A Guide to IPM in French Beans Production

with Emphasis on Kenya

by
Abdurabi Seif
Ana Milena Varela
Susanne Michalik
and
Bernhard Löhr





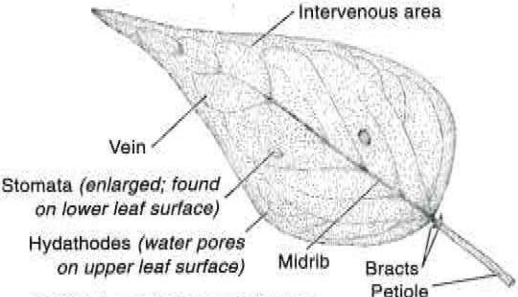


Figure 4. Leaf of a French bean

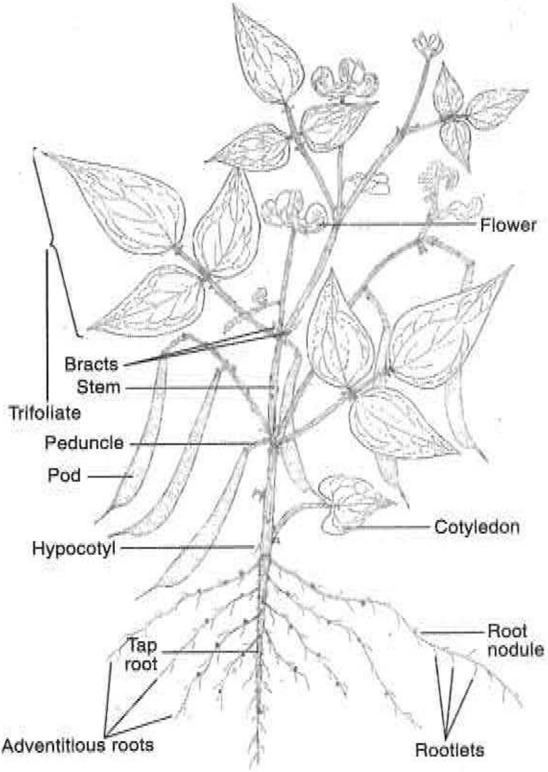


Figure 3. A French bean plant

A Guide to IPM in French Beans Production

with Emphasis on Kenya

by

Abdurabi Seif[1],
Ana Milena Varela[2],
Susanne Michalik[3]
and
Bernhard Löhr[4]

[1]Plant Pathologist, ICIPE, E-mail: aseif@icipe.org
[2]Consultant Entomologist, ICIPE, E-mail: avarela@icipe.org
[3]Agriculturist, GTZ-IPM and [4]Entomologist, ICIPE, E-mail: blohr@icipe.org

The International Centre of Insect Physiology and Ecology
P. O. Box 30772, Nyayo Stadium, Nairobi, Kenya
Tel: +254 (2) 861680–4/802501; Fax: +254 (2) 860110/803360
E-mail: icipe@icipe.org; Home Page: http://www.icipe.org

German Agency for Technical Cooperation—Integrated Pest Management (GTZ-IPM) Project on Horticultural Crops for Eastern and Southern Africa

International Centre of Insect Physiology and Ecology (ICIPE)—Horticultural Pests Sub-Division

The Netherlands Government, 'Direct Support to Training Institutes in Developing Countries (DSO)'

The Technical Centre for Agricultural and Rural Cooperation (ACP-EU), Wageningen, The Netherlands

Disclaimer

Where specific pesticides have been mentioned in the text, these are generally given as examples and should not be regarded as being exclusive of others. Mention of specific pesticides in the text does not imply any preference or advantage over similar compounds not mentioned by name. Trade names have generally been avoided in the text as the same active ingredient (generic compound) could bear several trade names of different manufacturers. Since some countries have restrictions on the use of certain pesticides, it is advisable to check local regulations before purchase or use.

A Guide to IPM in French Beans Production with Emphasis on Kenya

by A. Seif, A. M. Varela, S. Michalik and B. Löhr

ISBN: 92 9064 142 8

Edited by: A. Ng'eny-Mengech
Design and DTP: I. A. Ogendo
Illustrations: N. M. Komeri
Proofreading: D. Osogo
Photographs: The photographic material in this manual was provided by the GTZ-IPM Horticulture Project, Nairobi, Kenya, and by the CIAT Africa Bean Programme, Selian, Arusha, Tanzania [Plates: 1, 2 14, 15, 23 and 25 (right)].

Published and printed by: ICIPE Science Press
P. O. Box 72913
Nairobi, Kenya
Tel: +254 (2) 802501/861680–4
Fax: +254 (2) 860110/803360
E-mail: isa@icipe.org

Contents

Introduction 1
Figure 1: Flow chart on 'Guide to IPM in French Beans Production' 3
Figure 2: French beans growth cycle and occurence of pests 16
Figure 3: A French bean plant ...... Inside Cover
Figure 4: Leaf of a French bean plant .... Inside Cover
Arthropod Pests
Bean Seed Fly or Seed Corn Maggot 17
Bean Fly or Bean Stem Maggot 19
Striped Bean Weevil 22
Aphids 23
Whiteflies 25
Spider Mites 28
Bean Foliage Beetles 30
Hairy Caterpillars 32
Bean Flower Thrips 33
Flower and Pollen Beetles 37
Pod Borers 38
Bugs 41
Cutworms 44
Diseases of French Beans
Seed-Borne Diseases
Angular Leaf Spot 47
Anthracnose 49
Common Blight 51
Halo Blight 53
Bean Common Mosaic Virus (BCMV) 55
Diseases not Transmitted through Seed
Fusarium Root Rot 57
Powdery Mildew 59
Rust 61
IPM Options for French Beans 63
Hints for Growing a Healthy French Bean Crop 63
Bibliography 67
Glossary 69

List of Colour Plates

Arthropod Pests

Plate 1: Seedlings damaged by bean seed fly: (top) damage to cotyledons and (bottom) damage to first true leaves

Plate 2: Adult bean flies

Plate 3: Bean seedlings damaged by bean fly larvae

Plate 4: French bean field showing gaps due to bean fly damage

Plates 5 and 6: Black bean aphid infestation

Plate 7: Seedlings derived from seeds treated with imidacloprid (back) compared to untreated (front) seedlings infested by black bean aphids

Plate 8: Ladybird beetle (*Cheilomenes* sp.), a predator of aphids

Plate 9: Larva (main picture) and eggs (inset) of a ladybird beetle, a predator of aphids

Plate 10: Whitefly adults, nymphs and pupae

Plate 11: Whiteflies on lower leaf surface of a French bean plant

Plate 12: Red spider mite damage on upper leaf surface of a French bean plant

Plate 13: Webbing caused by spider mites

Plates 14 & 15: Left: *Ootheca* sp. adult foliage beetle, Right: *Monolepta* sp. adult foliage beetle

Plate 16: Plant damaged by foliage beetles

Plate 17: Adult moths of hairy caterpillars. Left, *Alpenus investigatorum*; right, *Spilosoma jacksoni*

Plate 18: Hairy caterpillars feeding on French beans

Plate 19: Bean flower thrips. Top, *Megalurothrips* sp. (black) and bottom, *Frankliniella* sp. (brown)

Plate 20: Flowers damaged by thrips (note two healthy flowers on upper right)

Plate 21: French bean pods damaged by flower thrips

Plate 22: *Orius albidipennis*, a predator of thrips. Left, nymph and right, adult bug

Plate 23: Blister beetle (*Coryna* sp.)

Plate 24: Moth of *Helicoverpa armigera*

Plate 25: Left, *Helicoverpa* larva on French bean pods. Right, pods damaged by *Helicoverpa* larvae

Plate 26: Larva of the legume pod borer (*Maruca* sp.)

Plate 27: *Acanthomia* bug

Plate 28: Cutworm (*Agrotis segetum*)

Seed-Borne Diseases

Plate 29: Angular leaf spot disease: symptoms on upper leaf surface

Plate 30: Angular leaf spot disease: symptoms on a French bean pod

Plate 31: Anthracnose: symptoms on lower leaf surface (left) and upper surface (right)

Plates 32 and 33: Anthracnose: symptoms on a stem (32) and pods (33)

Plate 34: Anthracnose: symptoms on seeds

Plate 35: Common bacterial blight: leaf symptoms

Plate 36: Halo blight: leaf symptoms

Plate 37: Bean common mosaic virus: Left, dark green mottling pattern on infected leaf; Right, stunted plant due to mosaic virus

Diseases Not Transmitted Through Seed

Plate 38: *Fusarium* root rot: wilting of seedlings

Plate 39: *Fusarium* root rot: rotting of roots

Plate 40: Powdery mildew: leaf symptoms

Plate 41: Powdery mildew: symptoms on pods

Plate 42: Bean rust: symptoms on upper leaf surface

Plate 43: Bean rust: symptoms on lower surface

Acknowledgements

Financial support for the production of this manual was provided by the GTZ-IPM Horticulture Project and the Netherlands Government, through their 'Direct Support to Training Institutes in Developing Countries (DSO)' as part of a training project granted to the African Regional Postgraduate Programme in Insect Science (ARPPIS) of the International Centre of Insect Physiology and Ecology (ICIPE).

The authors wish to express their appreciation to the Centro Internacional de Agricultura Tropical (CIAT) Africa Bean Programme for allowing us to use some of their photographic material.

The authors are grateful to CTA for support in the printing of this manual. The Technical Centre for Agricultural and Rural Cooperation (CTA) was established in 1983 under the Lomé Convention between the ACP (African, Caribbean and Pacific) Group of states and the European Union Member States. Since 2000 it has operated within the framework of the ACP-EC Cotonou Agreement.

CTA's tasks are to develop and provide services that improve access to information for agricultural and rural development, and to strenghthen the capacity of ACP countries to produce, acquire, exchange and utilise information in this area. CTA's programmes are organised around four principal themes: developing information management and partnership strategies needed for policy formulation and implementation; promoting contact and exchange of experience; providing ACP partners with information on demand; and strengthening their information and communication capacities).

Introduction

French beans (*Phaseolus vulgaris* L.) are a major export vegetable commodity in many horticultural crop producing countries, such as Kenya. Most of the crop is grown by smallholders and virtually all is exported to Europe. Estimates indicate that up to 50,000 smallholder families are involved in French bean production in Kenya. Recent data show that almost 100,000 people earn an income from French bean production and another 500,000 derive income directly from export of this crop.

French beans can be harvested 45 days after planting and are immediately paid for upon delivery. They thus constitute a crop that provides for the daily needs of many smallholder families. However, recent export figures show a slight decline. This can be attributed to a variety of factors: in addition to meteorological and macro-economic factors, difficulties in protecting the crop against insect pests and diseases have contributed to a large extent to the decline in the sector.

French beans are attacked by a number of different pests. The most important pests and diseases are bean flies, bean flower thrips, aphids, pod borers, bean rust, red spider mites and various root diseases. The severity of infestation of different pests varies depending on the location and season. Farmers have relied in the past on controlling the various pests by application of foliar pesticides, especially insecticides. Pesticide applications are frequent, between 4–12 times in a crop cycle. This high application frequency is particularly worrisome, considering the short growing cycle of the crop (a crop may take only 12 weeks in the field). Furthermore, harvesting is done daily or every other day. As a result, farmers observe extremely short pre-harvest intervals of a few days or even one day only.

The introduction of the maximum residue levels for export vegetables by the European Union (EU) is a potential complication for the export industry because of the difficulties of ensuring compliance by a large number of smallholder growers with safe plant protection measures. By July 2001, European Union (EU) countries will have zero tolerance levels for pesticides in fresh agricultural produce. Growers will have to ensure that vegetable beans are produced with a minimum number of pesticide applications and that pre-harvest intervals are strictly observed.

It is within this context that the GTZ-IPM Horticulture Project initiated work on developing an integrated pest management (IPM) system for French beans. This project was later incorporated into the Horticultural Crop Pests Sub-Division of the International Centre of Insect Physiology and Ecology (ICIPE). This IPM system is based on the concept of avoiding the application of foliar pesticides for as long as possible, the idea being to give natural control agents a chance to keep pest populations at low levels. The second major principle is avoiding the application of any pesticide after the onset of pod formation, because none of the common commercially available pesticides registered for use has a waiting period of only two days or less.

This manual describes and outlines the biology of the main French bean pests and diseases and the damage they cause. A summary of the available control options is provided. The manual also recommends IPM options, including the IPM concept developed for Kenya by the GTZ- and ICIPE-IPM Horticulture Project.

Fig. 1. A Guide to IPM in French Beans Production

Before you get started

Check the following:

- **Soil fertility:** Take samples for analysis of macro- and micro-nutrients. Consult a soil chemistry laboratory for advice.
- **Water for irrigation:** Take samples for analysis of salt content and ensure that there is an adequate supply of high-quality water. Consult a soil chemistry laboratory for advice.
- **Disease history of the farm:** Do not grow French beans if the farm has a history of serious soil-borne problems such as root rots. (For identification refer to relevant sections of this manual).
- **Suitable varieties:** Choose the varieties in demand for fresh export and canning[1].
- **Marketing:** Make arrangements with reputable exporters[2].

Footnotes:

[1]In Kenya, consult the HCDA (Horticultural Crops Development Authority). Elsewhere, consult an export promotion agency.

[2]In Kenya, consult FPEAK (Fresh Produce Exporters Association of Kenya). Elsewhere, consult an export promotion agency.

Standard recommendations for all production areas

Do's & don'ts

Field preparation

- Use virgin land or a field where legumes have not been cropped for at least 2 years.
- Deep-plough the field.
- Incorporate farmyard manure (but not manure derived from animals fed on old bean straw) where available.
- Make hills or ridges for planting in areas where root rot could be a problem.
- Plant wildflower and/or grass strips around fields to promote biodiversity in the margin fauna, including beneficial insects and spiders.

Planting and field operations

- Use certified disease-free seed.
- Use seed treated with imidacloprid (e.g. Gaucho®) for bean fly control and carboxin (e.g. Vitavax®) or captan (e.g. Phytocape®) for control of damping-off diseases.
- Avoid planting in a field next to or near an old crop of French beans or legumes; if this cannot be avoided, always plant new fields upwind.
- Keep French beans fields weed-free.
- Avoid over-fertilising with nitrogen.
- Do not direct water flow from old bean fields to new fields where surface irrigation is used.
- Avoid furrow irrigation in areas prone to root rot problems.
- Avoid working in French bean fields when plants are wet.
- Inspect plants for pests and diseases weekly and keep records of the same throughout the crop cycle.
- Ensure proper identification of pests and diseases; when in doubt consult extension officers or nearest research institution prior to taking intervention measures.

Podding period and harvest

- Do not apply pesticides after full flowering.
- Adhere to pre-harvest intervals if application of pesticides after pod set is a must. Always check that pesticides to be applied are registered for use on the crop.
- Keep the harvested crop in a cool shaded area.
- Remove crop debris from fields after harvest.
- Avoid overlapping of French bean crops. Do not plant new fields of French beans next to old fields.
- Practise rotation with crops non-related to French beans; examples include babycorn, brassicas, brinjals, carrots, cereals, chillies, cucurbits, fodder grass, lettuce, okra, onions and tomato.

Pests and Diseases

Rainfall in French bean production areas can change the complex of pests and diseases and their intensity. Therefore, it is important to take into account weather conditions (hot and dry/cool and wet seasons) when planning pest and disease management measures

What are the major pests and diseases of French beans?

Hot/dry season

Diseases
- Powdery mildew (p. 59)
- Root rot (p. 57)

Pests
- Bean flies (p. 19)
- Aphids (p. 23)
- Thrips (p. 33) *(Frankliniella occidentalis & Megalurothrips sjostedti)*
- Red spider mite (p. 28)

Cool/rainy season

Diseases
- Angular leaf spot (p. 47)
- Rust (p. 61)

Pests
- Thrips (p. 33) *(Megalurothrips sjostedti)*

Minor pests and diseases attacking French beans

Diseases
- Bean common mosaic (p. 55)

Pests
- White flies (p. 25)
- Cutworms (p. 44)
- Pod borers (p. 38)
- Bugs (p. 41)
- Flower beetles (p. 37)

Diseases
- Anthracnose (p. 49)
- Common bacterial blight (p. 51)
- Halo blight (p. 53)

Pests
- Bean seed fly (p. 17)
- Pod borers (p. 38)
- Flower beetles (p. 37)
- Foliage beetles (p. 30)
- Catterpilars defoliators (p. 32)

Always remember that proper identification is the first and most important step in controlling pest and disease problems. A misdiagnosis leads to mismanagement and to increased losses and costs. If in doubt after consulting this manual, check with a qualified crop protection professional.

⇩

Specific management of major pests and diseases

⇩

Bean flies and aphids (early season pests)

Treat seed with imidacloprid (e.g. Gaucho®): 8 ml/kg of seed. The seed treatment effectively controls bean flies and aphids. It also accords good control of aphids until the beginning of flowering. The treatment makes weekly foliar sprays against these pests unnecessary. However, since smallholders will not be in a position to effectively treat their own seed, they should always purchase certified and treated seed.

Rust

Varieties Amy, Paulista and Samantha are more susceptible to rust than Monel. Avoid overlap of French bean crops in the same field in order to avert build-up of the disease. Plant maize, other cereals or sunflower between fields to minimise the spread of wind-borne rust spores from other French bean fields. Destroy crop residues after harvest. Inspect fields regularly for rust during early stages of the crop to detect the earliest appearance, when fungicide application could be made. Rust causes the most damage if it infects beans between the 3rd trifoliate and pre-flowering stages. No fungicide should be applied after full flowering as this may result in unacceptable chemical residues in the pods. Hexaconazole (e.g. Anvil®) has been found effective for French bean rust control. However, prior to purchase and application of any fungicide, check if it is registered in your country for use on the crop.

Angular leaf spot

Plant certified disease-free seed. Remove crop debris or plough it deep after harvest. Practise crop rotation without beans or legumes for at least 2 years. Avoid field operations when plants are wet. Always treat the seed with an appropriate fungicide. Regularly inspect French bean fields for angular leaf spot to detect its earliest appearance to determine timing of fungicide application. No fungicides should be applied after full flowering in order to avoid unacceptable chemical residues in the pods.

Root rots

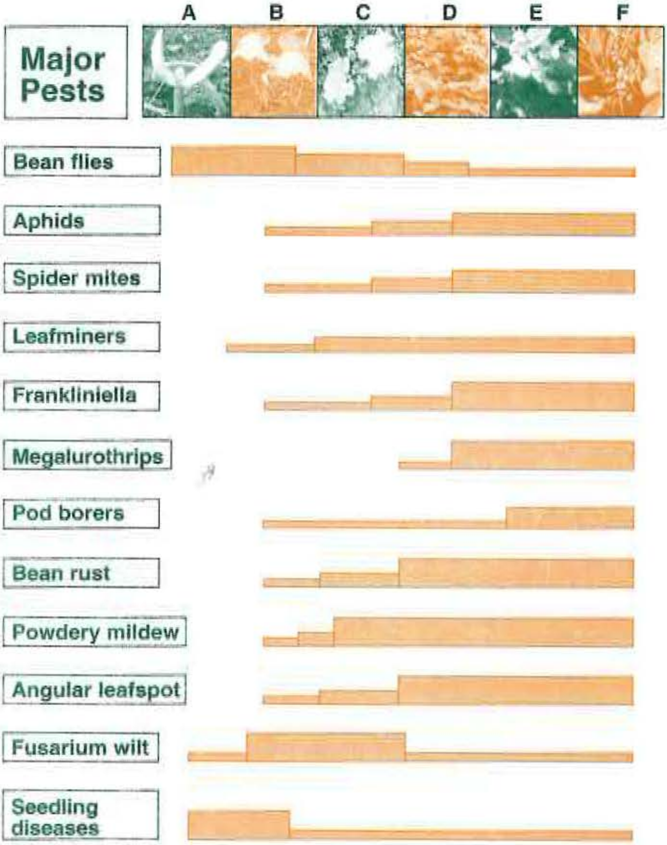
Treat the seed with captan (e.g. Phytocape®), thiram (e.g. Arasan®) or carboxin (e.g. Vitavax®). Old bean straw should not be fed to livestock if manure is to be used in bean fields. Surface irrigation water should not be directed from old bean fields to new fields. Residues from diseased plants should be removed from the fields and burnt. Implements and tools used in old fields should be washed prior to use in new fields. Plant beans on hills or ridges in areas prone to root rot problems. Chemical control is not viable and will not be effective.

Thrips

Megalurothrips are more common during cool and rainy seasons and/or in cool highland areas. They can be effectively controlled by an array of insecticides. However, adult *Frankliniella* that are prevalent in large numbers when it is hot and dry cannot be controlled by most of the commercially available insecticides. Products that give reasonable control include methiocarb (e.g. Mesurol®) and spinosad (e.g. Tracer®). Foliar applications of insecticides against bean flower thrips should only be carried out during the period from flower bud development to early flowering. Foliar applications at later stages are not allowed because they will lead to pesticide residues in the pods.

Always review what went wrong, but more importantly, what went right? Did the control measures work? Take a close look at the crop and compare pest and disease activity before and after treatment. What needs to be improved? Keep records of what you do and what you observe.

Fig. 2: French bean growth cycle and occurrence of pests



Stages in growth cycle: germination (A), appearance of cotyledons (B), first trifoliate (C), pre-flowering (D), flowering (E), podding (F).

Arthropod Pests

Bean Seed Fly or Seed Corn Maggot
(Plate 1)

Delia sp. (Diptera: Anthomyiidae)

Status and distribution: The bean seed fly has an almost worldwide distribution, and is found wherever *Phaseolus* beans are grown. Seed flies attack a wide range of crops, including onion, maize, sweetcorn, marrow, cucumber, lettuce, peas and some Cruciferae (e.g. cabbage, kale, rape).

Description and biology: Adult bean seed flies resemble small houseflies. They are slender, about 4 mm long and greyish-brown-black in colour. The females lay eggs in recently disturbed open soil, especially where there are residues of vegetative matter or where large amounts of manure have been applied. Small legless larvae (typical maggots) hatch from the eggs after 2–4 days and burrow into germinating bean seeds. The maggots are pale yellowish-white in colour. They feed for about 12–16 days, passing through three instars before pupating in the soil. Pupation lasts for about 2–3 weeks. The complete life cycle takes 4–5 weeks in warm conditions. Adults may live for 4–10 weeks. The polyphagous character of this pest allows it to survive in any crop debris, particularly of root crops. The optimal conditions for seed flies are high levels of organic matter and cool, wet weather.

Damage: The maggots bore into the seeds or the developing cotyledons (first seed leaves) of young plants. Infested seeds are eaten completely by the maggots, and the parts of the stem below ground are often hollowed out. The first sign of attack is a patchy emergence of seedlings. In the case of green beans, attacked plants emerge with damaged plumules and missing cotyledons, a condition known as 'snakehead' or 'baldhead' beans. The damaged plants emerging are stunted, weak and fail to develop into productive plants (Plate 1). The slower the germination and emergence and the earlier the infestation, the more severe the damage.

Control options: Limiting the amount of organic matter before planting can reduce the attractiveness of the field to the egg-laying flies and consequently the likelihood of infestation. Seed treatment with insecticides is commonly practised commercially.

Bean Fly or Bean Stem Maggot
(Plates 2–4)

Ophiomyia phaseoli (Tyron), *O. spencerella* (Greathead) and *O. centrosematis* de Meij. (Diptera: Agromyzidae)

Status and distribution: Bean flies (also known as bean stem maggots) are among the major pests of beans (*Phaseolus vulgaris*) and related crops in tropical and subtropical Africa, Asia, Australia, tropical China, Japan, and the Pacific Islands. Three species of the genus *Ophiomyia* are reported to attack beans. Among these, *O. spencerella* is restricted to Africa, while *O. phaseoli* and *O. centrosematis* are more widely distributed. *Ophiomyia spencerella* predominates at higher altitudes under cooler conditions and occurs together with *O. phaseoli* in medium- to low-altitude regions. *Ophiomyia centrosematis* occurs at low population levels on beans in Africa.

Bean flies attack a wide range of crops and wild plants in the family Leguminosae. Apart from beans, these include cowpea, soybean and mungbean.

Description and biology: The adult bean stem maggot is a tiny (about 2 mm long), shiny black fly with clear wings that reflect metallic blue in sunlight. The wings do not fold over, but form a 'V-shape' when the fly is resting (Plate 2). The three species of bean stem maggot are not easily distinguishable on the basis of external adult morphology (appearance and structure). Larvae and pupae can be found beneath the outer layer (epidermis) of the stem or root. They differ, however, in their oviposition or egg-laying behaviour. *Ophiomyia phaseoli* oviposits in the leaf blade, while *O. spencerella* and *O. centrosematis* oviposit mainly in the hypocotyl or directly in the stem. The eggs are long ovals and about 0.3 mm long. Incubation lasts 2–4 days. The larva, a small white maggot, eats its way from the site of oviposition to the root zone where pupation takes place. While emerging maggots of *O. phaseoli* have to travel through leaf veins, petiole and stem tissue to pupate near the root collar, *O. spencerella* and *O. centrosematis* do not travel far, but feed extensively in the stem tissue. *Ophiomyia phaseoli* leaves behind a feeding or mining track, but *O. spencerella* and *O. centrosematis* leave no visible tracks.

Ophiomyia spencerella puparia are shiny black with a grey ventral surface, while *O. phaseoli* and *O. centrosematis* puparia have a dull translucent brown color. The duration of the larval and pupal periods is about 10 days each.

Bean flies are especially active following the rainy season. During the rainy season and during prolonged dry spells, they usually do not occur.

Damage: The adult female pierces the young leaves with its ovipositor and sucks the exuding sap. This leaves a stippled effect on the leaves, which may serve as a characteristic indication of bean stem maggot activity in the field. The feeding activity of the third and final instar larvae destroys the stem tissue and reduces lateral root formation. Some plants try to compensate by forming adventitious roots above the damaged areas and this results in callus formation, stem swelling and cracking. Young seedlings and infested plants under stress wilt and die within a short time (Plate 3). Older or more vigorous plants may tolerate the damage, but their growth will be stunted and the yield reduced (Plate 4). The insect can cause up to 100% seedling mortality in a susceptible variety when infestations are high.

Control options: Bean flies can easily be controlled with two of the new insecticidal seed treatments. Fipronil at 4.8 ml/kg seeds or imidacloprid at 8 ml/kg seeds gives excellent control of bean flies. Although farmers' practice of applying either dimethoate or diazinon as foliar spray application on French bean fields at weekly intervals for four weeks *does* control bean flies, there are a number of disadvantages. Spray application is time- and labour-intensive compared to seed treatments. It has also been shown that spider mite problems tend to be more severe following repeated foliar insecticide application. Foliar sprays can therefore be avoided until the pre-flowering stage. Imidacloprid also controls bean aphids until early flowering. Since smallscale farmers will not be in a position to treat their own seeds with either one of these products, they should always purchase certified and treated seeds.

Striped Bean Weevil

Alcidodes leucogrammus (Erichson) (Coleoptera: Curculionidae)

Status and distribution: The bean weevil is apparently restricted to tropical Africa, where it attacks beans, cowpea and other legumes.

Description and biology: The adult is 10–15 mm long and has dark-brown elytra (see Glossary) with whitish to yellowish stripes running lengthwise. At rest, the elytra meet in a straight line down the middle of the back of the insect. The females lay eggs in the soil near bean plants. Emerging grubs bore and feed inside the stem, causing gall formation. Fully-grown grubs are white, about 10 mm long, without legs and C-shaped. Pupation occurs in an earthen cell attached to the plant.

Damage: The grub bores into bean stems and causes a cankerous swelling or gall. This leads to stunted plant growth, lodging and eventually plant death. The stem of French bean plants attacked by striped bean weevils breaks easily during harvesting of French bean pods. Adults cause damage by cutting circular discs out of leaf margins to feed.

Control options: If striped bean weevils only occur occasionally and only in some areas to a minor extent, control measures are not required. This is the case in Kenya, for example.

Aphids
(Plates 5–9)

Aphis fabae Scopoli (Black bean aphid), *A. craccivora* Koch (Black legume aphid) (Homoptera: Aphididae)

Status and distribution: *Aphis fabae* is widely distributed in many countries, including Scandinavia, Europe, Asia, the Middle East, parts of Africa and North and South America, but it is not common in the tropics. Nevertheless, it attacks common beans wherever the crop is grown in Africa. *Aphis craccivora* is primarily a pest of cowpea, but may also attack beans, particularly at lower altitudes.

Description and biology: The *A. fabae* adult is small (1–2.5 mm long) and dull black to dark olive green in colour, often with a powdery white secretion on the abdominal segments. *Aphis craccivora* is shiny black and lacks this secretion. It is polyphagous on legumes in many southern tropical countries. Nymphs are wingless, dark, and somewhat rounded in body shape. Winged forms (called alates) may develop under overcrowded conditions or when food quality deteriorates. In the tropics the insects reproduce by parthenogenesis. The life cycles of both species are similar.

Damage: Winged aphids (*A. fabae* and *A. craccivora*) start colonies of wingless aphids on bean plants which they infest. Colonies of aphids are found particularly around the stems, on growing points like leaf and flower buds, around flower clusters and on the underside of the leaves (Plate 5). Colonies develop rapidly, especially in warm, humid weather. Aphid infestations do not occur uniformly across a field. Some plants may be heavily infested, while neighbouring plants may not be attacked at all.

Aphids feed by sucking plant sap. Infested plants display wrinkled leaves and stunted growth and pods become deformed (Plate 6). Plants may become desiccated (dried out) and may die, especially under heavy infestations. Plant parts become contaminated with honeydew excreted by the aphids, which attracts the growth of black saprophytic moulds. French beans attacked by aphids or contaminated with honeydew are not marketable. Aphids are also vectors of plant virus diseases, including the bean common mosaic virus (see page 55). Aphid infestations are more common during dry spells.

Control options: Control measures against bean aphids are not required until the flowering stage, if seeds have been treated with imidacloprid seed dressing (Plate 7). (Apart from controlling bean flies, imidacloprid controls aphids well until just before flowering occurs. Insecticide applications against bean flower thrips will usually also control aphids). Should aphid colonies be found early on certain plants, spot application of insecticides can be carried out. Aphids have many natural enemies, mainly parasitic wasps and predators such as ladybird beetles (Plates 8 & 9), lacewings, and cecidomyiid flies (the larvae of gall midges), which help to keep these pests in check.

Whiteflies
(Plates 10 & 11)

Bemisia tabaci (Gennadius) (Homoptera: Aleyrodidae). Common name: the tobacco whitefly or the sweet potato whitefly

Trialeurodes vaporariorum (Westwood) (Homoptera: Aleyrodidae). Common name: the greenhouse whitefly

Status and distribution: *Bemisia tabaci* occurs throughout most tropical and subtropical regions of the world, mostly in hot and dry areas. It occurs naturally in a band around the earth at approximately 30–35 degrees latitude north and south of the equator. Distribution outside of this band is limited mainly by low winter temperatures. Hosts include a very wide range of wild and cultivated plants. *Trialeurodes vaporiorum* occurs at higher altitudes and cooler climates.

Description and biology: The four-winged adult is 1–3 mm long and is covered by a white-coloured, waxy bloom over the entire insect (Plate 10). Adults can fly only short distances, but may be dispersed over large areas by wind. Females usually lay their first eggs on the lower surface of the leaf on which they emerge, but soon move upwards to younger leaves, generally on the same plant. The pear-shaped eggs, which hatch in about 7 days, are about 0.2 mm long and are inserted vertically into the leaf tissue. They are anchored at the larger end by a stalk, which penetrates the leaf epidermis through a puncture made by the ovipositor, and passes into the spongy parenchyma. Upon hatching, nymphs only move a short distance before settling down to feed. Once feeding begins, nymphs do not move again. All nymphal instars are greenish-white in colour, oval in outline, scale-like and somewhat shiny. The last instar is about 0.7 mm long, quiescent, and the red-coloured eyes can often be seen through the larval body covering (integument). Nymphs complete three moults before pupation and emergence as adults.

Damage: The undersides of leaves are infested with adults and nymphs, which extract fluids from the plant tissue through sucking mouthparts (Plate 11). The stylets penetrate between epidermal and parenchyma cells of a leaf to the phloem (path of sugar and nutrient movement). Infested plants are of low vigour, and may wilt, turn yellow in colour and die when whitefly infestations are severe or of long duration. Damage may be accentuated when plants are under water stress. Whiteflies excrete honeydew, a clear fluid containing unabsorbed organic matter and sugars, which often completely covers foliage during heavy infestations. As a result of sooty mould fungi growing on the honeydew, leaves and pods may turn black in colour, thus reducing the plant's respiration and photosynthesis and rendering the French beans unmarketable. Whitefly populations may build up to large colonies on the underside of leaves and swarm in white clouds when disturbed.

Control options: Whitefly populations usually do not build up to such an extent that control measures are required. Control measures can only be justified if large whitefly populations build up during the early stages of the crop. Population build-ups after the onset of flowering should not have any effect on the yield.

Spider Mites

(Plates 12 & 13)

Tetranychus spp. (Acarina: Tetranychidae), mainly *T. urticae* Koch

Status and distribution: Tetranychid mites are found throughout the world on virtually every major food crop and type of ornamental plant. The subfamily Tetranychinae includes a number of economically important forms, of which the red spider mite, *Tetranychus urticae* is the most important species on beans as well as on many other horticultural crops.

Description and biology: Adults are tiny (about 0.4–0.5 mm in length), oval, and reddish or greenish in colour. Males are slightly smaller than females. Depending on the temperature, the life cycle may take 10–30 days and includes five stages: egg, larva (first instar), protonymph (second instar), deutonymph (third instar), and adult. Females lay 60 to 115 spherical, whitish coloured eggs (0.1 mm diameter) at a rate of five or six a day singly on the lower surface of the leaves. The larva is of a pinkish colour, slightly larger than the egg and has six legs. Protonymphs and deutonymphs have a green or red colour and four pairs of legs. The adult female lives for about three weeks.

Spider mites have well-developed passive ('ballooning') dispersal mechanisms, enabling them to be carried by the wind, and to spread over large areas and colonise widely separated host plants. *Tetranychus urticae* is also able to crawl over the soil surface to infest neighbouring plants.

Damage: Damage by spider mites is usually first evidenced as clusters of yellow spots on the upper surface of leaves, which may also appear bleached or chlorotic (Plate 12). On the leaf lower surface and at higher infestation levels, webs containing active mite stages will be present (Plate 13). Under severe infestations, the leaves turn reddish, whither, and drop. Mite damage may be especially severe during the dry season. As spider mites feed on bean plants, they inject saliva, which inteferes with growth-promoting substances present in the plants. This physiological effect can hinder plant growth.

Feeding by *T. urticae* on bean plants may cause reductions in plant height, flowering, pod number and length, and number of seeds per pod. Damage is most severe when mite feeding occurs early in the vegetative (growing) period. When mite infestations increase after flowering, no influence on yield results.

Control options: The IPM approach for spider mites is to use a seed dressing and avoid foliar sprays, especially broad spectrum insecticides. If this is done, spider mite populations usually do not build up to such an extent that other chemical control measures are required. From the time of flowering, no commercially available acaricide should be used at any time, because all registered products require a pre-harvest interval of at least one week (7 days). Using acaricides after flowering is likely to leave unacceptably high residues on the crop.

Bean Foliage Beetles

(Plates 14–16)

Ootheca spp., *Monolepta* spp. (Coleoptera: Chrysomelidae)

Status and distribution: Both the larvae and the adults of leaf beetles feed on a number of different crops including beans, cowpea and other pulses, groundnut, sesame, coffee, cocoa and cotton. Some *Monolepta* species also attack cucurbits, maize, citrus (e.g. grapefruit) and various stone fruits. *Monolepta dahlmanni* (Jac.) and *M. duplicata* (Sahlb.) have been recorded in tropical Africa.

Ootheca spp. are the most common foliage beetles found on beans in the region. *Ootheca bennigseni* Weise, *O. mutabilis* (Sahlb.) and *O. bifrons* Labois have been reported on *Phaseolus* sp. and *Phaseolus vulgaris* in East Africa. *Ootheca bennigseni* is reportedly restricted to the medium- to high altitude regions of eastern and southern Africa. *Ootheca mutabilis* is more common in the lowland areas and is also found in West Africa.

Description and biology: *Ootheca* adults are small beetles about 6–8 mm long. Adults are oval, shiny, convex-shaped beetles. The colour of their elytra varies from orange to black and the thorax from orange to brown (Plate 14). Different coloured forms are found within a population. *Ootheca* adults emerge with the rains and feed voraciously on young bean seedlings. They lay yellow, elliptical and translucent eggs in the soil at the base of bean plants. The larvae feed on the roots and nodules. They remain in the soil after beans are harvested and continue to develop through three instars to the adult stage. Large populations can be found in the soil after harvest. The larvae pupate in an earthen cell, and the adult may undergo diapause until the onset of the rainy season. Some *Monolepta* spp. are small beetles, about 2–3 mm long, with long antenna and two pairs of large pale spots on the elytra (Plate 15).

Damage: The adults chew small, roundish holes in the leaves (Plate 16). Heavy attacks may cause complete defoliation. Adults feeding on primary leaves and/or early trifoliate reduce plant vigour, plant size and yield. The larvae also feed on the roots, causing stunted growth and premature senescence (ageing). The problem is more acute in fields where continuous cropping of beans is practised. *Ootheca* is normally not a serious pest of French beans, but it is common on many leguminous crops. It is an important pest of common beans.

Control options: Control measures on French beans are not usually advocated. For common beans the following measures have been recommended:

- Post-harvest tillage exposes the larvae in the soil to the heat of the sun and increases mortality.
- Crop rotation with non-hosts, such as maize or sunflower breaks the development cycle and reduces the emerging population.
- Delaying sowing, where practicable, allows the crop to escape from high populations.
- Application of botanical pesticides such as neem has been shown to reduce pest populations and damage.

Hairy Caterpillars

(Plates 17 & 18)

Alpenus (Spilosoma) investigatorum Karsch.

Spilosoma (Diacrisia) jacksoni Rothschild (Lepidoptera: Arctiidae)

Status and distribution: This cosmopolitan family (Arctiidae) contains over 11,000 species, and includes the tiger and footman moths. Most species are defoliators in the larval stage. Most of the pest species belong to the genera *Amsacta*, *Creatonotos* and *Spilosoma*.

Description and biology: Adults are brightly coloured moths, often with rows of spots on the abdomen, and stripes or dots on the forewings (Plate 17). Some accumulate plant toxins and are distasteful to predators. They lay eggs in clusters of 50–100. The larvae are characterised by long yellowish- to black hairs (Plate 18) that have led to them being termed 'tiger moths' or 'hairy caterpillars'. Pupation takes place in the soil or in leaf litter close to the host plants.

Damage: Hairy caterpillars can be devastating, but are highly sporadic; for instance, they have been prominent during the El Niño rains. They are gregarious and often migrate from field to field in search of food after consuming the foliage in the field where they have hatched.

Control options: Hand-picking is a suitable option at low densities. Populations are seldom large enough to warrant pesticide application.

Bean Flower Thrips

(Plates 19–22)

Megalurothrips sjostedti Trybom, African bean flower thrips; *Frankliniella occidentalis* Pergande, western flower thrips; *Frankliniella schultzei* Trybom, blossom or cotton bud thrips; (Thysanoptera: Thripidae)

Status and distribution: *Megalurothrips sjostedti*, the African bean flower thrips, is usually considered to be an African thrips. It occurs widely in sub-Saharan Africa and attacks various crops within the family Leguminosae. *Frankliniella occidentalis*, the western flower thrips, originates from the western USA or California, where it was first reported in 1895 on apricot, potato leaves, orange flowers and various weeds. It has since spread throughout the United States and through Europe, where it was first detected in 1983. It has also been found in New Zealand, Australia, parts of Asia, Central and South America, and Africa. It was first reported in Kenya in 1986. *Frankliniella schultzei*, or the blossom bud thrips, is endemic to sub-Saharan Africa, but it also occurs in South and Southeast Asia, the Pacific and Australia. Both *Frankliniella* species feed on a wide variety of plants and are highly polyphagous.

Description and biology: Adult thrips are small (1–2.5 mm in length), slender, and winged. The front and hind wings are very narrow, featuring a wide fringe of hairs. The life cycle includes five stages: egg, first instar larva, second instar larva, pre-pupa, pupa, and adult. The white or yellowish coloured eggs are cylindrical and bean-shaped. The female inserts isolated eggs into the plant tissue. They hatch within a few days. The larval stages are small and active feeders but the pupal stages do not feed. Pupation normally takes place in the soil or under fallen and decayed plant tissues near host plants.

Adult thrips of the genus *Frankliniella* are small (males 0.9–1.1 mm, females 1.3–1.4 mm in length) and pale brownish-yellowish in colour (Plate 19). The newly moulted larva is characterised by a glassy white colour. It starts feeding immediately, becoming yellowish. Second instar larvae are more active than first instar larvae and feed up to three times more often than during the first instar stage. Upon reaching the adult size, they take on a yellowish waxy colour.

Adult thrips of the genus *Megalurothrips* are slightly larger in length (about 2 mm long), shiny black with a whitish band across the pronotum (Plate 19). Nymphs are cream to orange in colour. At maturity they move away from the flowers or other plant parts towards the soil where they pupate at a depth of 1.5–2.0 cm. The adult emerges upon the last moult and exhibits a whitish colour, which becomes progressively darker within 48 hours of moulting. Shortly after emergence, the insect begins feeding voraciously.

Damage: Thrips of the genus *Frankliniella* can sometimes be found feeding and ovipositing on the young leaves of young plants. As soon as the crop starts flowering, however, most thrips will be found in the flower buds, flowers, and on the young pods. Both adults and nymphs of *M. sjostedti* feed in the flowers at the base of the petals and stigma. They also attack the young and growing French bean pods. Punctures caused by feeding can be observed with a hand lens. Severe injury is characterised by flower malformation, distortion, and discolouration (Plate 20). Under very severe attack, flower buds do not open but abort prematurely. French bean pods abort prematurely or become scarred and malformed, and are not marketable (Plate 21).

Control options: The control of all bean flower thrips is extremely difficult. They are difficult to control chemically since they hide and feed in the flowers, where they are sheltered from pesticides. Thrips of the genus *Megalurothrips* are easier to control chemically than thrips of the genus *Frankliniella*, however. Therefore it is important to know the kind (species) and degree of thrips infestation before any control measures are carried out.

During cool and rainy seasons and/or at higher altitudes, thrips of the genus *Megalurothrips* are more common than the genus *Frankliniella*. When it is hot and dry, however, *Frankliniella* can usually be found in large numbers. In general, thrips numbers tend to be much higher during the hot and dry season.

Biological control of thrips, particularly the western flower thrips (WFT) is receiving a great deal of attention in the USA and Europe. The most commonly used natural enemies are anthochorid bugs (*Orius* spp.) (Hemiptera: Anthocoridae). Predators and parasitoids of thrips have also been recorded on French beans in Kenya. The most commonly found natural enemies are the predatory anthocorid bug *Orius* *albidipennis* (Reuter) (Plate 22), and the parasitoid *Ceranisus menes* (Walker) (Hymenoptera: Eulophidae). These two natural enemies have been found in French bean plantations throughout the year, however they are not able to keep the thrips population in check. Recorded parasitism by *C. menes* is low (up to 20%).

Megalurothrips can be controlled fairly well by foliar applications of pyrethroids such as lambdacyhalothrin, α-cypermethrin; bifenthrin, or dimethoate. These pesticides control the adult as well as the immature stages of the pest. None of the commercially available pesticides suitable for French beans can control adult thrips of the genus *Frankliniella*, however. Trials conducted in areas where pyrethroids like lambda-cyhalothrin had been used extensively showed that the highest number of *Frankliniella* thrips could be found in plots sprayed with lambdacyhalothrin. Thrips numbers in these plots were even higher than in unsprayed control plots. This is an example of the 'pesticide treadmill' (see Glossary).

Products that give reasonable control of *Frankliniella* include fipronil, methiocarb, and spinosad. In any case, foliar applications of insecticides against bean flower thrips can only be carried out during the short period of flower bud development to early flowering. Foliar applications at a later stage are no longer allowed, because applications would lead to pesticide residues on the bean pods.

Flower and Pollen Beetles

(Plate 23)

Mylabris spp. and *Coryna* spp. (Coleoptera: Meloidae)
Common name: blister beetles

Status and distribution: Flower and pollen beetles are reported from locations wherever beans are grown in Africa.

Description and biology: These beetles are generally strikingly coloured, with red or yellow bands on black elytra. *Mylabris* spp. are large beetles (2–4 cm long), while *Coryna* spp. are smaller (1–2 cm long), with a hairy head and thorax, but smooth elytra. The distal (end) segment of the antenna is club-shaped and yellowish (Plate 23). If handled, the adults release an acrid fluid which may burn the skin. The biology of both genera is complex, but generally similar. They lay eggs in the soil. There the larvae feed on grasshopper eggs and are not pests of crop plants.

Damage: The adults often appear in large numbers and eat flowers, thus reducing pod set. *Coryna* spp. may feed only on the pollen and not on the petals.

Control options: If flower and pollen beetles do occur in a bean field, they are difficult to control, because the more vulnerable stages occur in the soil, sometimes outside the bean fields. In small fields, manual removal and destruction of the insects may be a practical control strategy.

Pod Borers

(Plates 24–26)

Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae). Common name: African bollworm, tomato fruitworm (Plates 24 & 25).

Maruca testulalis (Gey.) (Lepidoptera: Pyralidae). Common name: legume pod borer (Plate 26).

Status and distribution: The African bollworm is a polyphagous pest that attacks a wide range of outdoor crops throughout the tropical and temperate regions of the world. Primarily a pest of vegetable crops, other hosts include cotton, field maize, tobacco, grain sorghum and a variety of ornamental plants. The legume pod borer attacks beans and other grain legumes throughout the tropics and subtropics. It is reported in nearly all countries of sub-Saharan Africa.

Description and biology: The adult of the African bollworm is a moth of approximately 30 mm in length (Plate 24). The anterior wings are covered with tannic-brown coloured scales and marked with dark grey, irregular lines. The irregular lines often shade into an olive colour. The distinctive eyes have a light-green colour. The moths are relatively strong fliers, dispersing widely within areas where their host plants are found. They can also be dispersed by strong winds and can be carried long distances. Females lay a single, white-coloured, hemispherical egg of 0.75 mm diameter, on leaves or other plant parts. Eggs hatch in about 3–7 days. The mature larva is about 37 mm long, with lengthwise alternating light- and dark-coloured stripes. Larvae vary greatly in colour, ranging from light green or pink to brown, the colour phases being influenced by the plants it feeds on, i.e. on dietary carotinoids (Plate 25). The average duration of the larval stage of five instars ranges from 15–31 days. Mature larvae descend to the soil and prepare a tunnel and an earthen pupation cell 5–10 cm below the soil surface. Pupae are copper-coloured and approximately 20 mm long. The pupal stage lasts between 10–19 days.

The adult moth of the legume pod borer has light brown forewings with white markings and pearly white hindwings. The wingspan is 1.5–3.0 cm. Though chiefly nocturnal, the moth may also be seen during the day. Early instar larvae are dull white, but later instars are black-headed, with irregularly shaped brown to black spots on the back, sides and underneath (ventral) surfaces of each body segment (Plate 26). Pupation takes place in the soil within a cocoon and lasts 5–10 days.

Damage: Pod borers usually do not cause significant yield reduction in French beans. Their importance lies in the fact that they are quarantine pests. If only one pod borer larva is found in a consignment shipped to Europe, the whole consignment may be rejected.

African bollworm: The larvae feed on flowers and pods of bean plants. The feeding hole is clean and usually circular, with faeces placed away from it (Plate 25). One larva may damage several pods, causing them to wilt. Attack is usually sporadic.

Legume pod borer: The larvae feed on flower buds, flowers, and often pods of bean plants. Flowers usually show little sign of damage until they wilt and drop. The larvae tend to hide when feeding and characteristically attack pods at the point of contact between two pods, or between a pod and a leaf or stem. They frequently make webs holding together flowers, pods, and leaves.

Control options: Pod borers usually do not appear in such large numbers that chemical control is required. Should a more serious attack occur, only *Bacillus thuringiensis* (*Bt*) preparations could be applied during the period of harvesting, because all other products require longer pre-harvest intervals. If pod borers are found in a field, the French beans harvested should be sorted very thoroughly to remove the pod borers manually.

Bugs
(Plate 27)

Clavigralla (=*Acanthomia*) *tomentosicollis* (Stal.), *C. schadabi*, *C. elongata*, and *C. hystricodes* (Hemiptera: Coreidae). Common name: spiny brown bugs (Plate 27).
Anoplocnemis curvipes F. (Hemiptera: Coreidae). Common name: giant coreid bug
Riptortus dentipes Fab. (Hemiptera: Coreidae). Common name: Riptortus bug
Nezara viridula (L.) (Hemiptera: Pentatomidae). Common name: green stink bug (Plate 27).

Status and distribution: *Clavigralla* species are widely distributed in Africa, where they attack a wide range of legumes. *Clavigralla tomentosicollis* is reported from most bean growing areas. *Clavigralla schadabi* is apparently restricted to West Africa, while *C. elongata* is more prevalent in eastern and southern Africa; *C. hystricodes* has been reported from Tanzania. *Anoplocnemis curvipes* and *Riptortus* are widely distributed throughout Africa. *Nezara viridula* is widespread in the tropics and subtropics. It is primarily a pest of soybean, but occasionally damages beans.

Description and biology: *Clavigralla tomentosicollis* adults are stout, about 10 mm long, furry, and brown. *Clavigralla schadabi* and *C. elongata* are narrower and grey and have a pair of elongated spines which project anteriorly on the prothorax. *Clavigralla hystricodes* is black and has a shorter body. The biology of the four species is similar. A single female may lay about 250 eggs singly. Nymphs are sluggish and form colonies on pods and peduncles. Adults feed singly or in mating pairs and drop off the plant when disturbed.

Anoplocnemis curvipes is black and about 3 cm long. It is a strong flier and escapes to nearby trees when disturbed. Males have a single large spine on each hind leg; females lack this feature. Dark grey eggs are laid in chains of about 10–40 on legumes, but seldom on bean plants. Newly hatched nymphs are bright red, but later turn black. There are five nymphal instars, the first two of which resemble ants.

Riptortus bugs are slender and about 20 mm long. They are light brown with white or yellow lines on the sides of the body. Adults lay eggs in small batches on weeds or other leguminous plants, but rarely on beans. There are five nymphal instars.

Nezara viridula adults are green and triangular in shape (Plate 27). When disturbed, they may emit an offensive smell. The females lay batches of 30–60 barrel-shaped eggs stuck together in rafts on the underside of leaves. First instar nymphs stay together near the raft and do not feed. They disperse after moulting and then begin to feed.

Damage: The external symptoms of damage on beans appear as tiny depressions on the pod wall and seed coat. The seeds rot or shrivel and lose viability. The whole pod may also be shrivelled.

Anoplocnemis sp. adults sometimes suck the sap on shoots, causing them first to wilt and later to turn necrotic and rot. The immature stages of this species rarely occur on beans. *Nezara viridula* also transmits a fungus to developing seeds, causing yeast spot, which is a widespread but minor disease of beans in Africa.

Control options: Bugs cause damage to the developing French beans pods, however at this stage of the crop, insecticides should not be applied. Insecticides applied for the control of bean flower thrips at the onset of flowering (p. 33) usually also control bugs, especially the nymphal stages.

Cutworms

(Plate 28)

Agrotis spp. and *Spodoptera* spp. (Lepidoptera: Noctuidae) e.g. *Agrotis segetum* (Dennis and Schiffermuller). Common name: common cutworm.

Status and distribution: Cutworms are the larvae of moths of various species and are commonly found throughout the world. They are reported to attack the seedlings of most crops, including those of beans.

Description and biology: Adult *Agrotis* moths have a wingspan of about 40 mm, and have grey-brown forewings with dark brown or black kidney-shaped markings. The hindwings are almost white. They fly at night. The female moth lays up to 1000 eggs in small irregular masses on the stems of weeds or crop plants or in the soil. The eggs are globular, about 0.5 mm in diameter and milky-white in colour, later turning cream-coloured with reddish-yellow markings and an orange band. The eggs are ribbed and have a reticulated pattern. They hatch in 10–28 days. The first two larval instars remain on the original host. Later instars disperse and migrate into the soil. During the day they remain in soil crevices or under stones and plant debris. At night they move up to the soil surface to feed. Feeding occurs at or below the soil surface. The latter instars have a plump body with colour varying from grey, greenish-brown to brown or black (Plate 28). The mature larva is about 4 cm long and pupates in an earthen cell in the soil. The pupa is about 15 mm long, smooth, and shiny brown. It has two dark spines at the tip of the abdomen. Under warm conditions the life cycle can be completed in six weeks.

Damage: The larvae girdle and cut off young seedlings at soil level, causing the seedlings to wilt and die. Damage may also occur below the ground, leaving cavities that cause plants to wilt and die. Cutworms tend to be more frequent in recently ploughed land that has plenty of decaying organic matter or where organic manure has been applied.

Control options: Cutworm damage is usually minor and does not warrant control measures. If plants which have been damaged by cutworms are found, the cutworms can be located near the damaged plants in the soil and removed physically.

Seed-Borne Diseases

Angular Leaf Spot

(Plates 29 & 30)

Cause: The fungus *Phaeoisariopsis griseola* (Sacc.) Ferraris

Symptoms: The fungal lesions may appear on primary leaves, but do not become prevalent until flowering or early pod set. The dark brown spots are small and have angular edges and are often so numerous that they give the foliage a checkerboard appearance (Plate 29). Lesions may increase in size, run together (coalesce), and cause necrosis and yellowing of leaves followed by premature defoliation. Pods have brown blotches (Plate 30). The fruiting fungus produces a grey mould on the lower surface of the leaf and may cover the pods and stems.

Disease cycle: The fungus penetrates the seed coat and may be spread over long distances in infected seed. The fungus can live from one season to the next or even for 18 months in the crop residue from diseased plants or as minute fungal resting bodies containing spores in the soil. The fungus can be spread from the crop residue by water splashes or on wind-blown soil particles. Once established in a crop, the fungus is usually spread by wind from lesions on the leaves. Infection and disease development are favoured by high moisture and moderate temperatures (between 20 and 25 °C).

Disease management: Plant only certified disease-free seed. Remove crop residues from the field or plow them down, and practise crop rotation without beans for at least two years. It is always advisable to treat the seed prior to sowing with both an insecticide and a fungicide. Captan could be used for seed treatment. Fungicide application may be considered if the disease is endemic and if the weather conditions are favourable for its development or if rotation is not feasible. No fungicide should be applied after full flowering due to the unacceptable residue levels it may leave in the pods. Avoid movement of workers in the bean fields when the plants are wet.

Anthracnose
(Plates 31–34)

Cause: The fungus *Colletotrichum lindemuthianum* (Sacc. & Magn.) Bri. & Cav.

Symptoms: Pale brown sunken spots may appear on the cotyledons of infected seedlings and water may spread the disease to the hypocotyl, which if girdled, kills the seedling. Lesions on leaves are dark brown. However on the lower surface, they are restricted to the veins (Plate 31). On stems, the lesions are elongated and sunken (Plate 32). On the pods, the fungus produces black, sunken lesions (Plate 33). These lesions penetrate deep into the pods and may cause shrivelling of the young pods. Infected seed become discoloured changing to yellow through brown to black (Plate 34). In damp weather, the centres of anthracnose lesions become covered with a pink spore mass.

Disease cycle: Anthracnose is seed-borne. The fungus survives in infected seed or on plant residues. The fungus is disseminated over long distances through infected seed. Short distance spread is by mechanical contact, water splashes or wind, particularly during cool damp weather. The disease is likely to be severe in cool, wet seasons or where overhead irrigation is used.

Disease management: The principal control measure consists of planting certified healthy seed. Seed treatment with captan will adequately take care of seedling diseases. The disease can be minimised by plowing under diseased bean refuse and practising a 3-year crop rotation in disease-prone areas. Overhead irrigation should be discouraged. Avoid movement of workers in the fields when wet. Since anthracnose is a minor problem in French beans, fungicide application is normally not warranted.

Common Blight
(Plate 35)

Cause: The bacterium *Xanthomonas campestris* pv. *phaseoli* (E.F. Smith) Dye

Symptoms: Leaf lesions first appear as small, water-soaked or light green areas. As the spots develop, the centre becomes dry and brown with a distinct narrow yellow halo (Plate 35). The spots may continue to expand until each spot affects much of the leaf surface or coalesces (runs together) with others to kill the leaflet. Similar water-soaked spots form on pods and can coalesce into broad irregular blotches. In humid weather, a yellow crust of the bacterium covers the lesion surface. The lesion margin is a shade of red. As lesions age, they gradually change to brown, and in intense disease severity, the entire pod shrivels.

Disease cycle: When diseased seed is planted, it produces seedlings with blight spots on stems, cotyledons and first true leaves. Secondary spread is by water splash, wind-blown rain, irrigation water and mechanically by insects. Following splash dispersion, the bacterium enters into plant parts through stomata, hydathodes or wounds. The bacterium survives in bean debris; it survives longer on the soil surface and in dry rather than moist conditions. Piles of bean crop residue in and adjacent to fields can serve as sources of the disease. Common blight is favoured by high temperatures (28–32 °C) and high humidity.

Disease management: The disease can be managed by use of certified disease-free seed, plowing under of bean debris after harvest, practising of 2–3 year crop rotation without legumes, and not working in bean fields when the plants are wet. If blight is observed on scattered young plants, spot application of copper hydroxide (e.g. Kocide DF®) could be considered. However, it must be noted that no fungicide should be applied after full flowering because of the danger of high residue levels in the produce.

Halo Blight

(Plate 36)

Cause: The bacterium *Pseudomonas syringae* pv. *phaseolicola* (Burk) Young, Dye & Wilkie

Symptoms: On leaves, halo blight spots consist of a central, semi-transparent and water-soaked area about 0.5 cm in diameter and surrounded by a pale green or yellowish halo up to 2–3 cm in diameter (Plate 36). When infection is severe, the spots may coalesce and dry up so that much of the leaf turns brown and withers. In hot weather, the spots may be less characteristic, being reddish brown and lacking a halo. On young plants, lesions on the stem appear as reddish streaks which may split and exude a bacterial slime in damp weather. When the disease is a result of using infected seed, the primary leaves of seedlings have interveinal chlorosis, suggestive of mosaic virus infection (see page 55). Pod lesions first appear as small water-soaked pinpricks on the pod surface. These spots gradually enlarge to form dark sunken spots of various sizes. A white bacterial ooze appears in the spot when wet. Halos do not develop around pod lesions.

Disease cycle: The principal sources of the bacteria in the field are diseased seed, infected bean plants and bean debris after harvest. Bean seed is the most important inoculum source, because not only can it carry the bacterium from one region or farm to another, but it can facilitate the bacterium to survive from one season to the next. Plant-to-plant spread occurs by water splash, overhead irrigation, contact between plants and movement of machinery or workers when the foliage is wet. Cool (16–22 °C) moist conditions favour the disease. The bacterium gains entry into the plant through stomata or injury points.

Disease management: Use of disease-free certified seed cannot be over-emphasised, as this practice usually results in a blight-free crop the first year. Plowing under of crop debris and exclusion of beans from the rotation for at least two years may keep the initial bacterial contamination low. Movement of workers in the fields should be discouraged when the plants are wet. In case isolated seedlings are found infected, they should be immediately rogued (pulled out) and removed from the field. Where young plants are observed to be diseased, a spot application with copper-based fungicides (copper hydroxide) could be considered. As with all pest problems, no chemical treatment should be done after full flowering in order to avoid unacceptable chemical residues in the pods.

Bean Common Mosaic Virus (BCMV)

(Plate 37)

Symptoms: Cupping and twisting of leaves with a light and dark green mosaic pattern. The dark green tissue is often bubbled and/or in bands next to the veins (Plate 37). Affected plants produce smaller, curled pods with a greasy appearance, and yields are reduced.

Disease cycle: A number of aphid species can transmit BCMV and are responsible for the spread of the disease within the crop. BCMV can be introduced into fields through infected seed. When infection takes place after flowering, however, the seed does not become infected. Sheltered areas are especially susceptible to field spread. Temperatures of 22–26 °C and dry weather favour aphid migration and therefore disease spread.

Disease management: Management is through use of disease-free certified seed; seed treatment with insecticides for control of aphids during the early stages of plant growth; roguing (pulling out) of infected plants; and early planting, where feasible. Seed treatment with imidacloprid has been found to accord effective aphid control until the flowering stage.

Diseases Not Transmitted through Seed

Fusarium Root Rot

(Plates 38 & 39)

Cause: The fungus *Fusarium solani* f. sp. *phaseoli* (Burk) Snyd. & Hans.

Symptoms: Infected seedlings appear dwarfed. The primary leaves are often yellow, later turning necrotic and finally the seedlings wilt (Plate 38). In severe attacks, weakened seedlings may also die from secondary fungal infections caused by *Pythium* species. The taproot of affected plants is initially discoloured reddish and may be streaked nearly to the surface of the soil. The red colour is later replaced by a brown discolouration, often accompanied by longitudinal fissures (cracks running lengthwise). Sometimes the main root and the lower stem become pithy. The small lateral roots that normally develop from the taproot usually are destroyed, after which a cluster of fibrous roots form above the lesions just below the soil line (Plate 39).

Disease cycle: *Fusarium* species infect bean roots when the soil is too wet, too cold or too hot for good bean growth. *Fusarium* survives in residues from diseased bean plants and also in the soil in the form of resting spores (chlamydospores). Pathogen spores are spread by irrigation water, bean-straw manure, and even by farm tools. Once the fungus is introduced into the field, it can survive for more than six years in the soil. The disease is more serious where the crop is under stress. After infection, an unusually dry period greatly adds to the loss. Deep planting and heavy watering also aggravate the disease.

Disease management: Sanitation and crop rotation are the two most important controls. Since *Fusarium* is soil-borne and can survive in soils for long periods, every effort must be made to exclude it from bean fields. Old bean straw should not be fed to livestock if manure from the animals is to be used on bean fields. Surface irrigation water should not be directed from old bean fields to new fields. Residues from diseased bean plants should be removed from the fields and burnt. Beans should be planted only in well-drained, well-fertilised soil that encourages excellent plant growth. In heavy soils it is advisable to plant beans on hills or ridges. Application of potassium nitrate has been found to reduce the severity of the disease in some countries. Chemical control is not effective.

Powdery Mildew

(Plates 40 & 41)

Cause: The fungus *Erysiphe polygoni* DC. ex St. Amans.

Symptoms: A white powdery mould first appears on small areas of the upper leaf surfaces. Under favourable conditions, mildew areas can enlarge rapidly and coalesce (meet) until the entire leaf surface is affected (Plate 40). Soon after the appearance of the white powdery spots, the plant tissue directly beneath becomes reddish brown; in severe cases, the leaves turn yellow and drop off. Leaf petioles, stems and pods can also be affected (Plate 41).

Disease cycle: The fungus covers the upper leaf surface with fungal threads which produce many short stalks (conidiophores), each of which bears spores resembling beads in a chain. The spores are easily detached from conidiophores and are carried by wind, rain and insects. The spores may be washed from leaves onto stems and pods by light rain, and spread over greater distances by rainstorms and strong winds. On reaching a suitable host, the spores are able to germinate in relatively dry air and in the absence of free water on leaves, and the germ tubes enter the plant. Optimal temperatures for conidial germination are between 20 and 24 °C. The fungus can be carried over from one season to the next in debris from diseased plants. A fairly dry soil and heavy application of nitrogen fertiliser tend to increase disease severity.

Disease management: Helpful measures to minimise the disease severity include plowing down crop residues from diseased plants after harvest; avoiding continuous close-planting of beans; crop rotation; and the removal of weeds that might reduce air drainage within the crop. Use of fungicides such as triforine (e.g. Saprol®) is the only direct control measure. However, use of fungicides can only be justified if the disease appears when the bean plants are still in early growth stages. Fungicides must not be applied after full flowering because of the danger of unacceptable residue levels in the pods.

Rust

(Plates 42 & 43)

Cause: The fungus *Uromyces appendiculatus* var. *appendiculatus* (Pers.) Unger

Symptoms: Rust spots (pustules) appear on all the above-ground parts (Plate 42); they are most numerous on leaves, particularly on the underside (Plate 43), less abundant on stems, and occur sparingly on pods. Initial symptoms are minute, slightly raised pustules, which later become distinct circles which are reddish brown and surrounded by a yellow halo. Each pustule consists of a mass of spores (uredospores) which give a rusty colour. Severely infected leaves drop off. Defoliation early in the season may lead to severe yield reductions.

***Disease cycle*:** The fungus lives its entire life on beans. Due to continuous bean cropping, uredospores mainly occur in fields. Long-distance spore dissemination is by wind; plant-to-plant spread is by farm tools, insects, animals or other moving bodies. Uredospores can germinate as soon as they mature and under favourable conditions, their germ tubes enter through the stomata causing symptoms within 5 days. Rust development is favoured by cloudy, humid days when dew remains on leaves until late in the morning. A relative humidity above 95% and temperatures of 18–27 °C are required for infection to take place, and for heavy infection, a medium to fairly high temperature is required.

Disease management: Rust spores can be blown long distances and infect plants where beans have not been grown previously. When one bean crop follows another in the same field, the amount of fungal inoculum can be increased enormously and this results in destruction of succeeding bean crops. Therefore, use of a long (3-year) crop rotation period is helpful. Immediately following harvest, prompt destruction of crop residues is recommended. Regular field inspection for rust during the season is necessary to detect the earliest appearance when fungicide application should be made. Rust has the maximum effect on yield if it infects beans between the third trifoliate and pre-flowering stages. No application of fungicide should be done after full flowering, as not only is it uneconomical, it may result in unacceptable chemical residues in the pods.

IPM Options for French Beans

The IPM strategy for French beans is based on the production of a healthy crop by using appropriate crop husbandry, the use of preventive measures to avoid attack by pests and diseases, and the avoidance of pesticide use, particularly foliar sprays, for as long as possible. This is intended to give natural control agents a chance to keep pest populations at low levels. For this purpose, it is very important to understand the growth stages (phenology) of the crop and the occurrence and importance of major pests and diseases related to the different stages. The occurrence and importance of major pests and diseases at various stages in the growing cycle of French beans is presented for Kenya (Figure 2).

Hints for Growing a Healthy French Bean Crop

Recommendations for pesticide application for specific pests are based on case studies in Kenya.

- Use virgin land or a field where legumes have not been cropped for at least 2 years.
- Use disease-free certified seed. Farmer's own seed should not be used. Plant Monel variety in areas where rust is endemic. Other varieties such as Amy, Paulista and Samantha are more susceptible to the rust races present in Kenya[1].

- Seed should be treated with both insecticide and fungicide before sowing. Imidacloprid or fipronil in combination with captan accord good control of bean flies and damping-off diseases, respectively. Imidacloprid is also very effective against bean aphids.
- Fertilise the soil well and plant French beans on hills or ridges in areas where root rot could be a problem. Avoid furrow irrigation in areas prone to root rot. Avoid planting of French beans and legumes where root rot problems are observed to avoid further spread.
- Avoid planting the beans too close together. A spacing of not less than 30 x 15 cm between rows and within the row is recommended. New plantings should be sited up-wind where continuous bean cropping is practised. Plant maize, other cereals or sunflower between French bean fields to minimise the spread of wind-borne diseases such as bean rust.
- Inspect the crop weekly for appearance of rust symptoms. Chemical intervention should only be considered if rust appears very early in a crop cycle to avert further build-up, particularly at the 3rd trifoliate and pre-flowering stages when it is most destructive in terms of yield loss. Although a number of products are recommended by manufacturers for rust control, Anvil® has been found to be very effective at threefold the recommended dosage.
- Do not direct water flow from old bean fields to new fields in areas where surface irrigation is used. Irrigation should be done early morning or late afternoon. Avoid movement of workers or farm implements in bean fields when crop foliage is wet. .

- Carefully read any pesticide label on the container before application. Use only those pesticides registered for French beans and which are acceptable to importers. If in doubt, consult extension agents, the Fresh Produce Exporters Association of Kenya (FPEAK), the Horticultural Crop Development Authority (HCDA) or the Pest Control Products Board (PCPB).
- Use the dosage indicated on the label. Avoid drift of pesticides to water bodies or sources. Use protective clothing when applying pesticides.
- Observe the pre-harvest intervals of pesticides as indicated on the labels. No pesticides should be applied after the full flowering stage of the French bean crop. Do not apply pesticides during pod formation and during the picking period. This is because none of the commonly commercially available pesticides has a pre-harvest interval of two days or less.
- Apply pesticides on a need-basis only, instead of routine application based on the calendar.
- The most important pest during the early growth stages of French beans is the bean fly. Treatment of seeds with an insecticide like imidacloprid (8 ml/kg) or fipronil (4.8 ml/kg) effectively controls bean flies. Imidacloprid also controls bean aphids until the beginning of flowering. Foliar applications of insecticides can therefore be avoided until week five (in an area of early maturity of French beans such as in Mwea, Kenya) or week six (in an area of late maturity, as in Naivasha). An

application of fungicides might be necessary if diseases such as angular leaf spot, bean rust or powdery mildew occur during the early stages of the crop.

- Foliar applications against late-season pests like bean flower thrips are only advocated during the period from flower bud formation until the onset of flowering. Occurrence of *Megalurothrips sjostedti* can be checked by application of dimethoate or pyrethroids as specified earlier. None of the current registered insecticides works satisfactorily against *Frankliniella* thrips species[2].
- Occurrence of other pests is usually not severe enough to warrant chemical intervention. Spider mites and whiteflies are often induced by careless and indiscriminate use of pesticides. Pesticide application could thus be reduced to about three applications or less if the above strategy is followed.
- Plow deep or remove from fields all bean culls and crop residues promptly after harvest. Do not feed bean culls and crop residues to livestock if the animal manure is intended to be used in bean fields.
- Practise crop rotation. Do not grow French beans, dry beans or other legumes more than twice in succession on the same piece of land. Rotate with non-legumes or cereals. A dry bean-maize intercrop is not a suitable rotation.

[1]*The National Horticultural Research Centre, Thika, Kenya, may soon come up with an improved selection of Monel which may be relatively more resistant to rust than the current commercial variety.*

[2]*Metathripol, a product made from a fungal pathogen called* Metarhizium anisopliae *and under development and testing by ICIPE, has provided satisfactory control for flower thrips.*

Bibliography

Allen D. J., Ampofo J. K. O. and Wortmann C. S. (1996) *Pest, Diseases and Nutritional Disorders of the Common Bean in Africa. A Field Guide*. Centro Internacional de Agricultura Tropical (CIAT). 132 pp.

Anonymous (1982) *A Handbook of Plant Diseases. Volume 1: Fruit and Vegetables.* Queensland Department of Primary Industries, Brisbane, Australia. 253 pp.

Beije C. M., Kanyagia S. T., Muriuki S. J., Otieno E. A., Seif A. A. and Whittle A. M. (1984) *Horticultural Crops Protection Handbook.* National Horticultural Research Station, Thika, Kenya. 170 pp.

Carlile W. R. (1995) *Control of Crop Diseases* (2nd Edition). Cambridge University Press, UK. 145 pp.

Food & Fertilizer Technology Centre (FFTC) (1986) Plant Virus Diseases of Horticultural Crops in the Tropics and Subtropics. *FFTC Book Series No. 33*, Taiwan, Republic of China. 193 pp.

Foster R. and Flood B. (1995) *Vegetable Insect Management with Emphasis on the Midwest.* Meister Publishing Company, Willoughby, Ohio. 206 pp.

Gitonga L. M. (1999) Bioecology of thrips in French bean growing agroecosystems in Kenya. PhD thesis, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya. 176 pp.

Horticultural Crops Development Authority [HCDA] (undated) French Beans. Export Crop Bulletin. Excerpt from the KEDS—Supported HCDA Export Crop Manual. 8 pp.

Heitefuss R. (1987) *Pflanzenschutz: Grundlagen der Praktischen Phytomedizin*. Verlag Thime. 342 pp.

Hill D. S. (1987) *Agricultural Insect Pests of the Tropics and Their Control*. Second edition. Cambridge University Press. 746 pp.

Hill D. S. and Waller J. M. (1992) *Pests and Diseases of Tropical Crops*. Vol. I. 4th edition. Longman, London.

Kranz J., Schmutterer H. and Koch W. (1977) *Diseases, Pests and Weeds in Tropical Crops*. Verlag Paul Parey, Berlin & Hamburg, Germany. 666 pp.

MacKinlay R. G. (1992) *Vegetable Crop Pests*. MacMillan Academic and Professional Ltd. UK. 406 pp.

Sherf A. F. and Macnab A. A. (1986) *Vegetable Diseases and Their Control* (2nd Edition). Wiley-Interscience, New York. 728 pp.

Glossary

Abort: (of flowers or fruit) to arrest development; remain undeveloped, often leading to shedding

Adventitious roots: a bunch of secondary roots originating from the stem below the soil level (Fig. 3)

Callus: tissue that forms over a cut or damaged plant surface

Chlorosis: yellowing of leaves

Chlorotic: blanched or yellowed

Cotyledons: the first leaf or primary leaves of a growing plant embryo; seed-leaf (Fig. 3)

Cucurbits: crops in the family of cucumber, pumpkin, melon or squash

Culls: plant removals

Defoliation: removal or shedding of leaves

Defoliators: insects that eat leaves

Elytra: thickened forewings of beetles which protect the underlying membraneous hind-wings used in flight

Endemic: established in a defined area (locality or country)

EU: European Union

Exuding: oozing out

Globular: spherical shape

Grubs: immature stages of beetles, often thick-bodied and six-legged

Honeydew: sugary liquid discharged by some insects such as aphids, scales, mealybugs and whiteflies

Hydathodes: water pores on leaves (Fig. 4)

Hypocotyl: that portion of the stem below the cotyledons (Fig. 3)

Incubation: (of diseases) time between infection to appearance of symptoms

Inoculum: disease source

Instars: insect form between successive moults; the first instar is the stage between hatching and the first moult

Larva (pl. **larvae**)**:** immature stages of an insect, often worm-like in appearance

Lateral: on the sides

Lodging: falling over of plants due to strong winds or damage to the root system caused by diseases and insects

Maggots: immature stages (larvae) of flies, often whitish, without a distinct head and legless

Maximum residue levels: maximum amount of pesticide residues allowed in and on crop produce at harvest time

Morphology: form and structure of a plant, insect or organism

Mosaic: a pattern of greenish and yellowish shades in leaves

Necrosis: death of part of a plant

Necrotic: dead part of a plant

Oviposition: laying of eggs by insects

Parenchyma (palisade): cells under leaf epidermis (leaf surface)

Parthenogenesis: form of reproduction in insects without males

Pathogen: any organism capable of causing disease

Peduncle: the stalk holding the bean pod to the plant (Fig. 3)

Pesticide treadmill: a situation resulting from the increased use of pesticides, whereby the pests develop resistance to the chemical(s) used, pest populations increase (resurge) and outbreaks of other (secondary) pests occur

Petiole: leaf stalk (Fig. 4)

Phloem: nutrient- or food-conducting tissue in plants

Plumules: undeveloped shoots in a seed

Polyphagous: organisms or insects feeding upon a range of plants (hosts)

Prothorax: part of an insect body immediately behind the head

Pupa: an inactive and non-feeding stage between larva and adult in insects (changing into a pupa is called pupation)

Quarantine pests: unwanted organisms (insects; disease-causing agents; weeds) which do not naturally occur in a country

Quiescent: dormant; inert: latent

Reticulate: having the appearance of or markings like a network

Roguing: physically removing of unhealthy or unwanted plants from a crop

Root collar: place on a plant where root system forms (just below soil level)

Saprophytic: organisms feeding on dead organic matter

Sp.: species

Spores: asexual reproductive structures of varied shapes and sizes produced by fungi and some bacteria

Stippled: dotted

Stomata: pores on the lower leaf surface (Fig. 4)

Translucent: allowing light to pass through (especially without being clearly visible or transparent)

Trifoliate leaf: a leaf comprised of three small leaves on a single petiole, typical of legumes (beans; clovers; desmodia) (Fig. 3)

Vegetative period: growth period of a plant from germination till flowering and before production of flowers and fruits

WFT: western flower thrips

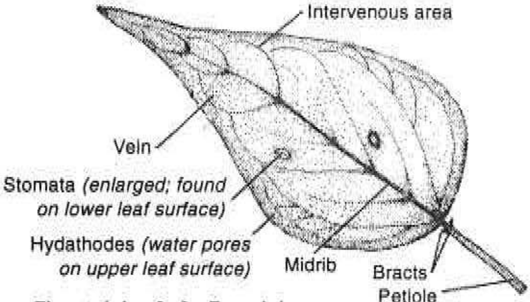


Figure 4. Leaf of a French bean

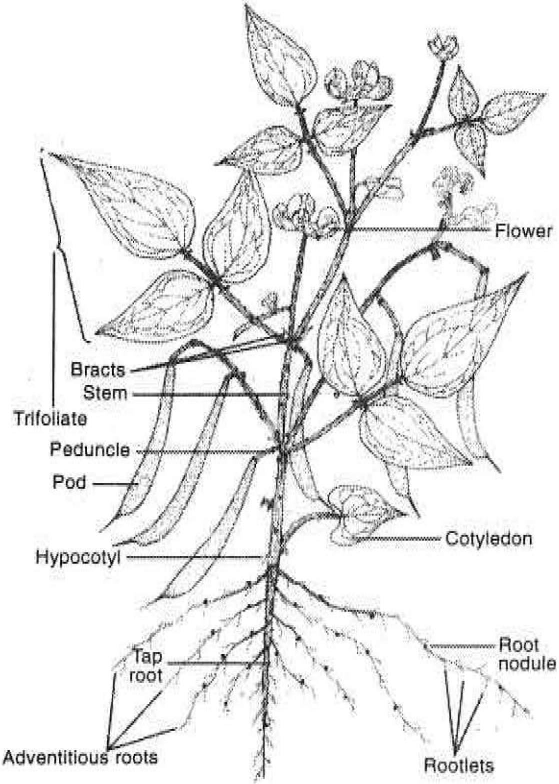


Figure 3. A French bean plant

Arthropod Pests

Plate 1: Seedlings damaged by bean seed flies: (top) damage to cotyledons and (bottom) damage to first true leaves

Plate 2: Adult bean flies

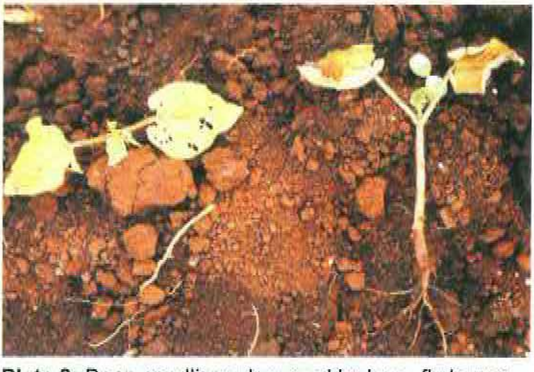


Plate 3: Bean seedlings damaged by bean fly larvae

Plate 4: French bean field showing gaps due to bean fly damage

Plates 5 and 6: Black bean aphid infestation

Plate 7: Seedlings from seeds treated with imidacloprid (back) compared to untreated (front) seedlings infested by black bean aphids

Plate 8: Ladybird beetle (*Cheilomenes* sp.), a predator of aphids

Plate 9: Larva (main picture) and eggs (inset) of a ladybird beetle, a predator of aphids

Plate 10: Whitefly adults, nymphs and pupae

Plate 11: Whiteflies on lower leaf surface of a French bean plant

Plate 12: Red spider mite damage on upper leaf surface of a French bean plant

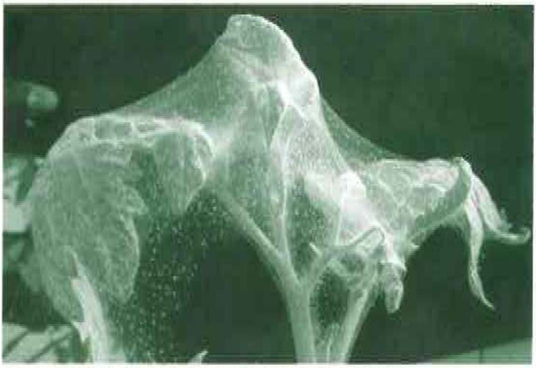


Plate 13: Webbing caused by spider mites

Plates 14 & 15: Left: *Ootheca* sp. adult foliage beetle, Right: *Monolepta* sp. adult foliage beetle

Plate 16: Plant damaged by foliage beetles

Plate 17: Adult moths of hairy caterpillars. Left, *Alpenus investigatorum*; right, *Spilosoma jacksoni*

Plate 18: Hairy caterpillars feeding on French beans

Plate 19: Bean flower thrips. Top, *Megalurothrips* sp. (black) and bottom, *Frankliniella* sp. (brown)

Plate 20: Flowers damaged by thrips (note two healthy flowers on upper right)

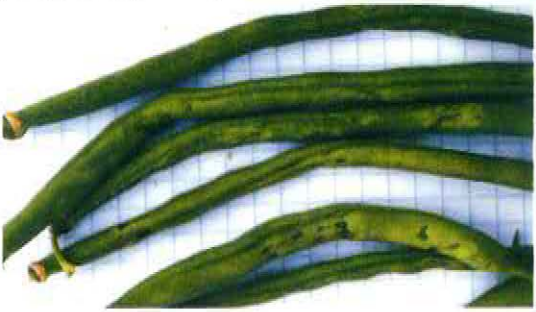


Plate 21: French bean pods damaged by flower thrips

Plate 22: *Orius albidipennis*, a predator of thrips. Left, nymph and right, adult bug

Plate 23: Blister beetle (*Coryna* sp.)

Plate 24: Moth of *Helicoverpa armigera*

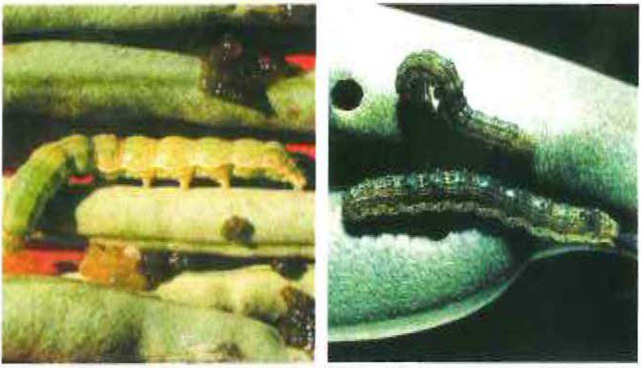


Plate 25: Left, *Helicoverpa* larva on French bean pods. Right, pods damaged by *Helicoverpa* larvae

Plate 26: Larva of the legume pod borer (*Maruca* sp.)

Plate 27: Bugs on French beans: *Acanthomia* sp. (left) and *Nezara viridula* (right)

Plate 28: Cutworm (*Agrotis segetum*)

Seed-Borne Diseases

Plate 29: Angular leaf spot disease: symptoms on upper leaf surface

Plate 30: Angular leaf spot disease: symptoms on a French bean pod


Plate 31: Anthracnose: symptoms on lower leaf surface (left) and upper surface (right)


Plates 32 and 33: Anthracnose: symptoms on a stem (32) and pods (33)

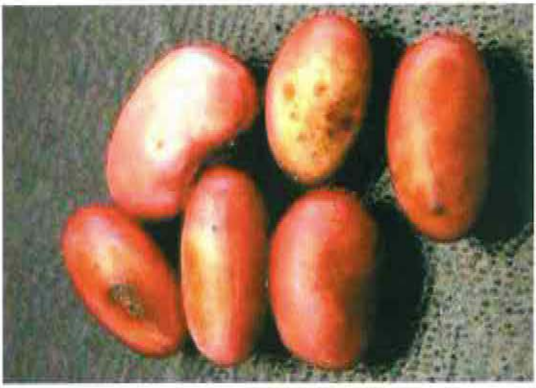


Plate 34: Anthracnose: symptoms on seeds

Plate 35: Common bacterial blight: leaf symptoms

Plate 36: Halo blight: leaf symptoms

Plate 37: Bean common mosaic virus: Left, dark green mottling pattern on infected leaf; Right, stunted plant due to mosaic virus

Diseases Not Transmitted through Seed

Plate 38: *Fusarium* root rot: wilting of seedlings

Plate 39: *Fusarium* root rot: rotting of roots

Plate 40: Powdery mildew: leaf symptoms

Plate 41: Powdery mildew: symptoms on pods

Plate 42: Bean rust: symptoms on upper leaf surface

Plate 43: Bean rust: symptoms on lower surface

ISBN: 92 9064 142 8

Stages in growth of French beans: germination (a), 1st trifoliate appearance (b), flowering (c)

French beans (*Phaseolus vulgaris*) are a major export crop in many horticultural-producing African countries. The recent introduction of maximum pesticide residue levels for export vegetables by the European Union has made it mandatory for growers to reduce the use of pesticides to a minimum.

This manual summarises the common pests and diseases of French beans and recommends IPM (integrated pest management) options that can be used by both small- and large-scale growers to help them meet the increasingly stringent demands by importers and consumers for safer produce. The IPM methods recommended are based on case studies in Kenya.

CTA

icipe

gtz

JE MAINTIENDRAI