence of 27-31 days on potted plants at 21 °C. The life cycles of *M. spencerella* and *O. centrosematis* from egg to adult emergence on potted plants at 21 °C were 28-35 and 35 days, respectively (Greathead, 1968). The development period is longer at higher altitudes, where temperatures are lower, than at lower altitudes (Davis, 1969). Agarwal and Pandey (1961) reported that eight to nine generations occur per year in India, while van der Goot (1930) reported 14 generations per year in Java, Indonesia.

Adult flies copulate two to six days after emergence. However, Greathead (1968) and Babu (1978) reported a pre-mating period of three days. Mating lasts only a few minutes and takes place only once in the fly's life. Lall (1959) observed a mating period of two to three minutes. The copulating males live for eleven days, while the ovipositing females live for 8-12 days. The female starts laying eggs two to four days after copulation.

Damage

Damage caused by bean flies is most devastating during the seedling stage of the bean plant. *Ophiomyia phaseoli* attacks the bean plant as soon as the first pair of leaves begin to unfold. It continues to attack as other new leaves unfold. *Melanagromyza spencerella* scarifies leaf tissue in the same way. *Ophiomyia centrosematis* does not damage bean leaves to any economic significance.

The main damage is caused by larval feeding and tunnelling in stem tissue. With *O. phaseoli* and *O. centrosematis*, most damage is done by larvae to the first pair of leaves. Later in the life of the plant, the larvae do little damage. Both species of bean fly are external stemborers and feed beneath the stem epidermis where pupation also takes place. A considerable portion of the stem tissue is eaten by larvae and the stem epidermis is later ruptured by puparia. Consequently, with heavy infestation, young plants are considerably weakened and growth is stunted. According to Greathead (1968), attack by *O. centrosematis* is less concentrated on young plants and is the rarest of the three species. It is of negligible economic importance in Uganda.

The larvae of *M. spencerella* bore internally in the stem pith. They also feed extensively in the hypocotyl and tap roots of the bean plant (Figure 162). Pupation occurs deep within the stem tissue. *Ophiomyia phaseoli* has been reported to cause heavy damage and high bean-plant mortality (Greathead, 1968; Ho, 1967; Karel and Matee, 1986; Otanes y Quesales, 1918; Swaine, 1969; Wallace, 1939). According to Greathead (1968), it is a serious pest of beans. Where both *O. phaseoli* and *M. spencerella* occur together, it is probable that the economic damage caused is by *M. spencerella*—the larvae of this species reach and destroy the root system before those of *O. phaseoli*.

A concentration of puparia results in the swelling, splitting open, and rotting of the base of the affected plant. If seedling bean plants are seriously affected, they suffer premature leaf fall and are either killed or severely stunted. Older plants are similarly affected but are not usually killed by the attack. Plant damage is more pronounced in dry conditions than in wet. The bean fly is more destructive when planting is delayed. Greathead (1968) reported that the overall effect of bean fly on the crop depends on each plant's powers of recovery, specifically, an ability to produce adventitious roots (Figure 163). Plants that do not rapidly recover from root damage by developing adventitious roots wilt (Figure 164) and die. They are also liable to break at ground level during windy periods or storms. Plants that produce adventitious roots soon recover from the initial heavy infestation and are sufficiently robust to survive later damage. However, as much as 100% yield losses (Table 1) have been recorded from attack by bean flies in eastern Africa (Wallace, 1939).

Control

Several methods have been used for the control of bean fly with varying degrees of success. Cultural practices such as adjustment of planting time, crop rotation, and associated cropping, can reduce bean-fly populations and damage (Karel and Matary, 1983; Karel et al., 1981; Mohamed and Karel, 1986). Earthing-up (hilling) is often recommended as a cultural control practice because the bean plant produces adventitious roots above the damaged stem part and so recovers from bean-fly damage. Several insecticides, including dimethoate, endosulfan, monocrotophos, cypermethrin, and pyrethrum, are effective against bean fly (Karel and Matee, 1986; Karel et al., 1981; Matee and Karel, 1984; Swaine, 1969; Walker, 1960). Mansuetus and Karel (1985) have effectively reduced bean-fly damage by using neem (*Azadirachta indica* A. Juss) extract, an insecticide of plant origin. Many parasites of bean-fly have been reported (Greathead, 1968; Hassan, 1947; Oree and Hallman, 198?; Taylor, 1958).

Development of resistant cultivars offers a promising means for bean-fly control. Varietal resistance to *O. phaseoli* in common beans has been reported from Mauritius (Moutia, 1945), Australia (Rogers, 1974 and 1979), and Taiwan (CIAT, 1981; Lin, 1981). In Ethiopia, Abate (1983a and 1983b) screened about 200 bean accessions under a moderate bean-fly attack. Resistant bean lines have also been found in Malawi (Edje et al., 1981).

A screening program for varietal resistance to *O. phaseoli* has begun at the Sokoine University of Agriculture, Morogoro, Tanzania, with several hundred exotic and local *Phaseolus vulgaris* accessions. The selection scheme is based on eliminating highly susceptible materials. Test cultivars are planted, using the Canadian Selian Wonder cultivar as a susceptible border plant. Plants are rated according to number of ovipunctures, larval and pupal counts, and stem damage. Several cultivars have shown low to moderate resistance to bean fly (Karel, 1985c; Karel and Maerere, 1985; Msangi and Karel, 1985; Mushebezy and Karel, 1986; Rwamugira and Karel, 1984). These are A 62, A 63, A 83; BAT 1210, BAT 1275, BAT 1570, CB 137 (CIAT materials), T 8, TMO 75, TMO 91, TMO 117, Chipulupulu, Kablanketi, Sumbawanga B, and YC-2 (improved lines from Uyole Agriculture Centre, Tanzania). Morphological and anatomical parameters such as trichome density on leaf surface, leaf thickness, leaf area, stem diameter, internode length, and adventitious roots, are being assessed on all promising materials to identify potential resistance mechanisms. Preliminary investigations suggest that resistance in some accessions is manifested as tolerance and antibiosis (Mushebezy and Karel, 1986; Rwamugira and Karel, 1984).

Leafminer (Diptera: Agromyzidae)

The leafminer, *Liriomyza trifolii* Burgess, is a minor pest of beans and other legumes in Africa. It is a sporadic pest in Kenya and Tanzania (De Lima, 1979; Katundu, 1980). It is an important pest of beans in Egypt and Mauritius (Fagoonee and Toory, 1983; Hammad, 1978).

Life cycle

The adult leafminer is a small agromyzid fly, about 2 mm long. The dorsal side of the body is dark, but has a bright yellow scutellum. The abdomen is barred with yellow bands. The head, legs, and ventral part of the body are also yellow. Females have well-developed ovipositors, which distinguish them from males.

The female fly makes several ovipunctures, like the bean fly, on the upper leaf surface. However, it makes them near the margins, especially in the apical half of the leaf, whereas the bean fly makes them near the basal region of the leaf. Eggs are laid in only some ovipunctures, while others are used for feeding (A.K. Karel, unpublished data). Feeding punctures and ovipunctures with eggs are clearly visible as white spots, unlike the bean fly which makes elliptical cavities on the upper surface of the leaf.

After hatching, the maggot tunnels through the palisade tissue. There are three larval instars. Fully grown larvae measure 2-3 mm long and are yellow. Mature larvae fall to the ground and pupate in plant debris. Adult flies emerge from the yellowish brown pupae. The entire life cycle, from egg to adult emergence, lasts about 21 days on beans (Katundu, 1980). Several generations can therefore develop in one season.

Damage

Damage is caused by the maggot which destroys the palisade tissue of leaves by making serpentine tunnels (Figures 165 and 166). These leafminer tunnels make leaves unacceptable for consumption as a green vegetable. Larval feeding and tunnelling also reduce the photosynthetic area, thereby resulting in yield losses if damage is severe. However, precise figures for losses on beans from leafminers are not available.

Control

Leafminers can be controlled with one or two applications of diazinon, monocrotophos, or dimethoate. The most promising approach, however, is the use of resistant cultivars. Some work on bean-plant resistance to leafminer has recently been started in Mauritius. Distribution and density of leaf trichomes, as well as nutritional status, are important selection criteria. High trichome density acts as a physical deterrent to leafminers, and senescing primary bean leaves are not preferred (Fagoonee and Toory, 1983).

Aphids (Hemiptera: Homoptera: Aphididae)

The bean aphid, *Aphis fabae* Scopoli, is the main aphid pest of common beans in Africa (Figures 167). It is widespread, especially in the higher altitudes of Sudan, Ethiopia, Kenya, Uganda, Rwanda, Burundi, Tanzania, Zaire, Malawi, Zimbabwe, Angola, Cameroun, and Nigeria (Remaudière et al., 1985b). The cowpea aphid, *Aphis craccivora* Koch, the major aphid problem of cowpea in Africa, may also damage beans, especially at lower altitudes (Figure 168).

Life cycle

Aphis fabae is a dull black aphid with black siphunculi and cauda. The third antennal segment bears 9-20 irregularly arranged sensoria, whereas in *A. craccivora* there are three to eight arranged in a row. The femora bears many fine hairs on all surfaces and the cauda has 10-19 hairs (Eastop and van Emden, 1972). The adult is 2 mm long with a powdery white secretion on abdominal segments (Karel, n.d.). Usually, only females are found and they reproduce parthenogenetically. Apterous forms are produced when food is abundant and climatic conditions are optimal. When food is in short supply or there is overcrowding in the colonies, alate (winged) aphids develop. Winged adults may invade bean fields soon after crop emergence.

Aphis fabae has a wide host range (Remaudière et al., 1985a), but the source of primary flights to beans is unknown. There are four nymphal instars. The entire life cycle from egg to adult emergence requires 11-13 days and adults live for 6-15 days. The biology of *A. craccivora* has been extensively studied (Singh and Allen, 1980) and is similar to that of *A. fabae.*

Damage

Apterous bean aphids are found in colonies around the stem, growing points, and leaves (Figure 167). Infested leaves are destroyed and yellowed by the aphids' feeding (sucking) activities. Plants become desiccated and may eventually die (Karel et al., 1981). Sometimes the infestation continues during postflowering. However, the direct damage by bean aphids is usually minimal. An indirect and usually more harmful effect of aphid attack is the transmission and spread of bean common mosaic virus (BCMV). This disease severely reduces the seed yield of susceptible cultivars (Karel, n.d.). Aphid infestation is often particularly severe during a dry spell or late in the season. However, in humid weather, large aphid infestations can be wiped out by entomophagous fungi (Autrique et al., 1985).

Control

Insecticide control of aphids on common beans is effective (Karel et al., 1981; Swaine, 1969). However, there is always a danger of aggravating aphid problems by eradicating their parasites and predators (Ingram, 1969a) (Figure 169). For example, in Burundi, *Aphidius colemani* Viereck (Aphididae) naturally reduces the populations of *A. fabae* (Starý et al., 1985). Pirimicarb is the safest aphicide for beneficial insects.

Bean cultivars resistant to aphids offer a good possibility for control. Rose et al. (1978) identified sources of resistance at the Asian Vegetable Research and Development Center (AVRDC) in Taiwan. Although there are no studies on bean resistance to aphids in Africa, the high mortality of bean aphids on resistant cultivars occurs because they are caught by the hooked trichomes on bean leaves. de Fluiter and Ankersmit (1948) reported that increased trichome density on bean leaves increased aphid capture. More aphids were trapped by plants grown under dry conditions than by those grown under ample moisture. Farrell (1976) reported that beans intercropped with peanuts in Malawi reduced the spread of peanut rosette virus because their leaf trichomes trap *A. craccivora*, the virus vectors.

Leafhoppers (Hemiptera: Homoptera: Cicadellidae)

Leafhoppers of the genus *Empoasca* are widely distributed in tropical and subtropical Africa. *Empoasca lybica* Le Berg is a minor pest of beans and other legumes in many parts of Africa. *E. dolichi* Paoli is a minor pest of beans in eastern Africa. Leafhoppers are serious bean pests in Egypt. Eight species of leafhoppers, *E. signata*, *E. lybica*, *Asymmetrasca decedens*, *Orosius albicinctus*, *Neolinmus aegypticus*, *Balclutha hebe*, *B. rosea*, and *B. saltuella* have been identified on beans in Egypt (Hammad, 1978). *Empoasca kraemeri* Ross *et* Moore is one of the most important insect pest of beans in Latin America (Wilde and van Schoonhoven, 1976), but apparently does not occur in Africa.

Life cycle

Adult leafhoppers are elongate, light green to yellowish green, and measure about 2.5 mm long. Females lay eggs in leaf veins on the lower surface of young leaves, on petioles, or sometimes within stems of young seedlings. The number of eggs laid varies with the species. A female *E. lybica* lays 80-140 eggs which hatch in six to nine days, depending on the temperature. Five nymphal instars occur over a period of about seven to ten days. Adult longevity is 30-50 days. The biology of *E. kraemeri* on beans in Latin America (Wilde and van Schoonhoven, 1976) is similar to that of *E. lybica*.

Damage

Leafhoppers infest beans during the seedling stage. Frequently, severe leaf damage occurs without reducing the bean yield. Both adults and nymphs infest the lower surface of leaves and suck plant sap. Symptoms of damage, often described collectively as "hopper-burn," comprise a characteristic yellow discoloration of leaf margins, followed by a downward cupping of leaves. The downward cupping results from losing plant sap and possibly from injection of toxic saliva. Infested plants lose vigor and become increasingly susceptible to diseases and other insects. Infestation is favored by hot dry conditions.

Control

Leafhoppers on beans can be controlled with one or two applications of dimethoate, methomyl, monocrotophos, and permethrin. The most promising approach, however, is the use of resistant cultivars. Bean cultivars with low to moderate resistance to *E. kraemeri* have been identified in Colombia (Wilde and van Schoonhoven, 1976).

Whitefly (Hemiptera: Heteroptera: Aleyrodidae)

Common whitefly, or tobacco whitefly, *Bemisia tabaci* Genn., is a minor pest of common beans in Africa. It occurs in northeastern, eastern, central, and western Africa.

Life cycle

The adult common whitefly is an active insect about 1 mm long and males are slightly smaller than females. The light yellow body is covered with a white mealy secretion. The wings are white and similar in size. The third segment of the antennae is much longer than other segments. Eggs are elliptical and measure 0.2-0.3 mm. They are laid singly on a short pedicel which is inserted into the stomata on the lower surface of the leaf. Eggs are white when laid but later turn brown before hatching in about seven days. A female lays 25-32 eggs. Nymphs, except for first instars, are immobile. They cluster on the underside of leaves and resemble tiny scale insects. There are three nymphal stages. The pupa (puparium) is oval, whitish to yellowish, and measures about 0.6-0.8 mm. The entire life cycle from egg to adult emergence requires about 21 days.

Damage

Both adults and nymphs of whitefly suck sap from leaves. When infestation is severe, the upper surface of leaves becomes mottled with light yellowish spots. However, direct feeding damage is minor compared with the possible indirect effect of virus transmission: *B. tabaci* is the vector of the bean golden mosaic virus (BGMV). However, this virus has not yet been identified on beans in Africa. *B. tabaci* also transmits cowpea mild mottle virus (CMMV), long known in various hosts in Africa, including peanuts. CMMV has recently been found in beans in Tanzania (G. I. Minks, personal communication). However, *B. tabaci*'s role as vector of CMMV in beans has not yet been confirmed.

Control

Chemical control is most effective with one or two applications of carbofuran, dimethoate, or monocrotophos. Carbofuran and phorate granule application at planting time is also effective.

Beetles (Coleoptera: Chrysomelidae)

A number of coleopterous beetles feed on foliage and flowers of common beans. They are very diverse in habits and distribution. Some of the more economically important species of beetles are described here.

Foliage beetles (*Ootheca* spp.)

Ootheca mutabilis Sahlberg and *O. bennigseni* Weise are the two most important foliage-feeding chrysomelid beetles on seedling and adult bean plants in Kenya, Tanzania, Uganda, Burundi, Zambia, and Malawi. *Ootheca mutabilis* is also an important foliage feeder of cowpea (Singh and Allen, 1980; Singh and van Emden, 1979). Bean seed yield losses from *O. bennigseni* range from 18% to 31% in Tanzania (Karel and Rweyemamu, 1984). They are also vectors of some cowpea viruses, including cowpea mosaic and cowpea mottle (Singh and van Emden, 1979). *Ootheca* spp. may be potential vectors of viruses in beans in Africa, but research is needed to confirm this.

Life cycle. The adult *O. bennigseni* is about 6 mm long, oval, and shiny light brown or orange in color (Figure 170). However, the color varies considerably and light black or brown adults are not uncommon. Eggs are elliptical, yellow and translucent, and are laid in the soil. Eggs are held together in masses of 40-60 by a sticky substance secreted by the female. The total number of eggs laid by a single female varies from 200 to 400. Eggs hatch in 11 to 14 days. Larvae develop in the soil and there are three larval instars that together last 40-45 days. Pupation requires 14 to 20 days. The development period from larva to adult varies considerably and ranges from 65 to 180 days, depending on climatic conditions. Diapause during the dry season ensures the beetles' survival, thereby synchronizing adult emergence with the onset of rains and crop emergence. The life cycle of *O. mutabilis* is similar to that of *O. bennigseni* (Ochieng, 1977).

Damage. Adults feed on leaves by making holes in the interveinal regions (Figure 171). Heavy infestation reduces leaves to a skeleton, thus seriously impairing photosynthetic activity (Karel et al., 1981). Severe damage can result in seedling death. Sometimes, the beetle continues to feed on plants even after flowering and occasionally feeds on floral parts (Karel and Rweyemamu, 1984).

Control. Infestation of *Ootheca* beetles can be avoided to some extent by late planting. Several insecticides, including cypermethrin and endosulfan, are effective against this pest (Karel and Rweyemamu, 1984). Recent studies on natural insecticides from plants demonstrated that *O. bennigseni* can be effectively controlled with two or three sprays of 2% neem kernel extract (Hongo and Karel, 1986; Mansuetus and Karel, 1985).

The most promising approach to controlling *Ootheca* beetles is developing resistant cultivars. Recently, some bean cultivars resistant to *O. bennigseni* have been developed in Tanzania. Bean cultivars A 62, A 67, A 87, BAT 1252 (CIAT materials), Kabanima, Mexican 142, T 8, UAC 116, and YC-2 (Uyole Agriculture Center materials) are moderately to highly resistant to *O. bennigseni* (Karel, 1985b; Karel and Rweyemanu, 1984).

Striped foliage beetle (Coleoptera: Chrysomelidae)

The striped foliage beetle, *Luperodes quaternus* Fairmaire (syn. *Medythia quaterna* Fairmaire), is widely distributed from eastern to western Africa and also occurs in Sudan (Schmutterer, 1969). It is a minor pest of beans.

Life cycle. The adult is a small beetle, about 4 mm long, with white and light brown longitudinal stripes on the elytra. The biology of this beetle is not fully known. Adults lay eggs in the soil where larval and pupal development takes place.

Damage. The striped foliage beetle feeds on the margins of newly emerged leaves of bean seedlings. The beetle sometimes also damages developing pods (Figure 172). Although cowpea mosaic virus is transmitted by this beetle to cowpeas (Whitney and Gilmer, 1974), it is not known if it transmits bean viruses.

Control. Insecticide control is seldom required as populations of striped beetles on beans are usually low. However, several insecticides, including dimethoate and endosulfan, are effective, should insect populations warrant control measures.

Striped bean weevil (Coleoptera: Curculinonidae)

The striped bean weevil, *Alcidodes leucogrammus* Erichson, is a sporadic pest of beans in eastern, central, and western Africa.

Life cycle and damage. The adult weevil is 7-9 mm long and reddish brown to dark brown with three white markings on the elytra (Figure 173). The adult female lays its eggs on the stem. After the larvae hatch, they tunnel and feed inside the stem, causing cankerous swellings (Figure 174). The damage results in stunted growth of bean plants. In severe infestations, the stem may break and the plant often dies. Fully grown larvae are about 10 mm in length, legless, C-shaped, and white. Adult weevils cut round holes out of leaf blades during their feeding activity.

Control. Usually, control of this pest is not required. However, if infestation is heavy, several insecticides, including cypermethrin, dimethoate, and endosulfan, are effective.

Blister beetles (Coleoptera: Meloidae)

A number of blister beetles, or flower beetles, belong to two genera, *Mylabris* and *Coryna*, and are important pests of bean flowers. They are commonly found in most of sub-Saharan Africa from eastern to western Africa and down to South Africa. Some common species of *Mylabris* are *M. amplectens*, *M. aperta*, *M. bifasciata*, *M. bipartita*, *M. dicincta*, *M. dilloni*, *M. escherichi*, *M. farquharsoni*, *M. hypolachna*, *M. ligata*, *M. severeni*, *M. sjöstedti* Borchm, *M. temporalis*, *M. tristigma* (Figure 175), and *M. tristis* (Buyckx, 1962; Forsyth, 1966; Hall, 1985; Le Pelley, 1959; Schmutterer, 1969). *Coryna kersteni* Gerstaecker (Figure 176) and *C. apicicornis* Guerin are two important flower-feeding beetles of beans in eastern Africa (Le Pelley, 1959).

Life cycle. Flower beetles are easily recognized by the characteristic brightly colored elytra with broad black, yellow, or red bands (Figures 175 and 176). They are about 15 to 35 mm long and are strong fliers. Eggs are laid in the soil where larvae and pupae are usually found. Larvae undergo hypermetamorphosis and each larval instar is different. Pupation takes place in the soil.

Damage. Beetles cause serious damage to beans by devouring recently opened flowers. They often appear in larger numbers on beans intercropped with maize, sorghum, and other cereals (A. K. Karel and A. Autrique, unpublished data).

Control. Because adult beetles are strong fliers, controlling them with insecticide is difficult. Repeated sprays of endosulfan can control the pest to some extent. However, the most practical means of control is to handpick the beetles.

Flower Thrips (Thysanoptera: Thripidae)

Flower thrips, *Megalurothrips sjöstedti* Trybom (syn. *Taeniothrips sjöstedti*) is an important bean pest in Nigeria, Rwanda, Burundi, Zaire, Zimbabwe, Botswana, and South Africa (Annecke and Moran, 1982; Ingram, 1969b; Nyiira, 1973; Taylor, 1969). Another species of flower thrips, *T. nigrocarnis* (syn. *T. distalis*), has also been recorded feeding on flower buds and flowers of beans in Egypt and Tanzania (Hammad, 1978; Karel et al., 1981; Schmutterer, 1969). *Frankliniella dampfi* Priesner has occurred on beans in Uganda (Ingram, 1969b).

Life cycle

Flower thrips, *M. sjöstedti*, is a shiny black insect that measures about 1 mm in length (Figure 177). Males have not been observed and it is assumed that breeding is parthenogenetic (Ingram, 1969b). Eggs are probably laid in flower buds and are difficult to detect. Two nymphal instars have been recorded. Pupation occurs in the soil. The entire life cycle from egg to adult emergence probably requires 10 to 14 days (Ingram, 1969b). However, Singh and Allen (1979) reported that the life cycle took 14 to 18 days on cowpeas. The biology of the insect is, however, not completely known.

Damage

Both nymphs and adult thrips damage bean flower buds and flowers. It is a more serious pest in drier areas (Karel, n.d.). In severe infestations, flower buds do not open and no flowers, and hence pods, are produced. Feeding punctures on the base of flower petals and stigma can be observed with a hand lens. Feeding injury is characterized by distortion, malformation, and discoloration of flowers. Heavy infestations sometimes lead to flower abortion (Karel et al., 1981).

Control

Spraying with cypermethrin and monocrotophos effectively controls flower thrips (Karel, 1984a; Karel and Mghogho, 1985;

Karel et al., 1981). However, Ingram (1969b) reported that insecticides reduce thrips populations without improving seed yield.

The use of resistant bean cultivars offers a more promising approach to flower thrips control. Screening for resistance to flower thrips in common beans has recently begun at the Sokoine University of Agriculture, Morogoro, Tanzania. Some cultivars show a low level of resistance (A. K. Karel, unpublished data). When thrips infest cowpea peduncles ethylene is produced (Wien and Roesingh, 1980). This fact has been used to develop a screening technique with a synthetic growth regulator, ethephon [(2-chloroethyl) phosphonic acid]. Cowpea cultivars susceptible to abscission caused by thrips also show increased abscission after ethephon treatment. The technique may also be useful in identifying sources of resistance in common beans to abscission from flower thrips.

Legume Pod Borer (Lepidoptera: Pyralidae)

The legume pod borer, *Maruca testulalis* (Geyer), occurs throughout the tropics and subtropics, including all of sub-Saharan Africa. It is an important pest of common beans and other legumes, especially cowpea, in many parts of Africa. *Maruca testulalis* is one of the most important post-flowering pests of beans in Tanzania and other eastern African countries (Karel, 1985d; Karel et al., 1981). Losses in seed yield of common beans in Tanzania from *M. testulalis* has been estimated to be over 30% (Karel, 1985d).

Life cycle

The biology of *M. testulalis* has been studied extensively in Africa, especially in relation to cowpeas (Akinfenwa, 1975; Jackai, 1981; Taylor, 1967 and 1978). Eggs are laid singly on flower buds, flowers, and young leaves of bean plants. Eggs are round to oval, measure 0.65 by 0.45 mm, are light yellow, translucent, and have reticulate sculptures on the thin and delicate chorion (Taylor, 1978). The number of eggs laid is 10-100 per female (Singh and van Emden, 1979). Eggs hatch in two to three days (Taylor, 1967).

Caterpillars are whitish with dark spots on each side of the body segment, forming dorsal longitudinal rows. There are five larval instars, which together last eight to 14 days (Jackai, 1981; Karel, n.d.). The mature caterpillar is about 16 mm long. A prepupal stage of one to two days exists before pupation occurs in a double-walled pupal cell under leaf debris. The pupa is initially green or pale yellow but later darkens to grayish brown. The pupal period lasts five to 15 days. The complete life cycle from egg to adult emergence varies from 18 to 35 days (Taylor, 1978). Adult moths are active during the rainy season and survive for five to seven days. Adult moths have brown forewings with three white spots and grayish white hind wings (Figure 178).

Damage

The most serious damage from caterpillars is their feeding on flower buds and flowers. They also cause extensive damage to green pods (Figure 179). The early instars also infest peduncles or tender parts of stems. The characteristic larval feeding symptom is the webbing together of flowers, pods, and leaves. Frass is often present on pods (Figure 180) (Singh and van Emden, 1979).

Control

Several insecticides, including cypermethrin, carbaryl, endosulfan, fenitrothion, and monocrotophos, are effective against *Maruca* larvae (Karel, n.d.; Karel, 1985d; Karel et al., 1981; Singh and Allen, 1980). Although host-plant resistance to *M. testulalis* offers great potential in the control of legume pod borer, screening for pod-borer resistance in beans has not been done.

American Bollworm (Lepidoptera: Noctuidae)

The American bollworm, *Heliothis armigera* Hubner, is distributed widely in the tropics and subtropics, including most of the African continent. The common name is a misnomer as *H. armigera* does not occur in the Americas, although the closely related *H. zea* (Boddie) and *H. virescens* (F.) do occur. *H. armigera* is a major pest of common beans and other legumes in Africa, especially in eastern Africa (Karel, n.d. and 1985d; Karel et al., 1981; Nyiira, 1973;

Roberts and Chipeta, 1973; Swaine, 1969). It is a polyphagous pest, attacking several other cultivated crops besides grain legumes (Karel, n.d.).

Life cycle

The adult is a stout-bodied, brown, nocturnal moth with a wingspan of about 40 mm. Eggs are spherical, 0.5 mm in diameter, and yellow but turn brownish before hatching. They are laid singly, usually on growing points and leaves. Each female moth may lay as many as 1000 eggs. The incubation period varies from three to five days on beans. There are six larval instars and the larval period lasts from 14 to 24 days (Hill, 1975). Larvae have a characteristic pale white longitudinal band against an almost black band on each side of the body (Figure 181). Larvae often appear green or brown on beans, although their color varies considerably on other crops (Karel, n.d.). Fully grown larvae are about 40 mm long. Pupation occurs in the soil at a depth of about 40 mm. Pupae are shiny black and measure 16 mm long. The pupal period may vary from 10 to 14 days on beans. The life cycle can be completed in 28 to 42 days. Two generations of larvae are recorded in Tanzania—the first generation on early season beans and the second generation on beans sown later in the season (Swaine, 1969).

Damage

Larvae cause serious damage to the bean crop as they feed on pods. The early instar larvae feed on flowers and young pods by making clean circular holes. The main damage is caused by older larvae burrowing into green pods and eating developing seeds (Figure 182) (Karel, n.d.). Infested pods shrivel as a result of seed damage. Infestation is generally heavier during the long rainy season than during the short rainy season in eastern Africa. Losses in seed yield as heavy as 20% have been recorded on beans (Karel, 1985d).

Control

Several insecticides, including carbaryl, endosulfan, monocrotophos, and cypermethrin, effectively control young larvae (early instars) of *Heliothis* (Karel, 1984a, 1985d, and n.d.; Karel et al., 1981; Swaine, 1969). Several larval parasites of *Heliothis armigera* have been recorded (Karel, 1981; Reed, 1965). No host-plant resistance studies have yet been undertaken.

Pod-sucking Bugs (Hemiptera)

Various species of pod-sucking bugs infest beans during pod production and cause considerable damage and yield losses. Among the major pests are spiny bugs (*Clavigralla* spp.), giant coreid bug (*Anoplocnemis curvipes* F.), coreid bug (*Riptortus dentipes* F.) (Coreidae), and green stink bug (*Nezara viridula* (L.) (Pentatomidae). These insects suck sap from developing pods, thereby shrivelling pods and seeds. Affected pods turn yellow, dry prematurely, seeds do not develop, and, in severe infestation, pods fall off the plants. The bugs not only cause loss of seed yield but also reduce the germination rate of surviving seeds.

Spiny bugs (Hemiptera: Coreidae)

Spiny bugs, *Clavigralla schadabi* Dolling (syn. *Acanthomia horrida* Germar) and *C. tomentosicollis* Stål (syn. *Acanthomia tomentosicollis* Stål), constitute two common species of coreid bugs that infest beans and other legumes in eastern and western Africa. A third species of *Clavigralla*, *C. hystricodes* (syn. *A. hystricodes*) occurs in Tanzania (Bohlen, 1978).

Life cycle. The biology of the three species of *Clavigralla* is similar. Materu (1968) described the biology and population dynamics of *C. schadabi* and *C. tomentosicollis* in Tanzania. Adult bugs measure 7-10 mm in length. The body of these bugs is covered with conspicuous short hair and the prothorax has two spines. The prothoracic spines project anteriorly in *C. schadabi* and *C. hystricodes*. In *C. tomentosicollis*, the spines are smaller and project from the lateral sides of the prothorax (Figure 183). *Clavigralla schadabi* is grayish and smaller than *C. tomentosicollis* which is hairy and brownish. *Clavigralla hystricodes* is black and has a shorter body than the other two species (Karel, n.d.).

Females lay eggs in batches of 10-70. A female may lay as many as 200 eggs which hatch in about six days. There are five nymphal instars over a total period of 28-35 days (Materu, 1968). Nymphs and adults are sluggish and are not easily disturbed. The bugs often feed together on a single pod.

Damage and control. Bugs suck sap from developing seeds and cause dimpling in the seed coat and browning and shrivelling of seeds and pods. Insecticides such as dimethoate, endosulfan, and monocrotophos, provide good control (Karel, n.d.; Nyiira, 1978; Swaine, 1969). However, Matteson (1982) reported that in northern Nigeria spraying cowpeas grown in association with cereals increased pod-sucking bug populations, especially those of *C. tomentosicollis*, and reduced yields considerably. The increase in pod-sucking bug populations was attributed to the insecticide having killed the pest's natural enemies.

Giant coreid bug (Hemiptera: Coreidae)

The giant coreid bug, *Anoplocnmeis curvipes* F., is a minor pest of beans, and a major pest of cowpeas and pigeonpeas, in tropical Africa.

Life cycle. The adult *Anoplocnemis* is dull black, about three cm long, and is a strong flier. Male and female bugs can be easily distinguished by the shape of their hind legs. In males, these are abnormally broad and each bear a large spine. The gray eggs are laid in chains on leguminous plants other than beans—eggs are rarely laid on bean plants. A single female lays 6-12 chains of 10-40 eggs each. The eggs hatch in about 7-11 days. There are five nymphal instars. The early instar nymphs resemble ants. The total nymphal period requires 30-60 days, depending upon climatic conditions. The adult life span varies from 24 to 84 days.

Damage and control. Damage to beans is caused mainly by adult bugs feeding on young pods. The bugs also feed on tender shoot tips, causing dieback-like symptoms. Insecticides used for the control of *Clavigralla* are also effective in controlling this bug. Ochieng (1977) has identified several egg parasites of *Anoplocnemis* in Nigeria.

Coreid bug (Hemiptera: Coreidae)

Several species of *Riptortus*, known as coreid bugs, have been recorded feeding on common beans in Africa. *Riptortus dentipes* F. is the most common of these species. Other species are *R. tenuicornis* Dall. and *R. longipes* Dall. (Forsyth, 1966; Le Pelley, 1959).

Life cycle. Adult bugs are slender, about 17 mm in length, and light brown with white or yellow lines on the sides of the body. They are strong fliers. One female lays about 50 eggs in small batches. Eggs are rarely laid on the bean plant and are more commonly laid on other leguminous plants and weeds. The eggs hatch in about six days. Five nymphal instars develop over an 18-day period.

Damage and control. The bugs cause considerable damage to bean plants by sucking sap from green pods. Because the bugs are strong fliers and constantly visit bean plants from alternative host plants, the control of *Riptortus* spp. is difficult. However, insecticides used for the control of *Clavigralla* are also effective against *Riptortus* spp., if repeated applications are made. Some egg parasites also keep the bug population in check. The development of resistant bean cultivars offers good potential for future control.

Green stink bug (Hemiptera: Pentatomidae)

The green stink bug, *Nezara viridula* (L.), is a minor pest of beans. It has a wide range of hosts in tropical and subtropical Africa (Karel et al., 1981; Nyiira, 1978; Swaine, 1969).

Life cycle. The biology of the bug varies considerably according to climatic conditions. Because these insects breed very little on beans, the damage is caused by adults which fly from alternative host plants into the bean field during flowering. A female bug lays 150-400 eggs in four to six batches of 30-80. Eggs are laid on the underside of young leaves. There are five nymphal instars. The early instar nymphs are brightly colored and spotty (Figure 184). They are usually found in clusters. The entire life cycle from egg to adult emergence requires 40 to 80 days. Adults are always green and are strong fliers. The adult life span is 30-60 days. The bugs breed throughout the year if food sources are available (Figure 185).

Damage. Damage to bean pods is caused primarily by adults sucking sap from young pods. Feeding punctures cause necrosis, resulting in pod spotting and deformation. Typical damage symptoms are yellowing, premature drying of pods, and lack of seed formation. Affected pods may wither and sometimes fall off. The bugs also inject a fungus, *Nematospora coryli* Peglion, into developing seeds, and cause additional damage (Wallace, 1939; Chapter 10, this volume, p. 247-248).

Control. Several chemicals, including dimethoate, diazinon, endosulfan, fenitrothion, and monocrotophos, are effective against *N. viridula* (Karel et al., 1981; Swaine, 1969). Certain cultural practices such as adjustment of planting time, also reduce damage from the bugs. Several egg parasites also keep the pest population in check.

Storage Insects

Several species of bruchids (Coleoptera: Bruchidae) infest and damage stored beans in Africa. However, two species, *Acanthoscelides obtectus* (Say) (bean weevil) and *Zabrotes subfasciatus* (Boheman) (Mexican bean weevil), are the most important stored-bean pests in Africa and Latin America. In addition, *Callosobruchus chinensis* (L.) and *C. maculatus* (Fabricius) also cause some damage to beans in Africa.

Bean weevil (Coleoptera: Bruchidae)

The bean weevil, *Acanthoscelides obtectus* (Say), is a widely distributed pest of stored beans. It occurs in Africa, Latin America (Chapter 22, this volume), southern USA, and southern Europe. It is the most important pest of stored beans in the cool highlands of Africa, ranging from Ethiopia in the north to South Africa.

No precise information on losses in stored beans by bruchids is available. However, farm storage for six months is accompanied by about 40% loss in weight with as much as 80% of the seed being infested and unfit for human consumption. Losses vary between 7% in Colombia to 73% in Kenya (Khamala, 1978; van Schoonhoven, 1976).

The biology and life cycle of bruchids have been extensively studied in Latin America (Chapter 22, this volume).

Bruchids can be controlled, with little trouble and expense, by cleaning storage containers and surrounding area. Growing beans at least one kilometer from farm stores (the primary sources of bruchid infestation) effectively controls bruchids in the fields.

Other control methods used in Africa are similar to those used in Latin America. However, in Burundi, good results are obtained with laterite dust (Standaert et al., 1985). Neem-seed oil effectively controls the Mexican bean weevil and could be equally effective on *A. obtectus* (Kiula and Karel, 1985). In eastern Africa, bruchids are commonly controlled by dusting with pyrethrins (McFarlane, 1970). As yet, little work has been done on varietal resistance in beans to this pest in Africa, although some work has started recently in Rwanda.

Mexican bean weevil (Coleoptera: Bruchidae)

The Mexican bean weevil, *Zabrotes subfasciatus* (Boheman) (syn. *Z. pectoralis*, *Z. dorsopictus*, and *Spermatophagus subfasciatus*) is the most important pest of stored beans in warmer regions. It usually occurs at altitudes below 1000 m above sea level in tropical Africa and Madagascar (Davies, 1972; Southgate, 1978). However, no documented information on losses caused by Mexican bean weevil is available from Africa.

As with *Acanthoscelides obtectus*, the biology and life cycle of the Mexican bean weevil have been extensively studied in Latin America (Chapter 22, this volume).

The control measures described for *A. obtectus* are equally effective against *Z. subfasciatus*.

Other Pests

Red spider mite (Acarina: Tetranychidae)

The red spider mite or two-spotted spider mite, *Tetranychus cinnabarinus* Boisd. (syn. *T. telarius* L.), is widely distributed in tropical and subtropical parts of the world. In Africa, it is found on beans, cotton, and other plants (Hill, 1975; Khamala, 1978; Nyiira, 1978). A closely related species, *T. urticae*, occasionally infests bean leaves in Uganda (Nyiira, 1978).

Life cycle. Adult females are oval, red or green, and measure 0.4-0.5 mm long. Males are slightly smaller. Immature forms and adults have two spots on their dorsa. The female mite lays spherical, white eggs, about 0.1 mm in diameter. They are laid singly on the underside of leaves. A single female lays as many as 200 eggs. Eggs hatch in four to seven days. Nymphs are six-legged, pinkish, and slightly larger than the eggs. There are two nymphal stages, the protonymph and deutonymph (Hill, 1975), each lasting three to five days. They are green or red and have four pairs of legs. The total nymphal period lasts six to ten days. Adult females live for three weeks.

Damage. Both nymphs and adults feed on the lower side of leaves between the main veins. Yellow spots appear where a group of mites have been feeding together. Clusters of yellow spots are visible on the upperside of leaves, especially between main veins near the leaf stalk. Mite feeding causes a silvering of bean leaves. Later, the affected area spreads, the leaf reddens, withers, and falls off. Since mites usually attack beans near plant maturity, they rarely influence seed yield. The mites cause more damage when there is moisture stress (Nyiira, 1978).

Control. Usually, the mite population is very small on beans and control measures are not required. However, if damage is appreciable, control is achieved by spraying with carbaryl, dicofol, endosulfan, malathion, or monocrotophos. A predacious mite, *Phytoseiulus riegeli* (Phytoseiidae) has controlled *T. cinnabarinus* on cotton in Kenya and Uganda (Hill, 1975). This predator can also be used for controlling red spider mite on beans.

Tropical spider mite (Acarina: Tarsoneinidae)

The tropical or broad spider mite, *Polyphagotarsonemus latus* (Banks), is a minor pest of beans, cotton, coffee, potato, and tomato in some parts of Africa. It has occurred in Kenya, Tanzania, Uganda, Burundi, Central African Republic, Sudan, and Nigeria (Hill, 1975).

Life cycle. The adult mite is yellow or pale green. It is about 1.5 mm long and, because of its color and size, is sometimes very difficult to see without a magnifying glass. Eggs are laid singly on the underside of young leaves. They are oval shaped but flattened on the lower side. The upperside of the egg is covered with five or six rows of white tubercles. Eggs are 0.7 mm long and hatch in two to three days. The larva turns into a pseudopupa and remains in this stage for two to three days. Adult males usually pick up the female pseudopupae and carry them to newly opened leaves. Male pupae are not usually moved but when the adult males emerge, they migrate to new leaves. A female mite lives for about 14 days, laying two to four eggs per day (Hill, 1975).

Damage and control. The broad spider mite damages bean plants after flowering, especially during humid and warm weather. The sucking activity of the mite causes leaf edges to roll upwards with a shiny appearance. The lower leaf surface may turn purplish. Young leaves do not develop normally and remain stunted, turning yellow. Sometimes pods are also attacked (Hill, 1975).

Insecticides used for *T. cinnabarinus* effectively control this mite. Dimethoate is not effective.

Snails and slugs (Molluscs)

Snails and slugs are minor pests of beans in some parts of Africa, slugs being more important.

Limicolaria kambeul (Achatinidae). Limicolaria kambeul Burgess is a snail found in humid parts of Africa south of the Sahara. It has occurred in eastern Africa, Sudan, and Congo (Schmutterer, 1969), in wet places and in areas with high relative humidity.

The snail possesses a calcium salt spiral shell in which the visceral hump is coiled (Figure 186). The head and foot of immature and adult snails are grayish brown to brown. Juvenile and adult snails measure 1.2-1.6 cm and 6-10 cm, respectively. The shell is usually yellow or yellow-brown and sometimes has longitudinal brown stripes. The adult snail lays white, spherical eggs in a nest prepared in damp soil. After hatching, young snails remain within the soil for some time before surfacing to feed on organic matter. The pest is nocturnal and rests during the day on either plants or soil.

The snail attacks a variety of crops, including beans, during the rainy season. However, maize and peanuts are preferred hosts. Immature snails do the most damage by making large holes in bean leaves during the night. They usually appear in large numbers.

Handpicking is the easiest way to control the pest in small bean fields as populations of the snail are usually low. However, molluscide baits, consisting of metaldehyde added to wheat or sorghum bran, can also be placed under attacked plants.

Slugs. The most commonly found slugs on beans are *Limax maximus* L., *Deroceras agreste* L., and *Vaginulus plebeius* (Fisher). These species also occur in tropical countries of Asia and Latin America. Slugs, unlike snails, are streamlined and have no spirally wound shell. The biology of slugs is not well known, but see Chapter 22, this volume, for a description.

To control slugs, it is important to keep bean fields clean of plant debris and weeds which act as shelter for slugs. Because infestation by slugs often starts from field borders, control can be achieved by spraying border plants with carbaryl or dimethoate in late afternoon or early evening.

Future of Pest Control in Africa

Chemical control is perhaps the most common method of controlling bean pests. Although the use of insecticides such as dimethoate, endosulfan, fenitrothion, and monocrotophos, has been highly successful, it has sometimes caused adverse effects, especially in developed countries. For example, insecticides kill the natural enemies of pests and encourage the development of resistant strains of economically important pests. Moreover, insecticides are often too expensive or unavailable to subsistence farmers in many developing countries, including those of Africa. Hence, a high research priority in bean entomology in Africa must be to conserve the natural biological control of existing and potential pests.

That insecticides are applied only when pest infestation warrants it and not on a routine basis, must be stressed as part of effective and economical control of bean pests. More attention must also be given to nonsynthetic chemical insecticides. The use of plant extracts such as neem, offers a new dimension for future chemical control of insects on beans (Hongo and Karel, 1986).

Sources of resistance to important insect pests must be incorporated into agronomically acceptable cultivars such as those which are already resistant to important plant diseases. The development of varietal resistance to bean pests, however, will take time. Moreover, as with other crops, resistance to insect pests will not, by itself, prevent yield losses caused by the whole disease and pest complex. However, the use of resistant cultivars will reduce the need for repeated insecticide applications and favor the survival of natural enemies, allowing for a more effective, natural, biological control of pests.

The use of natural enemies (parasites, predators, and pathogens) as a method of controlling bean pests has not yet been adopted in Africa, even though it is effective. Yet, many pests such as bean aphids, are controlled, without human intervention, by their parasites in many bean-growing countries of Africa. It is only recently that exotic aphidiid parasites (Hymenoptera) were introduced into Burundi to assist the indigenous *Aphidius colemani* Viereck (Autrique et al., 1985) that was partly regulating bean aphid populations. The short growing season of beans and fallow periods may hinder the implementation of an effective and deliberate biological control strategy for bean pests in traditional African farming systems.

Various cultural practices such as optimal plant populations, appropriate time of planting, species diversity, use of trap crops, crop rotation, intercropping, and removal of crop residues, have shown potential for controlling bean pests (Karel et al., 1983). Cultural practices are readily available to the subsistence farmer and, in most cases, do not require extra investment. Future control methods must emphasize the implementation of cultural practices that support biological control and host-plant resistance strategies.

The integration of various control methods requires the development of an "integrated pest management (IPM)" strategy. IPM approaches the control of crop pests from an ecological viewpoint and must be based on an adequate knowledge of the agroecosystem. It offers a framework for developing a system of pest control which combines all suitable control methods such as host-plant resistance, cultural practices, biological control, and chemical control. The core of this approach lies in applying the concept of "economic damage threshold." This threshold is defined as the density of a pest population at which it does not cause enough injury to justify the economic costs of control efforts (Karel, 1983; Karel et al., 1983; Matteson, 1984). When the pest density surpasses the economic threshold, control measures must be taken. Because IPM is dynamic, its improvement requires constant feedback from field experiences. Hopefully, some progress will be quickly made to develop and implement IPM programs for beans in Africa. However, the needs of subsistence farmers are complex and require a total production package. IPM programs must therefore be developed as part of that package.

References

Abate, T. 1983a. Screening of haricot bean varieties against bean fly (BNF) and African boll worm (ABW), Nursery I, Nazret, 1982/83. Nazret Research Station, Institute of Agricultural Research, Addis Ababa, Ethiopia. 7 p. (Typescript.)

———. 1983b. Screening of haricot bean varieties against bean fly and African bollworm (Nursery II), Nazret, Jima, Kobo, Mekele. Nazret Research Station, Institute of Agricultural Research, Addis Ababa, Ethiopia. 3 p. (Typescript.)

Abul-Nasr, S. 1977. *Ophiomyia phaseoli* (Tryon). In: Kranz, J.; Schmutterer, H.; and Koch, W. (eds.). Diseases, pests and weeds in tropical crops. Verlag Pard Parey, Berlin. p. 519-521.

Adams, M. W. 1984. Beans-cowpeas: production constraints and national programs. Bean/Cowpea Research Support Project. Michigan State University, East Lansing, MI, USA. 67 p.

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

Akinfenwa, S. 1975. Bioecological study of *Maruca testulalis* Geyer (Lepidoptera: Pyralidae) in the Zaria area of northern Nigeria. M.Sc. thesis. Ahmadu Bello University, Zaria, Nigeria.

Ali, A. M. 1957. On the bionomics and control of the bean-fly, *Agromyza phaseoli* Coq. Bull. Soc. Entomol. Egypte 41:551-554.

Annecke, D. P. and Moran, V. C. 1982. Insects and mites of cultivated plants in South Africa. Butterworths, Durban, South Africa.

Autrique, A. 1985. Les ravageurs de la culture du haricot en Afrique Centrale. Département Défense de Végétaux, Institut des Sciences Agronomiques du Burundi (ISABU), Bujumbura, Burundi. 10 p. (Typescript.)

———; Remaudière, G.; and Starý, P. 1985. Observations écologiques sur les pucerons du haricot et du pois au Burundi, et perspectives du lutte biologique. Communication presentée au Colloque International sur les légumineuses alimentaires en Afrique. Association des Universités Partiellement ou Entièrement de Langue Française (AUPELF), Niamey, Niger.

Babu, C. S. J. 1978. Bionomics and control of bean stem fly, *Ophiomyia phaseoli* (Tryon) (Dipteria: Agromyzidae). Mysore J. Agric. Sci. 12(3):522-523. (Abstr.)

Bohlen, E. 1978. Crop pests in Tanzania and their control. 2nd ed., rev. Verlag Paul Parey, Berlin. 142 p.

Buyckx, E. J. E. 1962. Précis des maladies et des insectes nuisibles rencontrés sur les plantes cultivées au Congo, au Rwanda et au Burundi. Publications Hors série. Division de Phytopathologie et d'Entomologie Agricole, Institut National Pour l'Etude Agronomique du Congo (INEAC), Brussels, Belgium. p. 592-610.

Chiu, S. F. 1939. Toxicity studies of so-called inert materials with the bean weevil, *Acanthoscelides obtectus* (Say). J. Econ. Entomol. 32: 240-248.

CIAT (Centro Internacional de Agricultura Tropical). 1981. Bean Program annual report, 1980. CIAT series no. 02EBI-80. Cali, Colombia. p. 40.

Davies, J. C. 1972. A note on the occurrence of *Zabrotes subfasciatus* Boh., Coleoptera (Bruchidae), on legumes in Uganda. East Afr. Agric. For. J. 37(4):294-299.

Davis, J. J. 1969. Bean fly and its control. Queensl. Agric. J. 95:101-106.

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

de Fluiter, H. J. and Ankersmit, G. W. 1948. Gegevens betreffende de aantasting van bonen (*Phaseolus vulgaris* L.) door de zwarte bonenluis (*Aphis* (Doralis) *fabae* Scop.). Tijdschr. Pflantenziekten 54:1-13.

De Lima, C. P. F. 1979. *Liriomyza trifolii* (Diptera: Agromyzidae), an important new leafminer pest in Kenya. Kenya Entomol. Newsl. 10:8.

———. 1983. Management of pests of subsistence crops: legumes and pulses. In: Youdeowei, A. and Service, M. W. (eds.). Pest and vector management in the tropics. Longman Group, London, England. p. 246-248.

Desir, S. and Pinchinat, A. M. 1976. Producción agronómica y económica de maíz y frijol común associados, según tipo y población de plantas. Turrialba 26(3):237-240.

Dieudonné, C. 1981. Bean production in Burundi. In: Potential for field beans in eastern Africa: proceedings of a regional workshop held in Lilongwe, Malawi, 9-14 March 1980. CIAT series no. 03EB-1. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia. p. 31-34.

Eastop, V. F. and van Emden, H. F. 1972. The insect material. In: van Emden, H. F. (ed.). Aphid technology with special reference to the study of aphids in the field. Academic Press, London, England. p. 1-45.

Edje, O. T.; Mughogho, L. K.; Rao, Y. P.; and Msuku, W. A. B. 1981. Bean production in Malawi. In: Potential for field beans in eastern Africa: proceedings of a regional workshop held in Lilongwe, Malawi, 9-14 March 1980. CIAT series no. 03EB-1. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia. p. 55-97.

Fagoonee, I. and Toory, V. 1983. Preliminary investigations of host selection mechanisms by the leafminer, *Liriomyza trifolii*. Insect Sci. Appl. 4(4):337-341.

Farrell, J. A. K. 1976. Effects of intersowing with beans on the spread of groundnut rosette virus by *Aphis craccivora* (Hemiptera, Aphididae) in Malawi. Bull. Entomol. Res. 66(2):331-333.

Fernández, F.; Gepts, P.; and López-G., M. S. 1982. Etapas de desarrollo de la planta de frijol común: guía de estudio. Serie 04SB-09.03. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia. 26 p. (To accompany audiotutorial unit.)

Forsyth, J. (comp.) 1966. Agricultural insects of Ghana. Ghana University Press, Accra, Ghana. 163 p.

Greathead, D. J. 1968. A study in East Africa of the bean flies (Dipt., Agromyzidae) affecting *Phaseolus vulgaris* and of their natural enemies, with the description of a new species of *Melanagromyza* Hend. Bull. Entomol. Res. 59(3):541-561.

Hall, M. J. R. 1985. The blister beetle: a pest of man, his animals and crops. Zimbabwe Sci. Newsl. 19:11-15.

Hammad, S. M. 1978. Pests of grain legumes and their control in Egypt. In: Singh S. R.; van Emden, H. F.; and Taylor, T. A. (eds.). Pests of grain legumes: ecology and control. Academic Press, London, England. p. 135-137.

Hassan, A. S. 1947. The beanfly *Agromyza phaseoli* Coq. in Egypt (Diptera: Agromyzidae). Bull. Soc. Fouad 1er Entomol. 31:217-224.

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

Ho, T. H. 1967. The bean-fly (*Melanagromyza phaseoli* Coq.) and experiments on its control. Malays. Agric. J. 46(2):149-157.

Hongo, H. and Karel, A. K. 1986. Effect of plant extracts on insect pests of common beans. Z. Angew. Entomol. 102(2):164-169.

Howe, R. W. and Currie, J. E. 1964. Some laboratory observations on the rates of development, mortality and oviposition of several species of Bruchidae breeding in stored pulses. Bull. Entomol. Res. 55(part 3):437-477.

Ingram, W. R. 1969a. A note on the failure to control aphid infestations on beans with insecticides in Uganda. East Afr. Agric. For. J. 34(4): 476-481.

———. 1969b. Observations on the pest status of bean flower thrips in Uganda. East Afr. Agric. For. J. 34:482-484.

———; Irwing, N. S.; and Roome, R. E. 1973. A handbook on the control of agricultural pests in Botswana. Gaborone, Botswana. 128 p.

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

Jackai, L. E. N. 1981. Relationship between cowpea crop phenology and field infestation by the legume pod borer, *Maruca testulalis*. Ann. Entomol. Soc. Am. 74(4):402-408.

Karel, A. K. 1981. The problems and progress of *Heliothis armigera* management in Tanzania. University of Dar es Salaam, Morogoro, Tanzania. 31 p.

———. 1982. Insect pest complex of common beans, *Phaseolus vulgaris* L., in Tanzania. Paper presented at the Tanzania Bean Researchers Meeting, Morogoro, Tanzania, Aug. 23-24, 1982. University of Dar es Salaam, Morogoro, Tanzania. 4 p. (Typescript.)

————. 1983. Integrated pest management on beans in East Africa. Paper presented at the International Workshop on Integrated Pest Control for Grain Legumes, Goiânia, Brazil. (Typescript.)

———. 1984a. Effect of insecticide applications on insect pests and yield of common bean (*Phaseolus vulgaris* L.). Bean Improv. Coop. (USA) Annu. Rep. 27:193-194.

———. 1984b. A list of insects attacking beans in East Africa. Sokoine University of Agriculture, Morogoro, Tanzania. 4 p.

———. n.d. Insect pest control: a tool for high grain legume yields. Tanzania Notes Rec. 94. (In press.)

———. 1985a. A bibliography of bean flies, *Ophiomyia phaseoli* (Tryon), *O. centrosematis* (de Meij.) and *Melanagromyza spencerella* (Greathead) (Diptera: Agromyzidae). Bean/Cowpea CRSP monograph no. 2. Michigan State University, East Lansing, MI, USA. 21 p.

———. 1985b. Host-plant resistance in common beans to foliar beetle (*Ootheca bennigseni* Weise). Bean Improv. Coop. (USA) Annu. Rep. 28:13-14.

———. 1985c. Resistance to bean fly, *Ophiomyia phaseoli* Tryon, in common beans. In: Minjas, A. N. and Salema, M. P. (eds.). Proceedings of the third workshop on bean research in Tanzania held at Sokoine University of Agriculture, Morogoro, Tanzania, August 27-28, 1984. p. 45-47.

———. 1985d. Yield losses from and control of bean pod borers, *Maruca testulalis* (Lepidoptera: Pyralidae) and *Heliothis armigera* (Lepidoptera: Noctuidae). J. Econ. Entomol. 78(6):1323-1326.

——— and Maerere, A. P. 1985. Evaluation of common bean cultivars for resistance to bean fly (*Ophiomyia phaseoli* Tryon). Bean Improv. Coop. (USA) Annu. Rep. 28:15-16.

——— and Matee, J. J. 1986. Yield losses in common beans following damage by beanfly, *Ophiomyia phaseoli* Tryon (Diptera: Agromyzidae). Bean Improv. Coop. (USA) Annu. Rep. 29:115-116.

——— and Matary, R. D. R. 1983. The effect of insecticide application and plant populations on insect pests and yield of intercropped maize and beans. Bean Improv. Coop. (USA) Annu. Rep. 26:43-45.

——— and Mghogho, R. M. K. 1985. Effects of insecticide and plant populations on the insect pests and yield of common bean (*Phaseolus vulgaris* L.). J. Econ. Entomol. 78(4):917-921.

——— and Ndunguru, B. J. 1980. Review of appropriate agriculture production practices for small farmers in Tanzania. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. 75 p.

———; ———; Price, M.; Semuguruka, S. H.; and Singh, B. B. 1981. Bean production in Tanzania. In: Potential for field beans in eastern Africa: proceedings of a regional workshop held in Lilongwe, Malawi, 9-14 March 1980. CIAT series no. 03EB-1. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia. p. 122-154.

——— and Rweyemamu, C. L. 1984. Yield losses in field beans following foliar damage by *Ootheca bennigseni* (Coleoptera: Chrysomelidae). J. Econ. Entomol. 77(3):761-765.

——— and ———. 1985. Resistance to foliar beetle, *Ootheca bennigseni* (Coleoptera: Chrysomelidae) in common beans. Environ. Entomol. 14(6):662-664.

———; Quentin, M. E.; and Mathews, D. L. 1983. Alternatives to the conventional use of chemical pesticides. In: Proceedings of the resource-efficient farming methods, Morogoro, Tanzania. Rodale Press, Emmaus, PA, USA. p. 104-110.

Katundu, J. M. 1980. Agromyzid leafminer: a new insect pest to Tanzania. Trop. Grain Legume Bull. 20:8-10.

Khamala, C. P. M. 1978. Pests of grain legumes and their control in Kenya. In: Singh, S. R.; van Emden, H. F.; and Taylor, T. A. (eds.). Pests of grain legumes: ecology and control. Academic Press, London, England. p. 127-134.

Kiula, B. A. and Karel, A. K. 1985. Effectiveness of vegetable oils in protecting beans against Mexican bean weevil (*Zabrotes subfasciatus* Boheman). Bean Improv. Coop. (USA) Annu. Rep. 28:3-5.

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

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

Leakey, C. L. A. 1970. The improvement of beans (*Phaseolus vulgaris*) in East Africa. In: Leakey, C. L. A. (ed.). Crop improvement in East Africa. Commonwealth Agricultural Bureaux, Farnham Royal, England. p. 99-128.

Lin, C.-S. 1981. Resistance of beans to insects. Chin. J. Entom. 1:1-6.

McFarlane, J. A. 1970. Control of the bean bruchid *Acanthoscelides obtectus* (Say.) by synergised pyrethrins powders. Pyrethrum Post 10(1):34-40.

Manohar, S. and Balasubramanian, M. 1980. Note on the oviposition behaviour of agromyzid stem fly *Ophiomyia phaseoli* Tryon (Diptera: Agro-Myzidae) in blackgram. Madras Agric. J. 67(7):470-471.

Mansuetus, S. B. A. and Karel, A. K. [1985]. Effect of various neem (*Azadirachta indica* A. Juss) extracts on insect pests of common beans. In: Minjas, A. N. and Salema, M. P. (eds.). Proceedings of the third workshop on bean research in Tanzania held at Sokoine University of Agriculture, Morogoro, Tanzania, August 27-28, 1984. p. 52-56.

Matee, J. J. and Karel, A. K. 1984. Investigation on chemical control of beanfly (*Ophiomyia phaseoli* Tryon) on common beans. Bean Improv. Coop. (USA) Annu. Rep. 27:187-188.

Materu, M. E. A. 1968. The biology and bionomics of *Acanthomia tomentosicollis* Stål and *A. horrida* Germ. (Coreidae: Hemiptera) in Arusha area of Tanzania. Ph.D. dissertation. Makerere University College (University of East Africa), Kampala, Uganda.

Matteson, P. C. 1982. The effects of intercropping with cereals and minimal permethrin applications on insect pests of cowpea and their natural enemies in Nigeria. Trop. Pest Manage. 28(4):372-380.

———. 1984. Bean IPC: status and recommendations. In: Proceedings of the International Workshop on Integrated Pest Control for Grain Legumes, Goiânia, Brazil. p. 393-406.

Mohamed, A. H. and Karel, A. [1986]. Effect of plant population density on insect pests and seed yield of common beans intercropped with maize. In: Minjas, A. N. and Salema, M. P. (eds.). Proceedings of the fourth workshop on bean research in Tanzania held at Sokoine University of Agriculture, Morogoro, Tanzania, September 5-7, 1985. p. 69-77.

Moutia, A. 1944. The bean fly, *Melanagromyza phaseoli* Coq. In: Annual report, 1943. Department of Agriculture, Mauritius. p. 10 and 17.

———. 1945. Annual report, 1944: Division of Entomology. Department of Agriculture, Mauritius. p. 14-19.

Msangi, R. B. and Karel, A. K. [1985]. Host plant resistance in common beans to beanfly (*Ophiomyia phaseoli* Tryon). In: Minjas, A. N. and Salema, M. P. (eds.). Proceedings of the third workshop on bean research in Tanzania held at Sokoine University of Agriculture, Morogoro, Tanzania, August 27-28, 1984. p. 60-63.

Mushebezy, D. M. K. and Karel, A. K. [1986]. Resistance to beanfly (*Ophiomyia phaseoli* Tryon) in common beans. In: Minjas, A. N. and Salema, M. P. (eds.). Proceedings of the fourth workshop on bean research in Tanzania held at Sokoine University of Agriculture, Morogoro, Tanzania, September 5-7, 1985. p. 62-68.

Nyabenda, P.; Sekanabanga, C.; and Nyangurundi, L. 1981. Bean production in Rwanda. In: Potential for field beans in eastern Africa: proceedings of a regional workshop held in Lilongwe, Malawi, 9-14 March 1980. CIAT series no. 03EB-1. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia. p. 99-121.

Nyiira, Z. M. 1973. Pest status of thrips and lepidopterous species on vegetables in Uganda. East Afr. Agric. For. J. 39(2):131-135.

————. 1978. Pests of grain legumes and their control in Uganda. In: Singh, S. R.; van Emden, H. F.; and Taylor, T. A. (eds.). Pests of grain legumes: ecology and control. Academic Press, London, England. p. 117-121.

Ochieng, R. S. 1977. Studies on the bionomics of two major pests of cowpea, *Vigna unguiculata* (L.) Walp.: *Ootheca mutabilis* Salhb. (Coleoptera: Chrysomelidae) and *Anoplocnemis curvipes* F. (Hemiptera: Coreidae). Ph.D. dissertation. University of Ibadan, Ibadan, Nigeria.

Ohlander, L. J. R. 1980. Research on haricot bean (*Phaseolus vulgaris* L). production in Ethiopia, 1972-1976. Report no. 82. Department of Plant Husbandry, Swedish University of Agricultural Science, Uppsala, Sweden. 294 p.

Oree, A. and Hallman, G. J. 198? An annotated bibliography of Agromyzid stem flies attacking beans, *Phaseolus vulgaris*. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia. 45 p. (Typescript.)

Otanes y Quesales, F. 1918. The bean fly. Philipp. Agric. 7(1):2-31. (Thesis no. 93 presented to the College of Agriculture.)

Phelps, R. J. 1956. Investigation on the biology of *Piezotrachelus varium* (Wagner) and *Apion (Conapion) chirindanum* Wagner (Coleoptera: Apioninae). J. Entomol. Soc. South Afr. 19(1):86-99.

Reed, W. 1965. *Heliothis armigera* (Hb.) (Noctuidae) in western Tanganyika, II: ecology and natural and chemical control. Bull. Entomol. Res. 56(part 1):127-140.

Remaudière, G.; Aymonin, G.; and Autrique, A. 1985a. Les plantes hôtes des pucerons africains. In: Remaudière, G. and Autrique, A. (eds.). Contribution à l'écologie des aphides africains. Plant production and protection papers, vol. 64. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. p. 103-139.

———; Eastop, V. F.; and Autrique, A. 1985b. Distribution des aphides de la région éthiopienne. In: Remaudière G. and Autrique, A. (eds.). Contribution à l'écologie de aphides africains. Plant production and protection papers, vol. 64. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. p. 77-93.

Roberts, M. J. and Chipeta, F. M. 1973. The effects of an insecticide-spraying trial on the yield of cowpeas. Res. Bull. Bunda Coll. Agric. Univ. Malawi 4:24-31.

Rogers, D. J. 1974. Studies on host plant resistance involving the French bean (*Phaseolus vulgaris* L.) and the bean fly (*Melanagromyza phaseoli* (Tryon)). M.Sc. thesis. University of Queensland, Brisbane, Qld., Australia. 112 p.

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

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

Rubaihayo, P. R.; Mulindwa, D.; Sengooba, T.; and Kamugira, F. 1981. Bean production in Uganda. In: Potential for field beans in eastern Africa: proceedings of a regional workshop held in Lilongwe, Malawi, 9-14 March 1980. CIAT series no. 03EB-1. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia. p. 155-186.

Rwamugira, W. P. and Karel, A. K. 1984. Varietal evaluation of common beans to beanfly (*Ophiomyia phaseoli* Tryon). Bean Improv. Coop. (USA) Annu. Rep. 27:186-187.

Schmutterer, H. 1969. Pests of crops in northeast and Central Africa with particular reference to the Sudan. Gustar Fischer Verlag, Stuttgart, Federal Republic of Germany. 296 p.

Singh, S. R. and Allen, D. J. 1979. Cowpea pests and diseases. IITA manual series 2. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. 113 p.

——— and ———. 1980. Pests, diseases, resistance, and protection in cowpeas. In: Summerfield, R. J. and Bunting, A. H. (eds.). Advances in legume science: volume 1 of the proceedings of the International

Legume Conference, Kew, 31 July-4 August 1978. Royal Botanic Gardens, Kew, Richmond, Surrey, England. p. 419-443.

——— and van Emden, H. F. 1979. Insect pests of grain legumes. Annu. Rev. Entomol. 24:255-278.

Southgate, B. J. 1958. Systematic notes on species of *Callosobruchus* of economic importance. Bull. Entomol. Res. 49:591-599.

———. 1978. The importance of the Bruchidae as pests of grain legumes, their distribution and control. In: Singh, S. R.; van Emden, H. F.; and Taylor, T. A. (eds.). Pests of grain legumes: ecology and control. Academic Press, London, England. p. 219-229.

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

Standaert, D. Y.; Autrique, A.; Bianquis, A.; Bizimana, A.; and Iyamugerna, P. 1985. Protection du haricot conservé en greniers traditionnels contre la bruche *Acanthoscelides obtectus* (Say) par de la latérite en poudre en tante que matière du charge comme telle au support au pirimiphos-méthyl. Institut des Sciences Agronomiques du Burundi (ISABU), Bujumbura, Burundi. 5 p. (Typescript.)

Starý, P.; Remaudière, G.; and Autrique, A. 1985. Les aphidiides parasites de pucerons en région éthiopienne. In: Remaudière, G. and Autrique, A. (eds.). Contribution à l'écologie des aphides africains. Plant production and protection papers, vol. 64. Food and Agricultural Organization of the United Nations (FAO), Rome, Italy. p. 95-102.

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

Talekar, N. S. and Chen, B.S. 1986. The beanfly pest complex of tropical soybean. In: Shanmugasundaran, S.; Sulzberger, E. W.; and McLeod, B. T. (eds.). Soybean in tropical and subtropical cropping systems: proceedings of the symposium, Tsukuba, Japan, 26 September-1 October 1983. Rev. ed. AVRDC publication no. 86-253. Asian Vegetable Research and Development Center (AVRDC), Shanshua, Taiwan, China. p. 257-271.

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

Taylor, T. A. 1967. The bionomics of *Maruca testulalis* Geyer (Lepidoptera: Pyralidae), a major pest of cowpeas in Nigeria. J. West Afr. Sci. Assoc. 12:111-129.

———. 1969. On the population dynamics and flight activity of *Taeniothrips sjöstedt* (Tryb.) (Thysanoptera: Thripidae) on cowpea. Bull. Entomol. Soc. Nigeria 2:60-71.

———. 1978. *Maruca testulalis*: an important pest of tropical grain legumes. In: Singh, S. R.; van Emden, H. F.; and Taylor, T. A. (eds.). Pests of grain legumes: ecology and control. Academic Press, London, England. p. 193-200.

van der Goot, P. 1930. De *Agromyza*-vliegjes der inlandsche katjanggewassen op Java. Mededeelingen, no. 78. Buitenzorg [University], Instituut voor Plantenziekten, Landsdrukkerij, Weltevreden, Indonesia. 105 p.

van Rheenen, H. A. 1983. Oil treatments for protection against insects. In: Paper presented at the proceedings of the International Workshop in Integrated Pest Control for Grain Legumes, Goiânia, Goiás, Brazil, 4-9 April 1983. 9 p. (Typescript.)

van Schoonhoven, A. 1976. Pests of stored beans and their economic importance in Latin America. Paper presented at the symposium on tropical stored product entomology, during the fifteenth International Congress of Entomology, August 19-27, 1976, Washington, DC, USA. 26 p. (Typescript.)

———. 1978. Use of vegetable oils to protect stored beans from bruchid attack. J. Econ. Entomol. 71(2):254-256.

——— and Cardona, C. 1982. Low levels of resistance to the Mexican bean weevil in dry beans. J. Econ. Entomol. 75(4):567-569.

———; ———; and Valor, J. 1983. Resistance to the bean weevil and the Mexican bean weevil (Coleoptera: Bruchidae) in noncultivated common bean accessions. J. Econ. Entomol. 76(6):1255-1259.

Walker, P. T. 1960. Insecticide studies on East African agricultural pests, III: seed dressings for the control of the bean fly, *Melanagromyza phaseoli* (Coq.), in Tanganyika. Bull. Entomol. Res. 50(part 4):781-793.

Wallace, G. B. 1939. French bean diseases and bean fly in East Africa. East Afr. Agric. For. J. 7:170-175.

Whitney, W. K. and Gilmer, R. M. 1974. Insect vectors of cowpea mosaic virus in Nigeria. Ann. Appl. Biol. 77(1):17-21.

Wien, H. C. and Roesingh, C. 1980. Ethylene evolution by thrips-infested cowpea provides a basis for thrips resistance screening with ethephon sprays. Nature (Lond.) 283(5743):192-194.

Wilde, G. and van Schoonhoven, A. 1976. Mechanisms of resistance to *Empoasca kraemeri* in *Phaseolus vulgaris*. Environ. Entomol. 5(2):251-255.