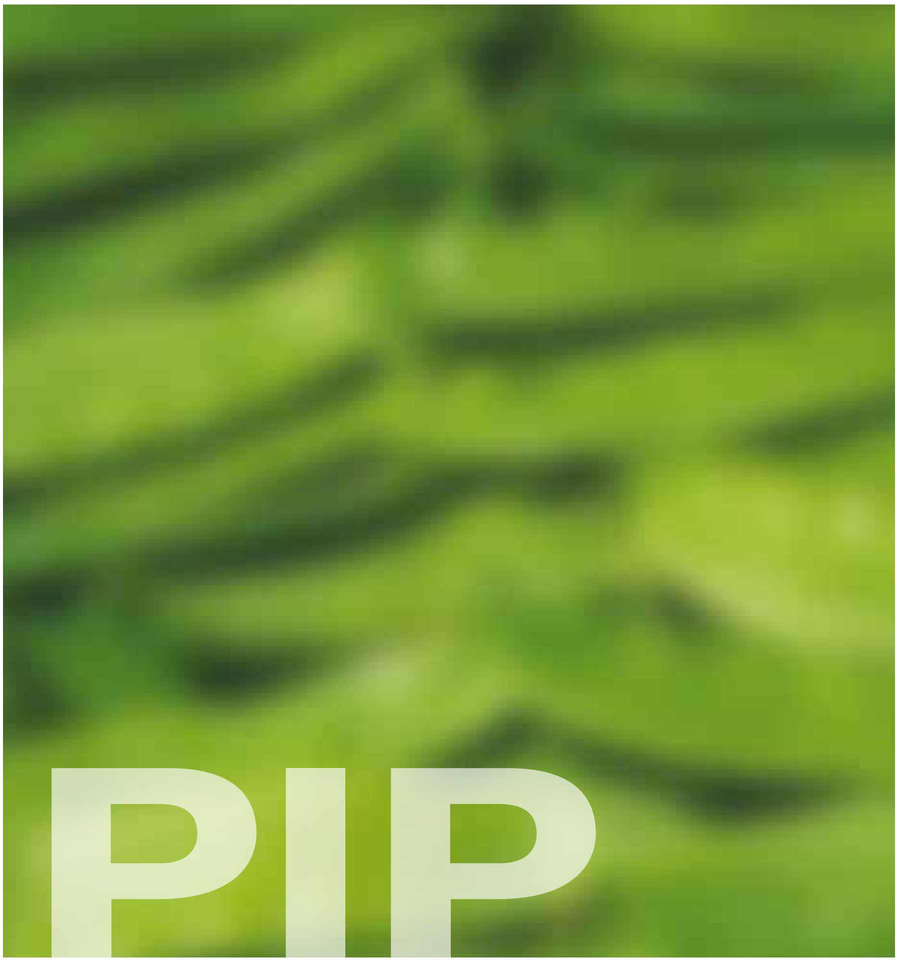

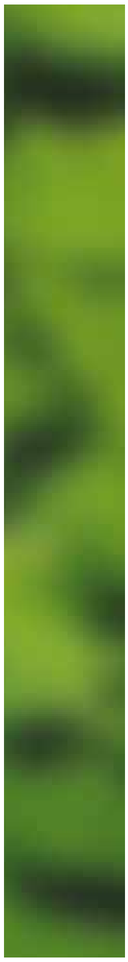

CROP PRODUCTION PROTOCOL

FRENCH BEAN (*PHASEOLUS VULGARIS*)

COLEACP is an international network promoting sustainable horticultural trade.

PIP is a European cooperation programme managed by COLEACP. It is financed by the European Development Fund and implemented at the request of the ACP (Africa, Caribbean and Pacific) Group of States.

In accordance with the Millennium Development Goals, the global objective is to: "Maintain and, if possible, increase the contribution made by export horticulture to the reduction of poverty in ACP countries".

www.coleacp.org/pip

COLEACP

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PIP

FOR SUSTAINABLE DEVELOPMENT OF THE ACP HORTICULTURAL INDUSTRY

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Disclaimer

The document «Crop Production Protocol » (fruit or veg.) describes all the agricultural practices linked with the (fruit or veg.) and suggests a pests and diseases control based mainly on active substances supported by the pesticides manufacturers in the EU Regulation 1107/2009 and due to comply with pesticides residues limits. Most of these active substances have been tested through a field trials programme and the residue level of each active substance has been measured. The pests and diseases control suggested is dynamic and will be adapted continuously integrating all informations gathered by the PIP. Nevertheless, each grower has the possibility to select among the products listed a set of active substances of no concern regarding residues.

It is obvious, that are allowed for usage only those formulations which have been legally registered in the country of application.
It is each grower obligation to check with the local registration authorities whether the product he wishes to use is mentioned on the list of registered products.

The PIP's crop protocols and guides to good phytosanitary practices are regularly updated. For further information, see the PIP website www.coleacp.org/pip

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DISCLAIMER

Ongoing regulatory reviews and the implementation of stricter standards have led to many changes to authorisations of plant protection products (PPPs) and maximum residue limits (MRLs), both within the European Union (EU) and at international level. This has a direct impact on producers, who often must change their production practices (good agricultural practices, GAP) to comply with the new rules. Any non-compliances can lead to the interception and destruction of produce, causing significant financial losses as well as reputational damage.

Please note that this document has not been updated since 2011, and information it contains regarding the status of PPP authorisations and MRLs may not be up-to-date. This document is currently under revision.

Before applying any PPP, it is advisable to consult the latest regulatory changes. Producers may supply diverse markets that follow different regulations. EU approval of active substances and MRLs can be consulted in the EU Pesticides database[1]. For domestic and regional markets, a list of PPPs registered for use is usually provided by the national competent authorities. African, Caribbean and Pacific (ACP) countries generally apply the MRLs set by the Codex Alimentarius[2].

Keeping track of PPP authorisations and MRL changes is complex and time-consuming, but is essential to ensure regulatory compliance. COLEACP has responded to requests to provide a PPP information service that keeps members up-to-date with the changes that are most critical for the ACP fruit and vegetable sector. This includes a database (e-GAP) for COLEACP members and partners, which lists EU and Codex Alimentarius MRLs for key horticultural crops in ACP countries. It also provides the GAP (dose rate, intervals between treatments, pre-harvest intervals) that ensure compliance with these MRLs. Additional information is also offered – type of pesticide, registration status of active substance in the EU and in ACP countries, classification recommended by the World Health Organization, and resistance group (FRAC code for fungicides; IRAC classification for insecticides. The e-GAP database can be accessed via COLEACP's e-services website: eservices.coleacp.org.

1 https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=homepage&language=EN
2 http://www.fao.org/fao-who-codexalimentarius/codex-texts/dbs/pestres/pesticides/en/

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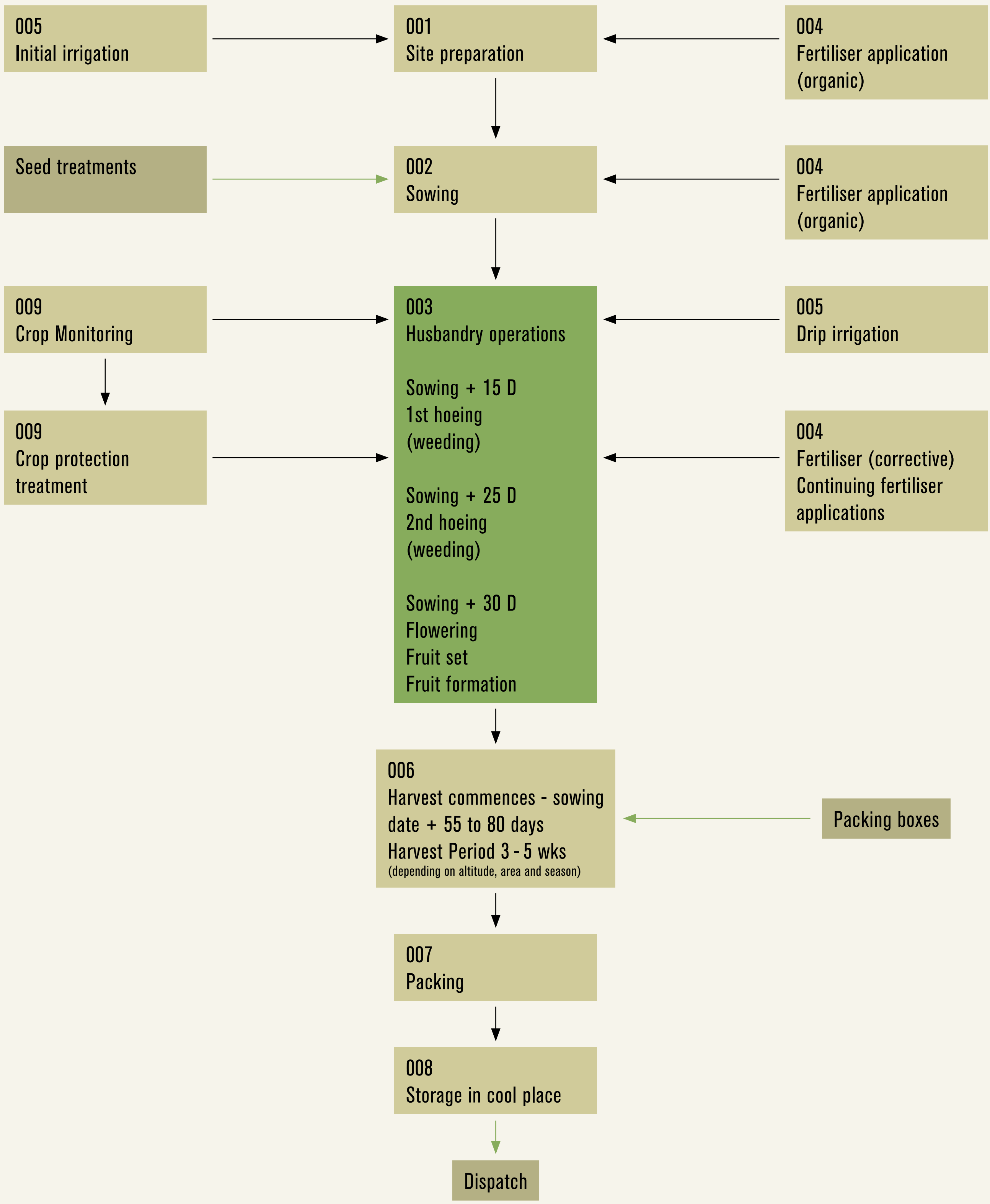
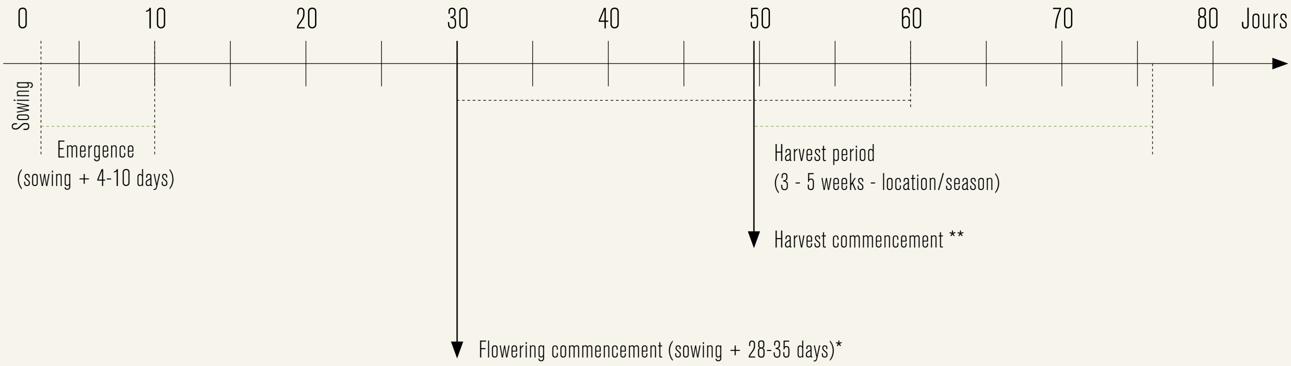
Production process

production process (each number refers to a detailed point in the document)



000 - Crop cycle in Senegal

Kenyan French beans are produced all year round due to the range in altitudes and climate available on the equator with an all-year round growing climate.
Hence there is a wide range of periods between sowing and commencement of flowering or harvest. Similarly, the length of the harvesting period depends on the location, variety and specification of the bean (fine or extra fine). See Appendix 6,7 and 8 for more details on classification of beans, climatic requirements and commercial varieties.



* In Kenya valid for 1500 m. Flowering 2 weeks later at 2000 m
** In Senegal 48 to 55 days after sowing
In Kenya:
- sowing + 60 days at 1500 m for fine beans
- sowing + 40 days at 1500 m for extra fine
- sowing + 80 days at 2000 m

Cropping period

Month	1	2	3	4	5	6	7	8	9	10	11	12
Senegal	■	■	■	■						■	■	■
Burkina	■	■	■							■	■	■
Kenya	■	■	■	■	■	■	■	■	■	■	■	■

001. Site preparation

1. Soil characteristics

Beans can provide good returns on a wide range of soils (sandy clay loam, sandy loam etc.) but they prefer a heavy soil. Silty soils that tend to form a crust impede germination (due to lack of oxygen) and emergence. Soil type and soil profile should be uniform throughout the field to ensure even crop development and harvest.

Soil conditions required for good yields are:

→ sufficient top soil depth (40 to 50 cm),
→ uniform soil structure,
→ fast draining (waterlogged soils increase risk of root and collar rot,and seed asphyxia at the germination stage),
→ optimum pH (H_2O) between 6.1 and 7.4
  - pH < 6,0: reduces bean yields,
  - pH > 7,5: yields gradually decline as alkalinity increases.
→ relatively stable structure,
→ salinity: beans are sensitive to as little as 1mS/cm, which reduces yields. Avoid saline soils and saline water. On soils with a low cation exchange capacity (CEC), fertiliser applications should be split up and applied in several instalments to avoid excess doses of salts.

2. Recommendations for previous crops in rotation

Crop rotation plays an important part in the health of the bean crop,which is susceptible to *Fusarium* and root knot nematode and other soil borne pests and diseases. Beans should not follow crops which arehosts to pests and diseases which attack beans (see table below); in particular, other legume crops such as runnerbeans should be avoided.

Ideally, the same land should not crop beans more than one crop in every three crops. In between the bean crop, a minimum of one and preferably two 'recommended crops' should be grown to actively manage soil health and optimise bean yields. Yields of beans will decline if no rotation is practised. Poor rotation will also build up levels of pests and diseases in the soil, which may be difficult to 'remove' by the use of chemical treatments. Crop rotation is the most cost effective means of maintaining soil health and crop yields

TO BE AVOIDED AS PRECEDING CROPS	NOT USEFUL AS PRECEDING CROP	RECOMMENDED AS PRECEEDING CROP
Beans, Peas	Groundnut	Cereals (maize, sorghum,
Potato	Pepper, Celery, Lettuce	millet, fodder grass)
African eggplant	Carrot	Cabbage, kale, sukumawiki,
Eggplant	Onion, Garlic, Shallot	pakchoi, turnip
Melon, Cucumber,		Karkade
Zucchini, Watermelon		Beetroot
Lettuce		Cassava
Okra		Sweet potato
		Strawberry

Incorporation of crop debris from cabbage-family crops provides useful partial soil sterilisation as the debris decomposes; it gives of gases similar to the active ingredients in certain chemical soil fumigants.
Care should be taken if herbicides have been used in previous crops as crop debris can sometimes contain residues of the herbicides which interfere with subsequent crop emergence and development (e.g. atrazine in maize).

If root knot nematode is a problem, it is possible to reduce the levels present by a short rotation with dwarf Mexican marigold (see notes in appendix 9).

3. Soil preparation - field preparation

BEAN CROP REQUIREMENTS:

- → A soil of uniform structure, tilled to a depth of 30 to 50 cm. The seed bed should have a fine structure and be well-aerated. Field preparation should allow the root system to establish easily throughout the top 25-30 cm, providing the plant with a good supply of water and minerals via its very delicate lateral roots. It is necessary to keep the soil well structured, slightly packed down and well-prepared.
- → Soils that tend to cap should be watered to field capacity and then tilled just before sowing. They should not be watered again until after crop emergence.
- → Very well-rotted, composted organic matter and basal fertiliser dressing should be incorporated at the time of soil preparation.
- → Excessive organic manure just before sowing is to be avoided because this increases susceptibility to disease (rot) and pests (nematodes, seed fly). Under no circumstances should fresh manure be applied to bean fields before planting due to the risk of contamination with *E.coli* bacteria when the cropping cycle from planting to picking is so short in French beans. If in doubt, cover the rotted manure with polythene to ensure that the temperature of the heap reaches at least 55°C for 3 days before application to the field.
- → The ground should be well levelled to prevent water from gathering in hollows, asphyxiating the plants or causing disease. The field should be perfectly flat and not too stony; this will enable greater sowing precision and subsequently facilitate harvesting.
- → Fields should be fenced to keep out livestock. It is unwise to let livestock into a bean field to graze on crop residues, as they may introduce weed seeds and disseminate nematodes. Fresh manure left by grazing animals is a potential source of E.coli in beans planted immediately afterwards. At least 6 months should elapse after application of fresh manure before beans are planted to reduce risk of contamination. Alternatively remove crop debris and feed animals off the growing site. The manure can then be composted with other crop debris before returning it to the planting site.

002 - Sowing operations

Seed requirements, records and inspection

The planting density varies depending on the irrigation method. Furrow irrigation wastes more cropping land due to the need for paths and will have lower seed requirements. (see planting pattern section). Drip irrigation allows more of the land to be cropped and the number of plants to aim for is 200,000 to 300,000 per ha of land. More vigorous varieties such as Teresa are planted at about 250,000 per ha whilst Amy is planted at about 200,000 per ha.

Average seed requirement: 29-34 kg/ha.

Exporters who distribute seeds obtained from an importer, should first check germination percentage is > 95% before distributing seeds to growers.

If seed viability is not optimal (95-100%), increase the number of seeds sown per ha.

Do not use self-saved seed as this increases the risk of seed borne diseases such as *Fusarium* and halo blight.

Inspect seeds before planting to ensure they are not physically damaged, shrivelled (old seed stock). Do not plant suspect seeds. If necessary grade-out poor quality seeds before planting.

If seeds have been treated with pesticides, ensure planting teams are provided with protective gloves.

In Kenya:

- All imported seeds used must have a plant health certificate. If the exporter supplies seeds, the seed lot number can be recorded in the Crop Records with reference to the health certificate number.
- Seed treatments must be recorded in the Pesticide Application Records (PAR) for a crop (including any treatments, which were applied by the seed producer in compliance with import requirements into Kenyausually thiram). If seeds are treated in Kenya (for beanfly prevention etc) this must also be recorded in the PAR. Ideally, seeds should be planted immediately after seed treatment with insecticide or fungicide.
- Delays can result in reduce efficacy of the seed treatment and even deterioration of seed quality.

Sowing pattern

The sowing pattern will depend on:

- the abundance of foliage of the variety used; whether maintenance operations are mechanised (passage of horse or tractor); type of irrigation (furrow, sprinkler or drip).
- sowing density should be lower during the rainy or wet season to increase air circulation and ensure leaves dry more quickly. This will reduce the risk of rust affecting yields in the rainy seasons. IN Senegal: sowing density should be lower at the start of the season, higher thereafter

Recommended sowing pattern:

Furrow irrigation

Seed rows are positioned on the shoulders of the furrow at the expected water line when the furrow is flooded. Seeds are spaced at 4 - 8 cm apart within the row, depending on variety, season and soil type. Rows of seeds are usually 1 ft apart (width of furrow). The ridges of furrows are usually 2.5 ft apart

Drip irrigation

Beans are planted on a raised bed in a range of patterns - either two rows, three rows or four rows of seeds per bed. The more rows per bed, the wider the beds.

Two-row beds are one meter wide (bed centre to adjacent bed centre); three-row beds are 1.5 to 1.8 m wide and a four row bed would be 2 - 2.2 m wide.

Aim to have about 40 cm between rows and plant seeds in a zig zag pattern between the rows - to increase airflow in dense plantings. Avoid higher density plantings in the rainy season or for varieties, which are prone to rust.

Plant one seed every 7 - 8 cm along the rows. Increase the spacing in rainy periods.

Sowing depth

Seeds must be sown uniformly for uniform emergence and ripening.

As the bean has epigeal germination (the cotyledons emerge above ground), easy emergence of the seedling must be ensured:

- in sandy soils: sowing depth between 3 and 5 cm,
- in heavy soils: 2 cm depth (no irrigation before emergence).

Anything that favours asphyxiation (heavy soils, too much water, compacted soil, and seeds sown too deep) will compromise emergence; emergence will be irregular and seedlings will be susceptible to root and collar diseases.

Sowing dates

Beans can be sown and harvested all year round in Kenya.

In other countries, beans sown in ground that has warmed up germinate faster and emerge more uniformly. This advantage continues right to harvest, with pods ripening more uniformly. Numerous other factors that must be taken into account in planning sowing dates, e.g. shipping capacity and duration of crop cycle (8 to 10 weeks for French beans).

003 - Cultural operations

Hoeing:

- Indispensable for aerating the soil. Hoeing must be very shallow to avoid damaging roots near the surface.
- 2 hoeings: sowing + 15 days and sowing + 25 days, incorporating corrective dressings at the same time.

Weeding:

- Beans benefit from weeding due to reduced competition for water, sunlight and nutrients. Spray penetration of the bean canopy is improved if weeds are removed. Some weeds also host bean pests such as thrips, spider mite and nematodes and should be removed.
- If necessary, combine with hoeing.
- Weeding must be shallow to avoid damaging bean roots.
- Selective chemical weeding (e.g. sowing + 15 days, with haloxyfop-R-methyl ester) - check registration in your country.

Incorporation / removal after harvest:

- Incorporate crop remains with roots. If there is weed infestation, remove weed plants complete with roots to avoid contaminating subsequent sowings and leaving residue that may harbour soil pests.
- Do not allow livestock to graze fields after harvest, to avoid contamination of succeeding crops with *E.coli*.
- Incorporate organic matter.

004 - Fertilisation

General remarks

Fertiliser applications must be planned with precision so that the dosage of each nutrient is appropriate to actual conditions in each field (this requires a soil analysis every 3 years). Records should be kept of any soil analysis undertaken which justifies fertiliser applications in order to comply with commercial referential.

The crop's requirements will be established as accurately as possible to avoid any excess.

As beans are a short-cycle crop, the fertiliser used must provide the nutrients in an easily assimilated form.

Beans develop root nodules that fix nitrogen, but for maximum yield, this does not replace mineral nitrogen inputs Commercially available *Rhizobium* seed treatments are obtained from the University of Nairobi. If *Rhizobium* inoculants are used, the initial fertiliser applications should have reduced nitrogen content, as excess N will reduce development of the *Rhizobium* in the bean roots. Healthy *Rhizobium* nodules are pink inside and appear to be attached to the outside of the root. These should not be confused with the gall of root knot nematode which are smaller, not as round and appear to be within the structure of the root. Roots, which are well endowed with *Rhizobium* nodules, are less susceptible to root knot nematode.

As beans are sensitive to salinity, fertiliser applications should be divided up and applied in several instalments.

Top dressings must be applied without touching the leaves, to avoid burning them. They will then be lightly incorporated (hoeing at same time). Alternatively soluble fertilisers can be applied down drip irrigation lines, or foliar feeds can be sprayed onto foliage. Do not apply in the peak heat of the day, to avoid scorching leaves.

Organic manure

Organic manure must be well rotted. It is wisest to apply this input to the previous crop.

Dose: 10 to 20 t/ha if possible. Unlike peas, beans respond well to farmyard manure: 20 to 30 T/ha of well-rotted manure at the time of sowing can be beneficial if the soil's organic content is too low. Aim to have up to 5% organic matter content.

Nitrogen (N)

To give the crop a good start, a nitrogen application is required (but never in excess) in the earliest growth stage (when there are not yet any nitrogen fixing nodes). Symbiotic N fixation begins from the 2nd trifoliate leaf.

Dose: 50 to 100 kg/ha (40 to 80 units/ha may be enough for a soil with average N content). High N input has little effect on yield and excess input (> 100 U N/ha) hampers node formation, makes the plant susceptible to lodging, and favours diseases and abortion.
Forms: ureic (urea)/ammoniacal/nitric (nitrate). Nitrate of sodium is to be avoided.
Balance: N:K_2O between 1:2 and 1:3.
Timing: nitrogen is incorporated into the soil just before sowing; basal dressing and sometimes top dressing: part of the N input (20 to 30 U) can be applied at start of flowering (25-30 days after sowing). Late application prolongs the growth cycle, reduces yield and provides favourable conditions for rust to develop.

Phosphorus (P_2O_5)

Phosphorus promotes firm rooting (important in sandy soils), it must therefore be present in a form which can be easily assimilated right from emergence. Phosphorous also promotes earliness. In mineral soils, optimum pH for P_2O_5 availability is 6.5. At 6.1 and between 6.5 and 7.4, availability declines; in these conditions, therefore, the basal dressing applications should be higher and a top dressing may be required.
Dose: 50 to 100 kg/ha of P_2O_5
Forms: phosphate of ammonia, triple superphosphate.
Timing: base dressing, and top dressing in certain soils if needed.
Although phosphorus is needed in smaller quantities, it is vital for plant growth. Signs of P deficiency are dark green leaf blade, upright habit, browning of older leaves followed by leaf fall. Where soil analyses give values below 12 mg, apply 50 to 60 units ofP_2O_5/ha in the form of superphosphate (rapidly assimilated) just before sowing.

Potassium (K_2O)

Like all legumes, beans respond well to potassium. K deficiency causes dark green coloration and loss of colour between leaf veins, bases of leaves roll downward. Later, leaf necrosis and leaf fall.
Potassium improves pod quality.
Dose: 100 to 200 kg/ha of K_2O.
Forms: potassium sulphate and potassium nitrate.
Avoid potassium chloride (KCl), which is toxic to beans).
Timing: base dressing and top dressing. A base dressing of 100 to 120 units of K_2O in the form of K sulphate can be applied.
If soil analysis reveals a very high potassium content, inputs should be reduced or omitted, to avoid excessive growth of the crop. NB: 20% of total mineral input is found in the pods.
Excess K is to be avoided because excessive growth of foliage will increase the risk of disease. Because beans are a short cycle crop, they must receive their minerals in a readily assimilated form.

Magnesium (MgO)

MgO deficiency can occur on acid, leached, sandy soils.
Dose: 10 to 30 kg/ha MgO.
Forms: magnesium sulphate, potamag (potash magnesium sulphate), patentkali. Decomposed organic matter also provides magnesium.
Timing: base dressing, drip irrigation, foliar spray.

Calcium (CaO)

Provided by the soil, organic matter, superphosphate and phosphogypsum.
Thomas slag, phosphal and natural phosphates also provide
CaO and can be used for medium-term action (not immediate).

Essential trace elements

Can be applied through drip irrigation system.
Deficiencies of the following can occur:

- Manganese: application of Thomas slag can reduce manganese deficiency in soils of pH > 7.
- Zinc: this can be remedied by low-pressure foliar spraying (at sowing + 25 d, 40 d and if necessary 60 d) of a 1% solution of zinc sulphate neutralised by 0.5% lime.
- Molybdenum: mainly in leached, acid sandy soils.
- Copper: if possible, use a foliar fertiliser containing calcium.

Toxic elements

Beans are sensitive to excesses of:

- **Chlorine:** beans are highly sensitive to the presence of chlorides (salinity) and use of fertilisers that contain it must be avoided. Chlorine in irrigation water can reduce yields by up to 20% or 25% (if water supply is chlorinated, temporarily store irrigation water in a storage tank, allowing the chlorine to evaporate before the water is used).
- **Sodium and boron** (avoid previous crops that have received fertiliser containing borax).

EXAMPLES OF FERTILISER APPLICATION (PER HECTARE) The figures are for quantity of input per hectare of actual crop.			
Fertilisation	**Example 1 (classic fertilisation)**	**Example 2 (Alternative fertilisation)**	**Example 3 (Fertilisation coupled to irrigation)**
Basal dressing	10 to 20 t organic matter* 200 to 400 kg 10.10.20	10 to 20 t organic matter* 200 kg K_2SO_4 150 kg diammonia phosphate (DAP)	10 to 15 t organic matter* 100 kg K_2SO_4 100 kg of 18-46-0
Sowing to flowering Corrective application 1 S +15 d. (1st hoeing)	150 to 300 kg 10.10.20	150 kg KNO_3 50 kg diammonia phosphate	100 kg K_2SO_4 100 kg of 18-46-0 25 kg urea 40 kg/week of 16-9-26 (soluble fertilisers) 20 kg / week of 0-52-34 (soluble fertilisers)
Corrective application 2 S +25 d. (2nd hoeing)	150 to 300 kg 10.10.20	150 kg KNO_3	100 kg K_2SO_4 25 kg urea 40 kg / week of 16-9-26 (soluble fertilisers) 20 kg / week of 0-52-34 (soluble fertilisers)
Flowering to harvest	(Foliar spray)	(Foliar spray)	40 kg / week of KNO_3 (soluble fertilisers)
Input in units N / P / K	50-100 / 50-100 /100-200	76 / 92 / 232	110 / 137 / 200
N/K_2O balance	1/2	1/3	1 / 32

*: IF ORGANIC MATTER IS AVAILABLE (WELL-ROTTED MANURE, POULTRY MANURE, COMPOST)

005 - Irrigation

Irrigation is indispensable for maximum output. Beans require 3,000 to 8,000 m^3/ha. If this requirement is not covered by available soil water reserves plus rainfall, irrigation will be needed. Crops are either furrow irrigated, drip irrigated or irrigated by sprinklers.

Furrow irrigation is the most labour intensive method of irrigation and also the most wasteful of water reserves. Larger amounts of water are needed for a given area and evaporation occurs from the water surface. Although it has the advantage of low initial capital investment, it also places a limit to the potential yields per area of land because of the need for ridges (which are not cropped) in addition to the walkways. Bean quality is reduced bymud splash on harvested pods. Mud splash from over-filled irrigated furrows, or on beans, which dangle into the furrows - can be a problem in furrow-irrigated crops (especially in the rainy season).

Drip irrigation, on the other hand, conserves valuable water resources, by delivering water directly to the plant root zone. There is no evaporation loss, as the water is contained within a tube. Drip lines need to be secured in a straight line with the holes facing upwards, so that they do not block.
Care must be taken to ensure that dirty water does not block the drip holes.
In some cases filters may be required to prevent drip lines from blocking.
Maintenance of drip lines and filters is essential if the full benefit from this system is to be obtained.

Simple drip irrigation systems are available in Kenya for small scale farmers.

If available soil water reserves are not sufficient, the field should be watered before sowing. Watering after sowing is generally not recommended, as it encourages only shallow root development. However, soils that tend to crust should first be watered abundantly (to field capacity), then tilled just before sowing.

Drought before flowering has a significant detrimental effect on final yield. From start of flowering, fields should be irrigated regularly according to need, continuing until pods are filling. Pods that receive sufficient water are of better quality (less string, lower seed percentage).

If sprinkler irrigation is used, in very hot periods, it should be applied early in the day, to avoid heat stress, burning of leaves, flower abortion and the formation of a micro-climate that encourages disease.

Irrigation instructions

Water requirement

Between 3,000 and 8,000 m^3 per ha of actual crop area.
On sandy soils, irrigation should be more frequent than on heavier soils.

Water quality

Avoid saline water, which will cause an immediate drop in yield.
Avoid irrigating directly with chlorinated water.

Watering regularity

From the moment of emergence, the plant must never be subjected to water stress. The emergence and flowering/pod formation stages are particularly sensitive.

Quantification of water input

Water consumption in relation to ETP (potential evapo-transpiration) varies according to growth stage. Do not exceed 12 mm per daily irrigation (apply several smaller quantities); stop irrigation a few days before bean harvest.To quantify water inputs, the following crop coefficients can be applied to ETP:

- from emergence to first leaves: 0.3 to 0.6,
- from first leaves to start of flowering: 0.6 to 0.7,
- from flowering to first pods: 0.7 to 0.9,
- during pod production: 0.9 to 1 or 1.2.

Example: for an ETP of 6 mm/d, daily amounts will be as follows, depending on crop growth stage:

- *6 mm x 0.3 to 0.6 = 1.8 to 3.6 mm*
- *6 mm x 0.6 to 0.7 = 3.6 to 4.2 mm*
- *6 mm x 0.7 to 0.8 = 4.2 to 4.8 mm*
- *6 mm x 0.9 to 1 = 5.4 to 6 mm*

Irrigation must be performed from a soil at field capacity.
ETP varies according to weather conditions:

- cool, overcast day, ETP<6 mm,
- sunny windy day with harmattan (very hot and dry wind in the sahel), ETP>6 mm.

Frequency of irrigation

To encourage the establishment of the root system, do not water too often until the crop has begun to put down roots (to encourage deeper rooting. To avoid root collar diseases, irrigation should be prudent and not excessive before emergence, in sandy soil.

Timing of irrigation

With spray or row irrigation, water in the morning to reduce the risk of prolonged high relative humidity on leaves and root collar (risk of rust, *Rhizoctonia*, *Sclerotinium*, Sclerotium anthracnose, blight and *Pythium*), and avoid water stress in very hot weather. With sprinkle irrigation, do not irrigate after applying a foliar treatment.

IRRIGATION METHODS			
METHOD	ADVANTAGES	DISADVANTAGES	COMMENTS
Furrow	Leaves remain dry, so reducing the risk of rust, foliar *Rhizoctonia* and blight	Leaves remain dry, which increases the risk of thrips and mites Facilitates movement of nematodes Any excess of water encourages collar and root rot	Difficult to control input, so excessive watering is possible. Quantities used: 6,000 to 8,000 m^3/ha
Sprinklers	Limits development of thrips and mites Dust is washed off leaves and pods	Increases risks of dissemination of blight,appearance of rust, foliar *Rhizoctonia*, *Pythium* and anthracnose	Use sprinklers at low output, 5 to 6 mm/h Quantities used: 4,000 to 6,500 m^3/ha
Drip	Leaves remain dry, so reducing the risk of rust, foliar *Rhizoctonia* and blight Limits movements of nematodes	Increases the risk of thrips and mites.	Reduces need for weeding, fertiliser and treatments can be applied in irrigation water. Quantities used: 3,000 to 3,500 m^3/ha

006 - Harvest

Method

Manual, with the pod stalk.
Preliminary sorting in the field (reject pods that are perforated, damaged, marked, twisted, etc.).

Precautions

Pick and handle with great care. Lay in a rigid container and do not pile more than 20 cm deep. Regularly bring harvested beans into shade (ideally every 10 minutes).
Bring harvest to packing centre as quickly as possible (every 30-45 minutes).
If pods are to be sorted and packed later, store them in a cool place. A 'charcoal cooler' , made of charcoal between chicken wire mesh, is useful if electricity is not available. The charcoal cooler should be designed to ensure all air passing into the cooler passes through the charcoal (no gaps in the charcoal walls). The charcoal should be kept wet to enhance the cooling effect. This can be achieved using a drip line at the top of the charcoal wall, fed from a water tank on the roof. Maintain product traceability throughout all operations from picking to storage and shipping.

Frequency

<u>In Senegal:</u>
String beans: every 2 days.
Bobby beans: every 3 days ("fine bobbies") or 4 days.
If these frequencies are not applied, one may find:
- a smaller percentage of small-calibre pods,
- an increasing proportion of rejects on sorting,
- fewer pods harvested per plant.

5 to 6 pickings per crop, sometimes 8. The last pickings do not keep so well in cold store (sometimes major losses).

<u>In Kenya:</u>
To obtain 'extra fine' beans the crop may have to be picked every day; whilst for the 'fine beans' specification, picking every second day may be sufficient. During hotter periods, the crop will grow faster and picking may have to be done more frequently to avoid losses due to growth over specification (over-specs).

Harvest Period

Start picking as early in the morning as possible to avoid harvesting wet pods or in hot sun.

<u>In Kenya:</u>
Harvest will commence from 40 to 60 days after sowing for extra fine and fine beans respectively at 1500 m altitude. At higher altitudes (2,000 m) it will commence around 80 days after sowing The harvest will continue for 3 - 5 wks depending on the altitude, variety and seasonal climate.

<u>In Senegal:</u>
Harvest commencement at 48-50 days, up to +75 days.

Labour force

To comply with the above, pickers must be trained and aware of the crop's importance. Pickers must be supervised.
They can harvest 5 to 10 kg per hour per person, depending on calibre, type, time of the season and number of pickings.

007 - Packing

The packing premises should be well-lit, cool, well-ventilated and clean. As soon as beans reach the packing station from the harvest field, they should be:

- Sorted:
  - reject pods that are perforated, twisted, broken, injured or rotten, etc.,
  - reject fragments of leaf, stem, flower, plant waste and other waste.

- Calibrated:
  - calibre is determined by the maximum width of the pod measured perpendicular to the groove. Calibration is only obligatory for string beans,
  - manually for bobby beans and stringless French beans,
  - manually or mechanically for string beans.

CALIBRE CLASSES ACCORDING TO MAXIMUM WIDTH OF POD	
extra fine	maximum 6 mm
very fine	maximum 8 mm
fine	maximum 9 mm
"fine bobbies"	maximum 9-10 mm
medium	maximum 12 mm *"Medium" string beans cannot be classed in the "Extra" class*
large	over 12 mm

- Arranged in cartons (400 x 300 x 110 mm) to provide 4 kg net per carton at the place of consumption. This means 4.2 or 4.3 kg gross per carton at the packing station, to allow for evaporation.
- Varieties and calibres must not be mixed.
- Cartons must be stacked in layers of 8, 12 layers deep (96 cartons = 384 kg net) on standard pallets for shipping by air.
- European legislation imposes quality standards for beans sold in the EU *(see Common Marketing Standard for beans, Commission Regulation (EC) N°912/2001 and revised norms CEE-ONU for beans (FFV-06), November 2000)*. It is essential to comply fully with this legislation, i.e.:
  - minimum characteristics defined in the Standards,
  - classification ("Extra" class, Class I, Class II),
  - quality and calibre tolerances: 10% (in weight or number) for all classes.

008 - Storage

For export, storage in a cold room is obligatory.
Optimum conditions:

- 4°C and 80% RH (or 6°C and 90-95% RH) can ensure 6 to 7 days' shelflife from harvest to sale (high RH = mould),
- do not reduce temperature below 4°C (blotches appear),
- at 12°C and 90-95% RH, the harvest-sale interval is only 4 days,
- moderate ventilation to prevent pods from drying out,
- the harvest-to-refrigeration interval must be as short as possible,
- avoid any rupture of the cold chain between packing station and retail sale.

009 - Crop protection

1. General remarks

Crop protection is governed by "Good Agricultural Practice" (GAP), following general recommendations of commercial referential. The goal is to provide a product that is sound, high-quality (i.e. complies the **Quality Standards** - *revised norms CEE-ONU for beans ("FFV-06")* and affordable. It is essential to combine the specific crop protection methods recommended below with all available husbandry methods (variety choice, rotation, staggered sowings, tillage, precision fertilisation, etc.) to obtain optimum protection **(Integrated Production and Protection)**, making full use of agronomic and ecological factors.

To limit pressure from parasites and certain pests:

→ use crop husbandry methods of pest control as far as possible,
→ avoid sowing beans near another crop that is infested by pests that may attack beans,
→ avoid sowing beans in a field where beans have been grown recently (a 3-year rotation is regarded as the minimum; ideally, rotations of 5 or 6 years are recommended for land infected with soil fungi or nematodes). However, see provisos in section on rotations above.

The effect of any operation(s) carried out must be subsequently assessed from all angles, to establish the "cost-benefit" balance of the operation(s):

→ effectiveness and profitability for the farmer,
→ selectiveness for the crop and for non-target organisms,
→ compliance with MRLs (consumer safety),
→ side effects for operators and domestic and wild animals,
→ effects on the environment (soil, water, vegetation, air),
→ effects on husbandry methods,
→ social consequences (e.g. reduced labour requirement where chemical herbicides are used).

The table below shows some crop protection principles to control some pests and diseases without pesticides.

Methods for the control of pests and diseases on French beans

CROP PROTECTION PRINCIPLE	spider mite	aphids	thrips	whitefly	bean and seed fly	root knot nematode	rust	root diseases
CHOICE OF LAND AND PREPARATION OF SOIL								
Rotation						■		■
Soil cultivation (e.g. deep ploughing post harvest etc.)			■		■			
Avoid planting near susceptible plants or infested crops	■	■	■	■	■		■	
Avoid land which is badly drained								■
Avoid shade							■	■
CULTIVATION METHODS								
Adapt irrigation methods (e.g. use drip irrigation or overhead)	■						■	
Use protective covers - plastic tunnels etc							■	
Adapt planting density							■	
CULTURAL CONTROLS								
Use straw mulches			■					
Organic manure applications						■		■
Regular weed control	■		■	■		■		
Avoid wet foliage for long periods							■	
Use trap plants or green manures		■	■	■	■	■		
CARE AND ATTENTION OF PLANTS								
Remove and destroy crop debris	■	■	■	■	■	■	■	■
Do not damage plants in normal husbandry								■
Remove infected parts of plants manually					■			
CROP PROTECTION METHODS								
Biological control	■	■	■	■			■	■

■ Control method for the pest or disease

2. Control treatments

Control treatments will be preventive or preferably in the light of intervention thresholds.
→ When there is no threshold, treatments must be done only if risks are medium or high for the area of growing (see Appendix 9 Pests and diseases sheets).
→ When a threshold exist, treatments must be applied when the threshold is reached or exceeded, taking into account the presence of natural enemies (See Appendix 3 for IPM Scouting methods and Appendix 4 and 5 for sensitivity of natural ennemies to pesticides).

3. Pesticides

Pesticides recommended for French beans, must take into account the following:
→ **marketing authorisation**, in compliance with authorised uses and approved dosages,
→ **obligatory precautions** for use (application period, pre-harvest interval, maximum authorised dose, existence or not of untreated areas, protective equipment) and any restrictions on use,
→ **any Maximum Residue Limit (MRL)** for the crop/pesticide combination in question. If the crop is exported, account must be taken of the MRL on the market where it is to be distributed (national MRL, European harmonised MRL or MRL set under the Codex Alimentarius).

In 2003/2004, the PIP carried out trials on residues for the pesticides considered the most important for French bean production in Kenya and in the ICDCS countries.
The tables in Appendix 1 show, for the active substances tested by the PIP, the registrations existing in Kenya and in the common registration system of the ICDCS countries. Effectiveness against the crop's main pests is also indicated.

Since there are often several trade names for the same active substance and because registrations change regularly, producers have to check those which are valid in their country at the time of using crop protection products, for instance, by consulting the PCPB web site for Kenya (http://www.pcpbkenya.org) or the CSP site for the ICDCS countries (http://www.insah.org/protectiondesvegetaux/csp/).
In Kenya, products with general authorisation for use on horticultural crops, vegetables or beans can also be used on French beans.

Other active substances, not tested by the PIP, are also registered for use on French beans. Some of the approved products contain active substances or live organisms which leave no residues. A non-exhaustive list of these products follows:
- *Bacillus thuringiensis*,
- garlic-based product,
- parasites or predators of insects or mites.

The tables of Appendix 2 show:
- the position of the active substances tested by the PIP with regard to European regulations (status in Regulation 1107/2009, existing MRLs),
- the results of trials on residues that have been undertaken in Senegal and Kenya,
- the Good Agricultural Practices (GAPs) used in the trials (dose of active substance/hectare, number of applications and interval between applications).

The producer must first and foremost follow the instructions (doses, interval between treatments, number of applications and Pre-Harvest Interval) provided on the labels of locally authorised products. Following such instructions, however, does not necessarily guarantee compliance with MRLs currently in force in the country where the commodity will be consumed. To comply with regulations on pesticide residues, it is recommended that the producer uses pesticides only within the limits of the Good Agricultural Practices tested by the PIP, which are critical GAPs. Any change to one or more elements of these GAPs indicated in Appendix 2 (increase in dose, frequency of application and number of applications;
final application closer to harvest than the recommended Pre-Harvest Interval) may result in a failure to remain within the MRL. For active substances where trials results have not permitted to know what is the PHI complying with existing MRL, it is recommended not to use them as long as a new MRL is not set.

Note on the status of active substances in EU

Before a Plant Protection Product can be marketed in EU, its active substance must be approved by the European Commission. Regulation (EC) 1107/2009 (replacing former "Directive 91/414/EEC") came into force on 14th June 2011. By 25th May 2011 the Commission adopted the Implementing Regulation (EU) N° 540/2011 as regards the list of approved active substances. These Regulations and all other related Regulations can be accessed using the search facility on the following: http://ec.europa.eu/food/plant/protection/evaluation/index_en.htm

It should be noted that if an active substance is not registered in the EU it can still be used in the ACP countries in food items exported to Europe, provided the residue complies with the EU MRL.

Note on MRLs:

The quantities of pesticide residues found in food must be safe for consumers and remain as low as possible.
The maximum residue limit (MRL) is the maximum concentration of pesticide residue legally permitted in or on food or feed.

MRLs in the EU

Pursuant to Regulation (EC) No 396/2005 harmonized Community MRLs have been established.

The European Commission (EC) sets MRLs applying to foodstuffs marketed in the territories of the EU countries, either produced in the EU or in third countries.

Annex I to the Regulation contains the list of crops (Regulation (EC) 178/2006) on which MRLs are assigned, Annexes II and III contain the MRLs: temporary MRLs can be found in Annex III, final MRLs in Annex II. Substances for which an MRL is not required are listed in Annex IV (Regulation (EC) 149/2008). When there is no specific MRL for a substance / crop a default MRL, usually set at 0.01 mg/kg, is applied.

When establishing an MRL, the EU takes into account the Codex MRL if it is set for the same agricultural practices and it passes the dietary risk assessment. Where appropriate Codex MRLs exist, the import tolerance will be set at this level.

EU harmonized MRLs came into force on 1 September 2008 and are published in the MRL database on the website of the Commission http://ec.europa.eu/sanco_pesticides/public/index.cfm

See also the leaflet "New pesticide residues in food" http://ec.europa.eu/food/plant/protection/pesticides/explanation_pesticide_residues.pdf

How are MRLs applied and monitored in EU?

- Operators, traders and importers are responsible for food safety, and therefore for compliance with MRLs.
- The Member State authorities are responsible for monitoring and enforcement of MRLs.
- To ensure the effective and uniform application of these limits, the Commission has established a multiannual Community monitoring program, defining for each Member State the main combinations of crops and pesticides to be monitored and the minimum number of samples to be taken. Member States must report results to the Commission, which published an annual report. At present the reports are published by the European Food Safety Authority (EFSA) http://www.efsa.europa.eu/en/scdocs.htm
- In case of detection of pesticide residue levels posing a risk to consumers, information is transmitted through the Rapid Alert System for Food and Feed (RASFF) and appropriate measures are taken to protect the consumer. The database is accessible on http://ec.europa.eu/food/food/rapidalert/rasff_portal_database_en.htm and RASFF publishes an annual report http://ec.europa.eu/food/food/rapidalert/index_en.htm.
- PIP monthly updates on its website a summary of RASFF notification for fruit and vegetable imports from ACP countries.

MRLs in ACP countries

ACP countries don't have set their own MRLs therefore they usually admit Codex LMRs for foodstuffs marketed in their country.
The Codex Alimentarius Commission was established in 1961 by the Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) with the objective to develop an international food code and food standards. Membership of the Codex Alimentarius Commission is open to all Member Nations and Associate Members of FAO and WHO. More than 180 countries and the European Community are members of the Codex Alimentarius Commission.

The Joint FAO/WHO Meetings on Pesticide Residues (JMPR) is not officially part of the Codex Alimentarius Commission structure, but provide independent scientific expert advice to the Commission and its specialist Committee on Pesticide Residues for the establishment of Codex Maximum Residue Limits, Codex MRLs for pesticides which are recognized by most of the member countries and widely used, especially by countries that have no own system for evaluating and setting MRLs.

The Codex MRL database can be found on the web site: http://www.codexalimentarius.net/pestres/data/index.html?lang=en.

4. Traceability

As with other husbandry operations, it is important to organise full record keeping for crop protection operations, by recording at least the following data for each treatment:

- pest or disease to control,
- date of application (+ days after sowing date, + days before planned harvesting),
- development stage,
- product used (full name, supplier, formulation, batch number, etc.),
- dose actually applied,
- amount of water used,
- type of application (equipment, nozzle, volume/ha, width of work, speed, wind, etc.).

5. Pests of economic importance

NAME	TYPE	SENEGAL	BURKINA	Importance KENYA DS	Importance KENYA RS
Tetranychus spp.(Red spider mite)	A	Great	Great	Medium	No
Ophiomyia phaseoli (Bean fly)	I	Little	Medium	Great	Great
Liriomyza trifolii (Leaf miner)	I	Great	Great	Little	Little
Sericothrips, Caliothrips, Megalurothrips sjostedti or *Frankliniella occidentalis* (Thrips)	I	Little	Little	Great	No
Helicoverpa armigera (Noctuid moth)	I	Great	Great	No	Medium
Aphids	I	Little	No	Medium	No
Trichoplusia ni (Looper)	I	Medium	Medium	No	Little
Bemisia tabaci (Whitefly)	I	Great	Little	No	Medium
Spodoptera exigua (Army worm)	I	Little	Medium	No	No
Meloidogyne spp. (Root knot nematode)	N	Great	No	No	No

No economic importance · Little economic importance · Medium economic importance · Great economic importance

DS: Dry season

RS: Rainy season

6. Diseases of economic importance

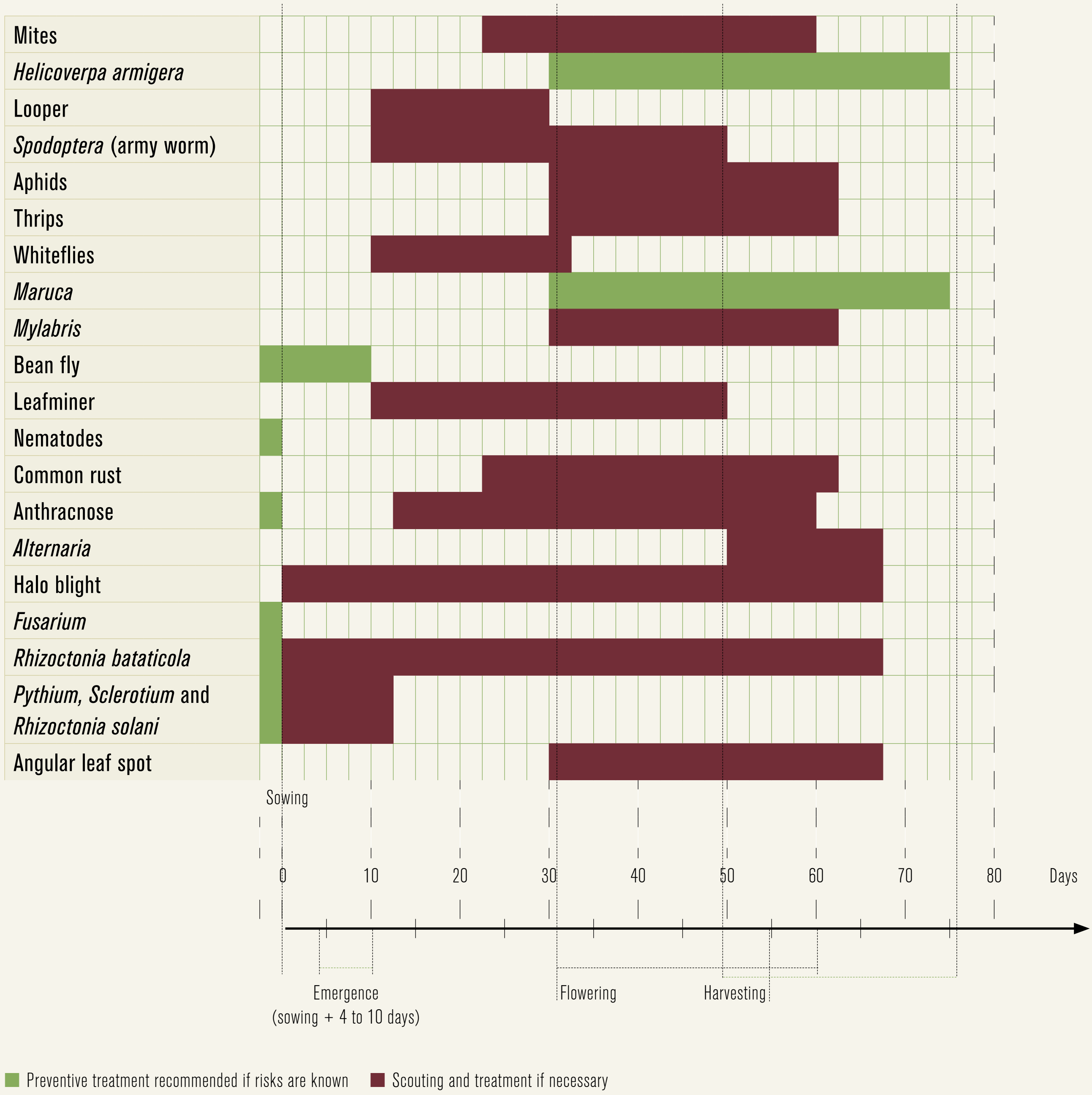
NAME	TYPE	SENEGAL	Importance BURKINA	Importance KENYA DS	Importance KENYA RS
Pseudomonas syringae f.sp. *phaseolica* (halo blight)	B	No	No	No	Medium
Xanthomonas campestris f.sp. *phaseoli* (common blight)	B	No	No	No	Medium
Uromyces appendiculatus	F	Great	Medium	Little	Great
Pythium - Fusarium solani- Rhizoctonia solani (damping-off disease- collar)	F	Great	Great	Little	Little
Colletotrichum lindemuthianum (Anthracnose)	F	Medium	Medium	No	Little
Isariopsis griseola (angular leaf spot)	F	No	Little	No	Medium

No economic importance · Little economic importance · Medium economic importance · Great economic importance

DS: Dry season

RS: Rainy season

7. Suitable periods for scouting and pest control with pesticides



Appendix 1: Registration of Plant Protection Products for use on French beans

INSECTICIDES, ACARICIDES AND NEMATICIDES

Active substance or biocontrol agent *	Registration in Kenya			CSP (Comité Sahélien des Pesticides) registration		Caterpilars	Bollworms	Mites	Leafminers	Aphids	Thrips	Cutworms	Whiteflies	Stink bugs	Bean flies	Beetles	Soil insects	Nematodes
	French beans	Beans	Vegetables	French beans	Vegetables or various crops													
Abamectin			X					X	X		■							
Acephate	X									X	X		■					
Acetamiprid	X								X	X	X		X					
Acrinathrin	X	X						X	X	X	X							
Alpha cypermethrin	X	X				■	■		X	X	X		X					
Azadirachtin	X	X	X				■		X	X	X		■					X
Bacillus thuringiensis	X		X			X					X							
Beauveria bassiana	X									X	X		X					
Bifenthrin	X		X			X	X	X		X	X	X	X					
Carbofuran		X													■		X	X
Carbosulfan		X				X											X	X
Chlorpyrifos-ethyl	X	X	X			X				X	X		X		X		X	
Chlorpyrifos methyl			X			X	X			X	X							
Clofentézine																		
Cyperméthrine	X		X				X			X	X							
Cyromazine	X								X									
Deltamethrin																		
Diafenthiuron	X		X					X		X	X							
Diazinon																		
Dicofol			X					X										
Dimethoate	X	X	X				X	X	X	X	X		X					
Fenitrofion		X				X												

Active substance or biocontrol agent *	Registration in Kenya			CSP (Comité Sahélien des Pesticides) registration															
	French beans	Beans	Vegetables	French beans	Vegetables or various crops	Caterpilars	Bollworms	Mites	Leafminers	Aphids	Thrips	Cutworms	Whiteflies	Stink bugs	Bean flies	Beetles	Soil insects	Nematodes
Hexythiazox	X		X					X										
Mineral oil		X						X		X								
Imidacloprid	X							X		X	X		X		X			
Lambda - cyhalothrin	X		X			X				X	X		X					
Malathion																		
Methiocarb	X										X							
Methomyl	X					X				X	X							
Methoxyfenozide			X			X	X					X						
Oxamyl	X																	X
Paecilomyces lilacinus	X																	X
Permethrin	X									X	X		X					
Phytoseiulus persimilis	X							X										
Pymetrozine	X		X			X				X	X		X					
Pyrethrins	X									X								
Spinosad			X	X		X	■		X		X							
Spinetoram	X					X												
Spiromesifen	X							X										
Sulfur			X					X		X	X							
Teflubenzuron	X										X							
Thiamethoxam	X	X	X	X						X	X		X		X		X	
Verticillium lecanii	X									X								
Zetacypermethrin	X									X	X		X					

* buprofezin (whiteflies), fenbutatin (mites), indoxacarbe (caterpillars), lufenuron (caterpillars, thrips), thiachloprid (sucking pests), thiocyclam-hydrogen (leafminer, aphids, thrips, whiteflies) are not currently registered for use on French beans but have been tested by PIP for residues

X: efficacy mentioned for registered products

■: efficacy known elsewhere

TABLE OF FUNGICIDES AND BACTERICIDES

Active substance or biocontrol agent *	Registration in Kenya			CSP (Comité Sahélien des Pesticides) registration											
	French beans	Beans	Vegetables	French beans	Vegetables or various crops	Halo blight and blight	Damping off	*Alternaria*	Rhizoctonia	Sclerotinia	Rust	Anthrachnose	Leaf spots	Powdery mildew	Broad spectrum
Azoxystrobin	X							■			X	X			
Bitertanol		X	X								X				
Bronopol	X					X									
Captan		X									■	■			X
Carbendazin	X								X	X		X	X		
Chlorothalonil	X		X								X	X			X
Copper	X	X	X			X					X	X	X		
Difenoconazole	X				X							X	X		
Epoxiconazole	X										X	X			
Hexaconazole		X									X			X	
Iprodione	X		X	X			■	X	X	X		■	X		X
Mancozeb	X				X	X	X	■			X	X	X		X
Metalaxyl-m			X				X						X		
Myclobutanil					X						X				X
Pencycuron	X						X		■						
Propineb			X					■			X	X	X		X
Sulfur	X		X								X	X	X	X	
Tebuconazole	X		X								X	X	X		X
Tetraconazole	X										X				
Thiophanate methyl	X							■			■	■			X
Thiram	X				X		X								
Trichoderma asperullum	X						X		X						
Trichoderma harzanium	X						X		X						
Trifloxystrobine	X													X	

* famoxadone + cymoxanil (sclerotinia, alternaria), cyproconazole (rust), maneb (same spectrum than mancozeb), vinchlozoline (rhizoctonia) are not currently registered for use on French beans but have been tested by PIP for residues

X: efficacy mentioned for registered

■ : efficacy known elsewhere

Appendix 2: Regulation and data on residues of Plant Protection Products

Residue trials have been undertaken in Senegal (2003-2004) and Kenya (2004). Tables below give the synthesis of the results and advices on the use of active substances to comply with the current MRL (EU or Codex) or minimal residues requirements (LOQ).

Data in the tables has been updated in september 2011.

Caution: The information contained in this table is subject to change by future directives of the Commission of the European Communities or Codex decisions.

TABLE 1.1: INSECTICIDES, MITICIDES AND NEMATICIDES

Active ingredient	EU regulation		MRL Codex	Trial results					
				PHI (days)			GAP tested		
	Status Regulation 1107/2009	MRL		EU MRL	Codex MRL	LOQ**	Dose g/ha	Number of applications	Interval between appli-cation (days)
Abamectine	Approved	0,01*	0,01*	In Senegal, 3 In Kenya, residues above MRL up to 7 days			Sen 10 Ken 13,5	Sen 3 Ken 3	Sen 14 Ken 7
Acephate	Not approved	0,02*	5	Residues above MRL up to 14 days***	7	Residues above LOQ up to 14 days***	Ken 800	Ken 2	Ken 14
Acetamiprid	Approved	0,01*	/	10	/	10	Ken 40	Ken 2	Ken 14
Alpha-cypermethrin	Approved	0,7	0,7	7	7	7	Ken 15	Ken 3	Ken 7
Azadirachtin	Approved	1	/	1	/	1	Sen 12 Ken 6	Sen 3 Ken 2	Sen and Ken 7
Bifenthrin	Not approved	0,5	0,05*	1	7	7	Sen 40 Ken 37,5	Sen 2 Ken 3	Sen and Ken 7
Buprofezine	Approved	1	/	7	/	14	Sen 132 Ken 400	Sen 1 Ken 2	Sen / Ken 14
Carbofuran	Not approved	0,02*	0,05*	Soil application before sowing (n.d.)			Ken 2500	Ken 1	Ken /
Chlorpyrifos-methyl	Approved	0,05*	0,1	3	3	3	Sen 1000	Sen 1	Sen /
Cyromazine	Approved	5	1	3	7	Residues above LOQ up to 21 days***	Sen 187,5 Ken 225	Sen and Ken 3	Sen 14 Ken 7
Deltamethrin	Approved	0,2	0,2	1			Sen 12,5 Ken 20	Sen 2 Ken 3	Sen and Ken 7
Dicofol	Not approved	0,02*	2	Residues above MRL up to 21 days ***	7	Residues above LOQ up to 21 days ***	Sen 720	Sen 2	Sen 14

Active ingredient	EU regulation		MRL Codex	Trial results					
				PHI (days)			GAP tested		
	Status Regulation 1107/2009	MRL		EU MRL	Codex MRL	LOQ**	Dose g/ha	Number of applications	Interval between application (days)
Dimethoate	Approved	0,02*	0,05*	14			Ken 800	Ken 2	Ken 14
Fenbutatin oxyde	Approved	0,05*	/	Residues above MRL up to 21 days ***	/	Residues above LOQ up to 21 days ***	Sen 495	Sen 2	Sen 14
Hexythiazox	Approved	0.5	0.5	7			Sen and Ken 50	Sen and Ken 2	Sen and Ken 14
Imidacloprid	Approved	2	2	3	3	10	Sen 50 Ken 202	Sen 2 Ken 3	Sen 21 Ken 7
Indoxacarbe	Approved	0,02*	0,02*	7			Sen and Ken 37,5	Sen and Ken 4	Sen and Ken 7
L-Cyhalothrine	Approved	0,2	0,2	1	1	3	Sen 25 Ken 15	Sen 2 Ken 4	Sen 7 Ken 7
Lufenuron	Approved	0,02*	/	3	/	3	Ken 40	Ken 3	Ken 7
Malathion	Approved	0,02*	1	7	7	10	Sen 750	Sen 2	Sen 7
Methomyl	Approved	0,02*	1	7	1	7	Sen 600 Ken 500	Sen 4 Ken 3	Sen and Ken 7
Methoxyfenozide	Approved	2	/	7	/	14	Ken 120	Ken 2	Ken 14
Oxamyl	Approved	0,01*	/	21	/	21	Sen and Ken 2000	Sen and Ken 1	/
Pyrethrin	Approved	1	0,05*	1	1	1	Ken 135	Ken 3	Ken 7
Spinosad	Approved	0,5	0,3	1	1	Residues above LOQ up to 7 days ***	Sen and Ken 160	Sen and Ken 2	Sen and Ken 7
Sulfur	Approved	n.a.	/	1	/	1	Ken 3200	Ken 3	Ken 7
Thiachloprid	Approved	1	0,02*	3	Residues above MRL up to 7 days ***	Residues above LOQ up to 7 days***	Ken 192	Ken 3	Ken 7
Thiamethoxam	Approved	0,2	/	3	/	3	Sen 100 Ken 50	Sen and Ken 3	Sen and Ken 14
Thiocyclam hydrogen	Not approved	0,01*	/	7	/	7	Ken 500	Ken 2	Ken 14

* LOQ value
** taking into account EU LOQ
*** recommended to not use as residues at maximum PHI tested in trials are above the current limit
/ means that for this a.i. Codex MRL or LOQ value is not specified or that is not possible to propose a PHI or that
n.a. = non applicable
n.d. = residues non detectable
Sen = Senegal ; Ken = Kenya

Table 2.1: Fungicides, bactericides

Active ingredient	EU regulation		MRL Codex	Trial results					
				PHI (days)			GAP tested		
	Status Regulation 1107/2009	MRL		EU MRL	Codex MRL	LOQ**	Dose g/ha	Number of applications	Interval between application (days)
Azoxystrobine	Approved	3	3	3	3	10	Sen 150 Ken 125	Sen 2 Ken 3	Sen and Ken 7
Bitertanol	Not Approved	0,05*	0,05*	10	10	10	Ken 180	Ken 2	Ken 14
Captan	Approved	2	/	7	/	14	Ken 2400	Ken 3	Ken 7
Chlorothalonil	Approved	5	5	3	3	Residues above LOQ up to 14 days***	Sen 1000 Ken 1440	Sen 2 Ken 3	Sen 7 Ken 7
Copper	Approved	20	/	3	/	3	Ken 1000	Ken 3	Ken 7
Cyproconazole	Approved	0,05*	/	7	/	7	Ken 30	Ken 3	Ken 7
Difenoconazole	Approved	1	0,02*	3	Residues above MRL up to 14 days***	7	Sen and Ken 125	Sen 1 Ken 4	Sen n.a. Ken 14
Famoxadone + Cymoxanil	Approved + Approved	0,02+ 0,05	0,02 + /	3	/	3	Sen and Ken 90 + 120	Sen and Ken 3	Sen and Ken 7
Iprodione	Approved	5	2	7	7	Residues above LOQ up to 14 days***	Ken 1000	Ken 2	Ken 7
Maneb	Approved	1	/	7	/	Residues above LOQ up to 21 days***	Sen 2000	Sen 3	Sen 7
Mancozeb	Approved	1	/	7	/	14	Sen 2000 Ken 1350	Sen and Ken 3	Sen and Ken 7
Metalaxyl-M	Approved	0,05*	0,05	Seed application before sowing (n.d.)			Seed treatment	Sen and Ken 1	n.a.
Myclobutanil	Approved	0,3	/	3	/	10	Sen 60 Ken 100	Sen and Ken 2	Sen and Ken 7
Pencycuron	Approved	0,05*	/	Seed application before sowing (n.d.)			Seed treatment	Ken 1	n.a.
Propineb	Approved	1	/	7	/	14	Ken 1750	Ken 3	Ken 7
Sulfur	Approved	n.a.	/	1	/	1	Ken 3200	Ken 3	Ken 7
Tebuconazole	Approved	2	0,05*	7	10	10	Sen 250 Ken 187.5	Sen and Ken 3	Sen and Ken 7
Tetraconazole	Approved	0,02*	/	Residues above MRL up to 7 days***	/	Residues above LOQ up to 7 days***	Ken 40	Ken 2	Ken 14

Active ingredient	EU regulation		MRL Codex	Trial results					
				PHI (days)			GAP tested		
	Status Regulation 1107/2009	MRL		EU MRL	Codex MRL	LOQ**	Dose g/ha	Number of applications	Interval between application (days)
Thiophanate-methyl	Approved	0,1*	/	10	/	10	Ken 500	Ken 2	Ken 14
Thiram	Approved	0,1*	/	Seed application (n.d.)			Seed treatment	Sen 1	n.a.
Trifloxystrobine	Approved	0,5	0,02*	3	Residues above MRL up to 10 days***	Residues above LOQ up to 10 days***	Ken 250	Ken 2	Ken 7
Vinchlozolin	Not Approved	0,05*	2	Residues above MRL up to 21 days***	7	Residues above LOQ up to 21 days***	Sen 750	Sen 3	Sen 7

* LOQ value
** taking into account EU LOQ
*** recommended to not use as residues at maximum PHI tested in trials are above the current limit
/ means that for this a.i. Codex MRL or LOQ value is not specified or that is not possible to propose a PHI or that
n.a. = non applicable
n.d. = residues non detectable
Sen = Senegal ; Ken = Kenya

Sources of GAP validated by PIP trials : insecticides

Active substance	Trade name	Manufacturer	Trials	
			Year	Country
Abamectin	Vertimec 18 EC Dynamec 18 EC	Syngenta	2005	Senegal Kenya
Acephate	Orthène 97P	Calliope	2005	Kenya
Acetamipride	Mospilan 200 SP	Calliope	2005	Kenya
Alpha-cypermethrin	Fastac 10 SC	BASF	2005	Kenya
Azadirachtin	Not specified Neemroc EC 0,3	Senchim Saroneem	2005	Senegal Kenya
Bifenthrin	Talstar 40 EC Brigade 2,5 %	Calliope	2005	Senegal Kenya

Active substance	Trade name	Manufacturer	Trials	
			Year	Country
Buprofezine	Applaud 250 SC Applaud 40 EC	Calliope	2005	Senegal Kenya
Carbofuran	Furadan 5 G	FMC	2005	Kenya
Chlorpyrifos-methyl	Reldan DF	Dow AgroSciences	2005	Senegal
Cyromazine	Trigard 75 WP	Syngenta	2005	Senegal Kenya
Deltamethrin	Decis 0,25 EC Decis Tab 25 %	Bayer Cropscience	2005	Senegal Kenya
Dicofol	Kelthane MF	Dow AgroSciences	2005	Senegal
Dimethoate	Danadim 40 EC	Cheminova	2005	Kenya
Fenbutation	Torque	BASF	2005	Senegal
Hexythiazox	Nissorun 10% WP Nissorun 10 EC	Nisso	2005	Senegal Kenya
Imidacloprid	Confidor 350 SC Confidor 70 WG	Bayer CropScience	2005	Senegal Kenya
Indoxacarbe	Avaunt 150 SC	Dupont	2005	Senegal Kenya
Lambda-cyalothrin	Karaté Zéon 2,5 CS Karaté 5 SC	Syngenta	2005	Senegal Kenya
Lufenuron	Match 050 EC	Syngenta	2005	Kenya
Malathion	Callimal 500 EC	Calliope	2005	Senegal
Methomyl	Lannate 90 Lannate 25 WP	Dupont	2005	Senegal Kenya
Methoxyfenozide	Runner 240 SC	Dow AgroSciences	2005	Kenya
Oxamyl	Vydate 10 G	Dupont	2005	Senegal Kenya
Pyrethrin	Pyerin 7,5 EC	JH Biotech	2005	Kenya
Spinosad	Tracer 480 SC	Dow AgroSciences	2005	Senegal Kenya
Sulfur	Kumulus DF 80 %	BASF	2005	Kenya
Thiaclopride	Calypso 480 SC	Bayer CropScience	2005	Kenya
Thiamethoxam	Actara 25 WG Cruiser 350 FS	Syngenta	2005	Senegal Kenya
Thiocyclam	Evisect's 50 %	Calliope	2005	Kenya

Sources of GAP validated by PIP trials : fungicides

Active substance	Trade name	Manufacturer	Trials	
			Year	Country
Azoxystrobine	Ortiva 250 SC	Syngenta	2005	Senegal Kenya
Bitertanol	Baycor 300 EC	Bayer CropScience	2005	Kenya
Captane	Captan 500 SC Captan 80 WG	Calliope	2005	Kenya
Chlorothalonil	Bravo 720 Daconil 720 SC	Syngenta	2005	Senegal Kenya
Cuivre	Cuprocaffaro WG 37,5	Caffaro	2005	Kenya
Cymoxanil	Equation Pro	Dupont	2005	Senegal Kenya
Cyproconazole	Alto 100 SL	Syngenta	2005	Kenya
Difénoconazole	Score 250 SC	Syngenta	2005	Senegal Kenya
Famoxadone	Equation Pro	Dupont	2005	Senegal Kenya
Iprodione	Rovral 50% Rovral 250 FLO	Bayer CropScience/BASF	2005	Senegal Kenya
Mancozèbe	Dithane M45 Dithane 75 DG	Dow AgroSciences	2005	Senegal Kenya
Manèbe	Triamangol 80 WP	Cerex Agri	2005	Senegal
Métalaxyl-m	Apron XL 350 SE Apron Star 42 WS	Syngenta	2005	Senegal Kenya
Myclobutanil	Systhane 24 E Systhane 20 EW	Dow AgroSciences	2005	Senegal Kenya
Pencycuron	Gaucho MT	Bayer CropScience	2005	Kenya
Propineb	Antracol 70 WP	Bayer CropScience	2005	Kenya
Tebuconazole	Folicur EW 250	Bayer CropScience	2005	Senegal Kenya
Tétraconazole	Domark 40 EW	Calliope	2005	Kenya
Thiophanate-méthyl	Topsin M50 SC	Nisso	2005	Kenya
Thirame	Semences traitées	UCB	2005	Senegal
Trifloxystrobine	Flint 50 WG	Bayer CropScience	2005	Kenya
Vinchlozoline	Ronilan DF 50 %	BASF	2005	Senegal

Note : GAPs indicated in previous pages are those corresponding to the trade names listed above. User of this information should check if the product used is equivalent (same concentration and same type of formulation) to the reference product. If it is not the case, the indicated GAP could not be adequate.

Appendix 3a: French bean IPM scouting method

Information below are of interest to Kenya. Principles remain valid for other growing areas but scouting instructions must be adapted to the context of each area of production.

Introduction

Integrated Pest Management involves the use of biological control agents (BCAs), such as predators and parasites detailed in the Pest and Disease summary sheets.

More detailed information is needed for IPM programmes than for straight forward chemical programmes because the degree of biological control is directly influenced by the balance between the numbers of beneficial insects and the pests. If there are only five pests for each beneficial present, this is a more secure position for the farmer than if there were 500 pests for every beneficial present. Therefore a means of sampling the crop to estimate the actual numbers of certain pests will be needed.

Weekly Scouting Data Sheets are completed for each field. Some of the data from these weekly sheets are transferred every week to a **Weekly Summary Sheet**. This enables the farm manager to compare progress week on week and provides objective guidance on what interventions need to be made to protect the crop, or whether progress is satisfactory.

If there were 150 pest for each beneficial in the field last week but this week the ratio had changed to 60 pest for every beneficial then the farmer will be able to measure a change in the balance in favour of the beneficial insect. This means that biological control is in progress. This may provide the evidence not to spray, but to allow the biological control programme to take it's course. The other factor that needs to be taken into account at the same time is the average number of the pest each week. It is less straight forward to just look at the average number of pest in isolation, since the average could even be going up week-onweek, whilst the ratio of the beneficial to pest is showing positive signs of coming close together.

IPM training courses are available to ensure correct scouting and interpretation of scouting data. The following information is a guide to IPM scouting and should be consolidated with IPM training from experienced service providers.

Preparation

Trained IPM-Scouts should be supplied with:

- clipboard to make recording easier,
- scouting sheets,
- piece of clean white paper for beating flowers onto (for thrips levels in flowers),
- 10 x magnification handlens,
- pen,
- calculator,
- sample bag,
- sufficient hot-spot markers (visible red tags etc - do not use yellow - it attracts pests).

A good quality automatic counter is a useful tool which speeds up the counting process, reduces mistakes and boredom.

Scouting Instructions

The area to be scouted should be as uniform as possible (slope and aspect of field, variety of crop etc). Too much variation will mean that the scouting will either over estimate or underestimate the pest or disease levels. If necessary divide the crop into sections, if they are likely to have very different pest and disease levels. The maximum area, which should be scouted as one unit, is about one hectare – unless the area is known to be very uniform.

For one hectare budget on approximately two man-hours for a trained, experienced scout to undertake IPM scouting per block. (one 'block' is twenty scouting rows).

Pests have habits of moving in and out of the crop at different times of day. The block should be scouted a minimum of once per week, ideally **twice per week**, preferably at the **same time of day** throughout its life - for accurate comparison of pest levels... If the scouting is not done at about the same time each week in the same field, the scout may indicate that pest levels are up, when in fact they have just hidden or flown out of the crop at that time. This is especially true of thrips.

Mark 20 station rows (these are whole rows **not marked 'spots'** in the field) at equal distances throughout the block. The scouting data will be collected whilst walking along the full length of each station row.

Walk down the alleyway path of the station row. Stop at five observation points whilst walking down the alleyway of the station row.
The **observation points** should be from plant rows on alternate sides of the alley way (i.e. sampling in a zigzag pattern along the station row as the scout proceeds to the end of the row) Spread the sample points out along the full length of the row (see diagram).
The reason for the zigzag pattern is that in row crops, one side of the row could receive more sun and heat than the other or more wind and rain etc. This will effect pest and disease levels. By taking samples in a zigzag pattern along an alleyway – the scout is taking leaves from different sides of a plant row. The differences in pest and disease levels are therefore averaged.

At each observation point first make the following observations before removing a leaf from the base and top of plants for other checks. Record the total number of the following in about one meter square of the French bean bed at the observation point:

- adult leafminer,
- adult *Diglyphus*,
- adult whitefly,
- adult *Encarsia*.

Add the numbers observed in each of the five observation positions for each row and enter the total figures in the weekly scouting form. The scout may need rough paper to record a running total from each of the five observation positions before he enters the totals for the row in the weekly scouting form.

When the scout has observed the above pests at each observation point, which could fly away if the leaves are disturbed too much – he can now **remove two leaflets** (not a whole tri-foliate leaf) from the same area (10 leaflets per station row or 200 per block) to count:

- large whitefly scales (>L2),
- black parasitised whitefly scales,
- thrips on leaves,
- spider mite.

If the crop is still very young and has few leaves, the above observations can be done without removing the leaves, just by turning the lower surface of the leaf upwards. **If spider mite** is found at the same time as the above checks, these should be recorded too in the **weekly background level of spider mite**.

Otherwise, the scout should look out for **leaves with spider mite damage** as he walks along the row and check these for numbers of:

- adult *Phytoseiulus*,
- adult *Amblyseius*,
- adult spider mite.

Normally spider mite predators are only found where there are higher levels of spider mite (is where there is spider mite damage on leaves) This is where the farmer will be recording the columns for **ratio of predators to spider mite** in the weekly scouting forms.

As soon as flowering commences, the scout will commence examining flowers for thrips. There is no need to remove the flower trusses to examine them. Place a piece of white paper below the flower truss and tap it sharply three times to dislodge any thrips within the flower truss.

Examine **two flower trusses per observation point** for:

- Thrips in flowers.

Black bean aphid tends to be sporadic and the scout can make **observations throughout the full length of the scouting row** for this pest and the following diseases and beneficial insects. As the scout walks the full length of the scouting row it is easy to observe disease symptoms and cutworm etc on all plants along the length of the scouting row.

- Black bean aphid **colonies** (no need to count individual aphids in the colony just number of colonies in the station row).
- Total **number aphid predators** in each of the colonies (ladybirds, *Aphidius*, hoverfly etc). No need to distinguish which predators are there. Just calculate (at bottom of column in scouting sheet) the ratio of combined numbers of aphid predators and parasites to aphid colonies in each scouting station row.
- Total number of caterpillar larvae (easy to spot leaf feeding damage).
- Total number of caterpillar pupae.
- Total number of adult moths observed.
- Presence of diseases (rust, etc).
- Presence of cutworm, root knot nematode, bean fly etc.

Exit checks

When the station rows have been scouted , the Scout will then complete an 'Exit Check' by walking up and down EVERY ROW to observe the following:

1 <u>Clearly mark</u> all **new black bean aphid hot-spots** (with **< 10% parasitism**) with markers and mark positions on a map of the block. These will need to have <u>spot treatments applied as soon as possible</u>.

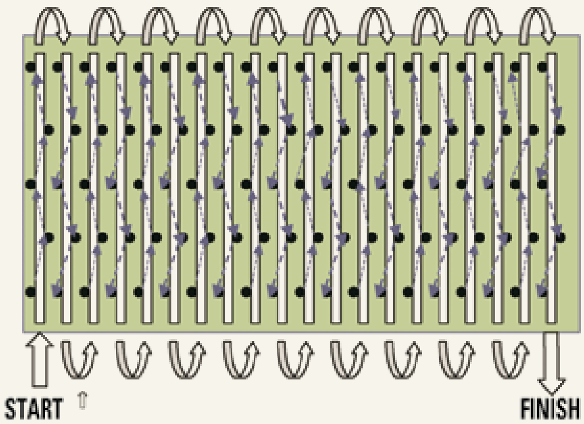
2 Check all previously marked aphid hot spots - if they have > 10% parasitism remove the hotspot marker.

3 <u>Mark on the block maps any disease hotspots</u> (**halo blight** or ***Fusarium*** etc). This will trigger instructions for hot-spot fungicide sprays for halo blight or an overall spray depending on risks (wet weather conditions and more than four halo blight hotspots per block). *Fusarium* cannot be treated but hotspots will be marked in the block history for treatment with *Trichoderma* and organic matter or soil improvement post harvest). <u>Total the number of disease hotspots (identify type of disease) and record this in the Front of the Scouting sheet</u>.

4 Mark on the block map any spider mite hotspots - these will need additional *Phytoseiulus* - introduction ratio at least 1:200) Make some estimates of total rsm per hotspot and enter number on Front of Scouting Sheet. Take a minimum of ten leaflet samples from the hot spot and determine the Phyto to spider ratio. Once the ratio get to less than 1:10 - the problem should be soon eliminated. Enter data for rsm hotspots on a separate scouting sheet and give each spider mite Hotspot a number. These will be scouted weekly until the problem is eliminated

5 Note presence of live caterpillars observed during exit check (enter number on Front of Scouting Sheet). This will trigger an overall spray of *Bacillus thuringiensis* or other appropriate spray, as this pest is difficult to spot and needs to be controlled when it is at a low level.

IPM Scouting pattern in French beans



Twenty sample '*station rows*' are chosen at equal intervals from all the beds across the fields. These are marked and numbered so that the data from the same rows can be compared week on week – to check on progress at a micro level if required.
The marked '*station rows*' are the alley walkways between rows.

As the scout walks down the alley walkway of the marked 'station row', he takes sample leaves from observation points on either side of the alleyway. It is necessary to take samples in this 'zig-zag' pattern from crops grown in straight lines, because one side of the plant row could be warmer than the other (depending on direction of sun movement) and this will lead to higher numbers of pest on one side of the crop row.

A zig zag sampling pattern will average out this difference and give a better estimate of pest numbers.
After the twenty 'station rows' are scouted. The scout walks up and down all rows as an 'exit check'. . . and marks any hotspots or problems which he finds (with a tag in the field and also marks it on the field plan for the attention of the manager

Appendix 3b: IPM scouting records sheets - French beans

Weekly Scouting Record Sheet (completed each week)

Farm	Block	Crop age (wks)	Date scouted	Scout name (PRINT)	TIME of DAY Scouted

Station row	Diglyphus adults near five obs.Points/row	Leafminer adults near five obs.Points/row	Thrips on five leaves per row	Thrips in five flowers per row	Total whitefly adults at five obs. Points per row	Total encarsia adults on ten lower leaves per row	Whitefly scales >12 on ten lower leaves/row	Black scales on ten lower leaves per row	Number of aphid bca in aphid colonies/row	Number of aphid colonies in row	Adult moths obs.Flying over field during scouting (indicates eggs being laid)	Number of caterpillar larvae in entire row	Has pupation begun? (Number pupae seen/row)	Total phytoseiulus adults in five rsm-infested leaves/row	Total amblyseius adults in five rsm-infested leaves/row	Total spider mite adults in five infested leaves/row	Background adult rsm level from five random leaves per row	Bean fly	Cutworm	Root knot nematode	Rust	Angular leaf spot	Root diseases	Halo blight	Ascochyta	Other diseases	Other problems
																		Presence/absence in row									
1																											
2																											
3																											
4																											
5																											
6																											
7																											
8																											
9																											
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11																											
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15																											
16																											
14																											
18																											
19																											
20																											
Total																											
av. per row																		comments									
ratio	:						% P		ratio	:				ratio	:												

Use data for individual ROWS to make **early spot treatments** in certain rows only for pests and diseases before the problem spreads. Transfer the data in the bold boxes to **weekly summary sheet**, to measure the effetct of crop protection action week/on/week. Mark any rsm hotspots in fied and o field map - treat early with predatory mites. (check hotspots weekly to ensure predators building up). Beanfly and bean seed fly are normally only a problemin weeks 1-5 and esprecially on outside rows or in wetter areas of field in dry weather. For beanfly to 'other problems' section - enter the total number of rows where pest or disease is present. **comments box**: severity of diseases, ID of root diseases, indicate waterlogged areas etc. Indicate **treatment advised**.

Week - on - Week Scouting Summary Sheet (transfer averages to this sheet each week, to view progress)

Farm				Block				Crop age (wks)				Date scouted					Scout name (print)							Time of day scouted	
Transfer data from bold boxes in weekly scouting forms Age crop (wks)	Dig: lm		Weekly av. Per row thrips on five leaves per row	Weekly av. Per row thrips in five flowers per row	Weekly av. Per row whitefly adults at 5 obs. Points per scouting row	Weekly av. Per row encarsia adults at 5 observation points per row	Weekly av. Per row whitefly scales >l2 at ten lower leaves/row	Weekly percentage parasitism (% black scales on ten lower leaves per row)	Ratio of total aphid bcas per row to total number of aphid colonies	Total weekly adult moths obs.Flying over field during scouting	Total weekly caterpillar larvae in entire row	Total weekly pupae per row	Ratio predators to rsm in infested leaves (if present)	Weekly average background level of rsm per row	Bean fly	Cutworm	Rkn	Rust	Angular leaf spot	Root diseases	Halo blight	Ascochyta	Other diseases	Other problems	Pesticides and bcas applied with dates
1									:				:												
2									:				:												
3									:				:												
4									:				:												
5									:				:												
6									:				:												
7									:				:												
8									:				:												
9									:				:												

Notes: Divide total number of adult leafminer by total number of adult *Diglyphus* each week = ratio *Diglyphus* to leafminer (aim to get below 1:5 for good control)

Scouting for thrips on leaves is essential before the flowers are present, then crop protection is applied when contact is easier (on leaves). Thrips control in flowers is difficult and there are PHI constraints.

The oldest, largest, whitefly scales (in which an *Encarsia* can develop to a blcak scale) will be on lower leaves only

Percentage weekly parasitism of whitefly scales is calculated from number of black scales divided by (total black scales plus large white scales >L2) = %P (do not count small scales as they cannot be parasitised)

Divide the total number of aphid colonies from all rows each week, by total number of aphid BCAs to obtain ratio of aphid BCAs to aphid colonies

Bacillus thurigiensis only works well on young caterpillarswhich are too difficult to find. If adult moths are present, they will be laying eggs and timely application of Bt would be soon after this period.

If most of the population of caterpillars have pupated, this life stage is not harmed by pesticides and it may be worth waiting for them to hatch and apply crop protection to the next generation. For section from 'beanfly' to 'other problems' - enter total number rows weekly with problem.

Appendix 4: Pesticide sensitivity charts - Kenyan approved insecticides for French beans - effect on relevant natural enemies

Insecticides (fine beans) Active ingredients	application method	Spider mite predator *Phytoseiulus persimilis* egg	adult	persistence (wks)	Thrips and mite predator *Amblyseius californicus* egg	adult	persistence (wks)	Spider mite predator *Feltiella acarisuga* larva	adult	persistence (wks)	Thrips and general predator *Orius laevigatus* nymph	adult	persistence (wks)
Abamectin	spray	?	>75%	2w	?	?	?	?	>75%	?	>75%	>75%	3w
Acephate	spray	?	>75%	>3w	?	>75%	>2w	?	>75%	>8w	>75%	>75%	?
Acrinathrin	spray	>75%	>75%	?	>75%	>75%	?	>75%	>75%	?	>75%	>75%	?
Alphacypermethrin	spray	>75%	>75%	>8w	?	?	?	?	>75%	>8w	>75%	>75%	?
Amblyseius californicus	bio	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w
Amitraz	spray	>75%	>75%	3w	?	>75%	0w	?	?	?	?	50-75%	3w
Aphidius transcaspinus	bio	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w
Azadirachtin	spray	?	<25%	?	?	?	?	?	?	?	<25%	?	v
Azinfos-methyl	spray	50-75%	50-75%	2w	?	25-50%	2w	50-75%	>75%	>8w	50-75%	50-75%	?
Azocyclotin	spray	50-75%	50-75%	3 days	25-50%	25-50%	?	?	?	?	?	25-50%	?
Beta cyfluthin (see cyfluthin)	spray	>75%	>75%	>8w	50-75%	50-75%	?	>75%	>75%	>8w	>75%	>75%	>8w
Bifenthrin	spray	>75%	>75%	>8w	?	?	?	>75%	>75%	>8w	>75%	>75%	>8w
Bt var kurstaki	spray	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w
Bt var kurstaki	dust	25-50%	25-50%	0.5w	?	?	?	<25%	?	?	?	?	?
Buprofezin	spray	<25%	25-50%	0w	<25%	<25%	0w	25-50%	<25%	1w	25-50%	<25%	0w
Carbaryl	spray	?	>75%	2w	?	?	?	50-75%	>75%		>75%	>75%	?
Carbofuran	spray	?	>75%	>3w	?	?	?	?	?	?	?	?	?
Carbosulfan	spray	25-50%	25-50%	1w	?	?	?	?	?	?	?	?	?
Chlorpyrifos-methyl	spray	<25%	<25%	0w	?	25-50%	2w	?	>75%	?	>75%	>75%	?
Cyfluthrin	spray	>75%	>75%	>8w	50-75%	50-75%	?	>75%	>75%	>8w	>75%	>75%	>8w
Cyhexatin	spray	<25%	>75%	0.5s	?	?	?	25-50%	25-50%	?	25-50%	25-50%	?
Cypermethrin (see also profenofos)	spray	>75%	>75%	>8w	?	?	?	>75%	>75%	>8w	>75%	>75%	>8w
Cyromazine	spray	<25%	<25%	0w	<25%	<25%	0w	?	>75%	0w	?	<25%	?
Cyromazine	drip	<25%	<25%	0w	?	?	?	?	?	?	?	?	?
Deltamethrin	spray	>75%	>75%	>8w	?	?	?	>75%	>75%	>8w	>75%	>75%	>8w
Diazinon	spray	<25%	<25%	1w	?	25-50%	2w	>75%	>75%	>6w	25-50%	50-75%	?
Dichlorvos	spray	<25%	>75%	1w	?	?	?	?	>75%	<1w	>75%	>75%	1w
Dicofol	spray	50-75%	50-75%	2w	?	50-75%	?	<25%	>75%	?	?	?	?
Dicofol+ tetradifon	spray	50-75%	50-75%	2w	?	50-75%	?	<25%	>75%	?	?	?	?
Diglyphus isaea	bio	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w
Dimethoate	spray	>75%	>75%	8w	?	50-75%	?	50-75%	25-50%	?	>75%	>75%	?
Encarsia formosa	bio												

Insecticides (Fine beans) Active ingredients	application method	Spider mite predator			Thrips and mite predator			Spider mite predator			Thrips predator		
		Phytoseiulus persimilis			*Amblyseius californicus*			*Feltiella acarisuga*			*Orius laevigatus*		
		egg	adult	persistence (wks)	egg	adult	persistence (wks)	egg	adult	persistence (wks)	egg	adult	persistence (wks)
Endosulfan	spray	?	>75%	2w	?	?	?	50-75%	>75%	?	25-50%	>75%	?
Fenazaquin	spray	?	?	?	?	?	?	?	?	?	?	?	?
Fenitrothion	spray	?	>75%	?	?	?	?	?	?	?	?	>75%	?
Fipronil	spray	>75%	>75%	?	>75%	>75%	?	>75%	>75%	?	25-50%	25-50%	?
Gamma - cyhalothrin	spray	?	?	?	?	?	?	?	?	?	?	?	?
Garlic (see also pyrethrins)	spray	?	?	?	?	?	?	?	?	?	?	?	?
Hexithizox	spray	<25%	<25%	?	<25%	<25%	?	<25%	<25%	?	<25%	<25%	?
Imidachloprid	spray	50-75%	50-75%	?	>75%	>75%	5 days	>75%	>75%	?	>75%	>75%	?
Imidachloprid	drip	25-50%	25-50%	?	<25%	<25%	?	<25%	<25%	?	25-50%	25-50%	1w
Lambda - cyhalothinn	spray	>75%	>75%	>8w	<25%	<25%	?	>75%	>75%	>8w	>75%	>75%	>8w
Malathion	spray	25-50%	25-50%	>1w	?	?	?	50-75%	>75%	2w	>75%	>75%	?
Methomyl	spray	>75%	>75%	2w	>75%	>75%	?	>75%	>75%	?	>75%	>75%	1w
Methoxyfenozide	spray	?	?	?	<25%	<25%	?	?	?	?	>75%	>75%	?
Mineral oil	spray	?	?	?	?	25-50%	>2w	?	?	?	?	?	?
Oxamyl	spray	>75%	>75%	>8w	?	?	?	>75%	>75%	>8w	>75%	>75%	>8w
Oxamyl	drip	<25%	<25%	0w	?	?	?	?	?	?	?	>75%	?
Oxydemeton - methyl	spray	?	>75%	1w	?	?	?	50-75%	>75%	?	?	?	?
Parathion methyl	spray	<25%	<25%	0w	?	?	?	?	?	?	?	>75%	?
Pirimicarb	spray	25-50%	25-50%	0.5s	?	<25%	?	<25%	>75%	1w	<25%	<25%	0w
Pirimiphos-methyl	spray	>75%	>75%	>2w	?	>75%	?	?	>75%	?	?	?	?
Propargite	spray	>75%	50-75%	0w	?	50-75%	?	25-50%	<25%	?	?	50-75%	?
Pymetrozine	spray	<25%	<25%	0w	25-50%	25-50%	?	?	?	?	25-50%	25-50%	1w
Pymetrozine	drip	<25%	<25%	0w	<25%	<25%	?	?	?	?	<25%	<25%	1w
Pyrethrine (+ p.B.O)	spray	<25%	>75%	1w	?	?	?	?	>75%	>1w	?	?	?
Spinosad	spray	<25%	<25%	0w	<25%	<25%	0w	?	?	?	25-50%	25-50%	3 days
Sulphur	spray	25-50%	25-50%	?	50-75%	50-75%	?	25-50%	25-50%	?	25-50%	<25%	?
Teflubenzuron	spray	<25%	<25%	0w	<25%	<25%	0w	?	?	?	>75%	<25%	?
Tetradifon	spray	<25%	<25%	0w	?	?	?	?	<25%	?	?	?	?
Tetradifon + dicofol	spray	50-75%	50-75%	2w	50-75%	50-75%	?	<25%	>75%	?	<25%	<25%	?
Thiamethoxam	spray	>75%	>75%	?	<25%	<25%	?	?	?	?	>75%	>75%	>2w
Thiocyclam	spray	?	25-50%	0.5s	?	?	?	?	?	?	?	?	?
Trichlorfon	spray	>75%	>75%	2w	?	?	?	?	?	?	>75%	>75%	?

Insecticides (Fine beans) Active ingredients	application method	Aphid predator *lady birds*			Aphid parasite *Aphidius colemani*			Whitefly parasite *Encarsia formosa*			Leafminer parasite *Diglyphus & Dacnusa*		
		larva	adult	persistence (wks)	larva	adult	persistence (wks)	larva	adult	persistence (wks)	larva	adult	persistence (wks)
Abamectin	spray	?	>75%	1w	?	>75%	?	>75%	>75%	3w	?	>75%	?
Acephate	spray	?	>75%	>6w	?	>75%	?	>75%	>75%	>8w	?	>75%	?
Acrinathrin	spray	>75%	>75%	?	25-50%	>75%	?	>75%	>75%	?	>75%	>75%	?
Alphacypermethrin	spray	?	>75%	?	?	>75%	?	>75%	>75%	>8w	?	>75%	?
Amblyseius californicus	bio	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w
Amitraz	spray	?	50-75%	?	?	?	?	>75%	>75%	3w	?	?	?
Aphidius transcaspinus	bio	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w
Azadirachtin	spray	?	?	?	?	?	?	?	?	?	?	?	?
Azinfos-methyl	spray	?	>75%	>6w	?	>75%	?	>75%	>75%	>8w	?	>75%	?
Azocyclotin	spray	50-75%	>75%	?	?	?	?						
Beta cyfluthin (see cyfluthin)	spray	50-75%	>75%	>8w	>75%	>75%	?	>75%	>75%	>8w	>75%	>75%	>8w
Biphentrin	spray	?	>75%	>8w	>75%	>75%	>8w	>75%	>75%	>8w	>75%	>75%	>8w
Bt var kurstaki	spray	?	<25%	0w	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w
Bt var kurstaki	dust	?	<25%	0w	?	?	?	?	?	?	?	?	?
Buprofezin	spray	?	50-75%	1w	<25%	<25%	0w	25-50%	<25%	0.5s	?	<25%	0w
Carbaryl	spray	25-50%	>75%	?	?	>75%	?	50-75%	>75%	4w	?	>75%	
Carbofuran	spray	?	?	?	?	?	?	?	?	?	?	?	?
Carbosulfan	spray	?	>75%	>8w	?	?	?	?	?	?	?	>75%	?
Chlorpyrifos-methyl	spray	?	?	?	>75%	>75%	?	50-75%	?	>8w	?	>75%	?
Cyfluthrin	spray	50-75%	>75%	>8w	>75%	>75%	?	>75%	>75%	>8w	>75%	>75%	>8w
Cyhexatin	spray	?	<25%	0w	?	>75%		<25%	>75%	2w	?	>75%	
Cypermethrin	spray	?	>75%	>8w	>75%	>75%	>8w	>75%	>75%	>8w	>75%	>75%	>8w
Cyromazine	spray	50-75%	25-50%	0w	?	<25%		<25%	<25%	0w	?	<25%	?
Cyromazine	drip	?	?	?	?	<25%		?	<25%	?	?	?	?
Deltamethrin	spray	?	>75%	>8w	>75%	>75%	>8w	>75%	>75%	>8w	>75%	>75%	>8w
Diazinon	spray	25-50%	25-50%	?	>75%	>75%	?	25-50%	>75%	4-6w	?	>75%	?
Dichlorvos	spray	?	>75%	<1w	?	>75%	?	>75%	>75%	1w	?	>75%	?
Dicofol	spray	?	<25%	0w	?	50-75%	?	<25%	>75%	>1w	?	50-75%	?
Dicofol + tetradifon	spray	?	<25%	0w	?	50-75%	?	<25%	>75%	>1w	?	50-75%	?
Diglyphus isaea	bio	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	>0w	<25%	<25%	0w
Dimethoate	spray	>75%	>75%	?	>75%	>75%	?	>75%	>75%	>8w	?	?	?
Encarsia formosa	bio												

Appendix 4: Pesticide sensitivity charts - Kenyan approved insecticides for French beans effect on relevant natural enemies

Insecticides (fine beans) Active ingredients	application method	Aphid predator *lady bird*			Aphid parasite *Aphidius colemani*			Whitefly parasite *Encarsia formosa*			Leafminer parasite *Diglyphus & Dacnusa*		
		egg	adult	persistence (wks)	egg	adult	persistence (wks)	larva	adult	persistence (wks)	nymph	adult	persistence (wks)
Endosulfan	spray	?	>75%	2w	50-75%	?	?	<25%	>75%	>8w	?	>75%	?
Fenazaquin	spray	?	?	?	?	?	?	?	?	?	?	?	?
Fenitrothion	spray	?	>75%	?	?	?	?	50-75%	?	>6w	?	?	?
Fipronil	spray	?	?	?	?	?	?	<25%	<25%	?	?	?	?
Gamma - cyhalothrin	spray	?	?	?	?	?	?	?	?	?	?	?	?
Garlic (see also pyrethrins)	spray	?	?	?	?	?	?	?	?	?	?	?	?
Hexithizox	spray	<25%	<25%	?	<25%	<25%	?	<25%	<25%	?	<25%	<25%	?
Imidachloprid	spray	>75%	>75%	?	>75%	>75%	?	>75%	>75%	?	>75%	>75%	?
Imidachloprid	spray	25-50%	25-50%	?	25-50%	25-50%	?	25-50%	25-50%	?	25-50%	25-50%	?
Lambda-cyhalothinn	spray	>75%	>75%	>8w	>75%	>75%	>8w	>75%	>75%	>8w	>75%	>75%	>8w
Malathion	spray	>75%	>75%	>8w	>75%	>75%	>8w	>75%	>75%	>8w	>75%	>75%	>8w
Methomyl	spray	>75%	>75%	?	>75%	>75%	?	>75%	>75%	?	>75%	>75%	?
Methoxyfenozide	spray	?	?	?	?	?	?	<25%	<25%	?	?	?	?
Mineral oil	spray	?	?	?	?	?	?	?	?	?	?	?	?
Oxamyl	spray	50-75%	>75%	>8w	>75%	>75%	>8w	>75%	>75%	>8w	>75%	>75%	>8w
Oxamyl	drip	?	<25%	0w	?	<25%	?	25-50%	<25%	?	?	<25%	?
Oxydemeton-methyl	spray	?	>75%	?	?	?	?	>75%	>75%	>8w	?	?	?
Parathion methyl	spray	>75%	>75%	?	?	?	?	?	>75%	?	?	?	?
Pirimicarb	spray	?	>75%	1w	?	<25%	?	<25%	50-75%	<1w	?	50-75%	<1w
Pirimiphos-methyl	spray	?	<25%	0w	>75%	>75%	?	>75%	>75%	>6w	?	>75%	
Propargite	spray	?	50-75%	?	<25%	<25%	?	50-75%	50-75%	1w	?	?	?
Pymetrozine	spray	?	?	?	<25%	25-50%	?	<25%	<25%	?	?	?	?
Pymetrozine	spray	?	?	?	<25%	25-50%	?	<25%	<25%	?	?	?	?
Pyrethrine (+ p.B.O)	spray	?	>75%	>2w	?	?	?	25-50%	>75%	2w	?	>75%	1w
Spinosad	spray	?	?	?	?	50-75%	?	?	50-75%	1w	?	?	?
Sulphur	spray	<25%	25-50%	?	25-50%	25-50%	?	<25%	>75%	>4w	?	25-50%	<1w
Teflubenzuron	spray	?	25-50%	?	?	<25%	?	<25%	25-50%	<1w	?	>75%	0w
Tetradifon	spray	?	<25%	?	?	<25%	?	<25%	>75%	<1w	?	<25%	0w
Tetradifon + dicofol	spray	<25%	<25%	?	50-75%	50-75%	?	<25%	>75%	>1w	50-75%	50-75%	?
Thiamethoxam	spray	?	?	?	?	?	?	?	?	?	?	?	?
Thiocyclam	spray	50-75%	25-50%	?	25-50%	>75%	?	<25%	25-50%	<1w	?	>75%	?
Trichlorfon	spray	?	>75%	?	?	>75%	?	<25%	50-75%	?	?	>75%	?

Appendix 5: Pesticide sensitivity charts - Kenyan approved fungicides for French beans - effect on relevant natural enemies

Insecticides (fine beans) Active ingredients	application method	Spider mite predator *Phytoseiulus persimilis* egg	adult	persistence (wks)	Thrips and mite predator *Amblyseius californicus* egg	adult	persistence (wks)	Spider mite predator *Feltiella acarisuga* larva	adult	persistence (wks)	Thrips and general predator *Orius laevigatus* nymph	adult	persistence (wks)
Azoxystrobin	spray	<25%	<25%	?	<25%	<25%	?	<25%	<25%	?	?	?	?
Benomyl	spray	<25%	50-75%	>2w	?	?	?	?	?	?	?	<25%	0w
Bitertanol	spray	<25%	<25%	0w	<25%	<25%	0w	25-50%	<25%	?	?	<25%	0w
Buprimate	spray	<25%	25-50%	4d	?	<25%	0w	50-75%	50-75%	0w	?	25-50%	0w
Captan	spray	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w	?	?	?
Chlorothalonil	spray	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w	?	<25%	0w
Copper oxychloride	spray	<25%	<25%	0w	<25%	<25%	0w	?	<25%	?	?	?	?
Cymoaxanil	spray	<25%	<25%	?	<25%	<25%	?	?	?	?	?	?	?
Difenoconazole	spray	?	<25%	?	?	?	?	?	?	?	?	?	?
Dithianon	spray	?	<25%	?	?	<25%	?	?	<25%	?	?	?	?
Fosetyl-aluminium	spray	<25%	<25%	0w	<25%	<25%	0w	<25%	?	?	?	<25%	0w
Garlic (see also pyrethrins)	spray	?	?	?	?	?	?	?	?	?	?	?	?
Hexaconazole	spray	?	<25%	?	?	<25%	?	?	<25%	?	?	?	?
Iprodione	spray	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w	?	<25%	0w
Mancozeb	spray	<25%	50-75%	0w	<25%	<25%	0w	25-50%	<25%	0w	?	<25%	0w
Metalaxyl (See also zoxamide)	spray	?	50-75%	?	?	?	?	?	?	?	?	?	?
Metalaxyl + mancozeb	spray	<25%	<25%	0w	<25%	<25%	0w	?	?	?	?	?	?
Metiram	spray	?	50-75%	?	?	?	?	<25%	<25%	0w	?	?	?
Myclobutanil	spray	<25%	<25%	0w	<25%	<25%	0w	25-50%			?	?	?
Oxycarboxin	spray	<25%	<25%	0w	<25%	<25%	0w	?	?	?	?	<25%	0w
Propamocarb	spray	<25%	<25%	0w	<25%	<25%	0w	?	?	?	?	<25%	0w
Propamocarb	spray	<25%	<25%	0w	<25%	<25%	0w	?	?	?	?	<25%	0w
Propiconazole	spray	?	<25%	?	?	?	?	25-50%	<25%	?	?	<25%	0w
Propineb (See also cymoaxanil)	spray	50-75%	>75%	1w	?	?	?	?	<25%	?	?	?	?
Pyrazofos	spray	<25%	<25%	0w	?	?	?	>75%	50-75%	?	?	>75%	?
Pyrimethanil	spray	?	25-50%	?	?	?	?	<25%	?	?	?	?	?
Quitozine	spray	?	<25%	?	?	?	?	?	?	?	?	?	?
Sulphur	spray	<25%	<25%	0w	?	?	?	25-50%	<25%	?	?	50-75%	<1w
Sulphur	dust	<25%	25-50%	1w	?	?	?	?	?	?	?	?	?
Sulphur	fog	<25%	25-50%	1w	?	?	?	?	?	?	?	?	?
Tebuconazole	spray	?	<25%		?	?	?	?	?	?	?	?	?
Thiamethoxam (seed trt only)	seed	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w

Fungicide (fine beans) Active ingredient	application method	aphid predator			aphid parasitoid			whitefly parasitoid		
		Ladybirds			*Aphidius*			*Encarsia*		
		larva	adult	persistence (wks)	larva	adult	persistence (wks)	larva	adult	persistence (wks)
Azoxystrobin	spray	?	?	?	<25%	<25%	?	<25%	<25%	?
Benomyl	spray	?	>75%	?	<25%	<25%	0w	<25%	<25%	0w
Bitertanol	spray	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w
Buprimate	spray	?	<25%	0w	<25%	<25%	0w	<25%	<25%	0w
Captan	spray	?	<25%	0w	?	?	?	<25%	<25%	0w
Chlorothalonil	spray	?	<25%	0w	<25%	<25%	0w	<25%	<25%	0w
Copper oxychloride	spray	<25%	<25%	0w	?	?	?	<25%	50-75%	<1w
Cymoaxanil	spray	?	?	?	?	?	?	?	?	?
Difenoconazole	spray	?	?	?	?	<25%	?	?	<25%	?
Dithianon	spray	<25%	<25%	?	?	<25%	?	<25%	<25%	0w
Fosetyl-aluminium	spray	?	<25%	0w	?	?	?	?	<25%	?
Garlic (See also pyrethrins)	spray	?	?	?	?	?	?	?	?	?
Hexaconazole	spray	25-50%	<25%		?	<25%	?	?	?	?
Iprodione	spray	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w
Mancozeb	spray	?	2	0w	<25%	<25%	0w	<25%	25-50%	0w
Metalaxyl (See also zoxamide)	spray	?	?	?	?	?	?	?	<25%	?
Metalaxyl + mancozeb	spray	?	<25%	0w	?	?	?	<25%	<25%	?
Metiram	spray	<25%	<25%	?	<25%	<25%	?	?	>75%	4w
Myclobutanil	spray	?	<25%	0w			?	?	?	?
Oxycarboxin	spray	?	?	?	?	?	?	<25%	<25%	0w
Propamocarb	spray	?	<25%	0w	?	?	?	<25%	<25%	0w
Propamocarb	drip	?	<25%	0w	<25%	<25%	0w	<25%	<25%	0w
Propiconazole	spray	25-50%	?	?	<25%	<25%	?	<25%	<25%	?
Propineb (See also cymoaxanil)	spray	50-75%	>75%	0w	?	<25%	?	<25%	>75%	>4w
Pyrazofos	spray	?	>75%		?	>75%	?	<25%	>75%	>3w
Pyrimethanil	spray	?	?	?	?	?	?	?	?	?
Quitozine	spray	?	?	?	?	?	?	?	?	?
Sulphur	spray	25-50%	25-50%		25-50%	50-75%	?	<25%	>75%	>4w
Sulphur	dust	?	>75%	>6w	?		?	<25%	>75%	>3w
Sulphur	fog	?	?	?	?		?	?	>75%	<1w
Tebuconazole	spray	?	?	?	?	25-50%	?	<25%	25-50%	?
Thiamethoxam (Seed trt only)	seed	<25%	<25%	0w						

Fungicide (fine beans) Active ingredient	application method	spider mite predator *Phytoseiulus persimilis* egg	adult	persistence (wks)	spider mite predator *Amblyseius californicus* egg	adult	persistence (wks)	thrips predator (and generalist) *Orius laevigatus* egg	adult	persistence (wks)	leafminer parasitoid *Diglyphus* egg	adult	persistence (wks)
Thiophanate-methyl	spray	25-50%	>75%	>2w	?	?	?	25-50%	?	?	?	<25%	0w
Thiram (spray to crop not permitted)	spray	?	25-50%		?	?	?	<25%	25-50%	?	?	<25%	0w
Thiram (dust to crop not permitted)	dust	50-75%	<25%	>1w	?	?	?	?	?	?	?	?	?
Thiram (Only seed trt allowed)	seed	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w
Triadimefon	spray	<25%	<25%	0w	<25%	<25%	0w	?	<25%	?	?	<25%	0w
Trichoderma	bio	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w
Triforine	spray	<25%	25-50%	0w	?	?	?	?	<25%		?	<25%	0w
Zoxamide	spray	?	?	?	?	?	?	?	?	?	?	?	?

Fungicide (fine beans) Active ingredient	application method	aphid predator Ladybirds larva	adult	persistence (wks)	aphid parasitoid *Aphidius* larva	adult	persistence (wks)	whitefly parasitoid *Encarsia* larva	adult	persistence (wks)
Thiophanate-methyl	spray	?	<25%	0w	<25%	<25%	?	<25%	<75%	0w
Thiram (spray to crop not permitted)	spray	?	25-50%	0w	<25%	<25%	?	<25%	50-75%	<1w
Thiram (dust to crop not permitted)	dust	?	?	?	?	?	?	<25%	50-75%	<1w
Thiram (only seed trt allowed)	seed	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w
Triadimefon	spray	?	<25%	0w	?	?	?	<25%	<25%	0w
Trichoderma	bio	<25%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w
Triforine	spray	25-50%	<25%	0w	<25%	<25%	0w	<25%	<25%	0w
Zoxamide	spray	?	?	?	?	?	?	?	?	?

Appendix 6: Classification of beans (*Phaseolus vulgaris L.*)

Green beans are classified by type according to the following factors:

- Growth habit: dwarf beans have determinate growth, reaching a height of 30 to 60 cm.
- Pod structure: this depends on the presence or absence of two fibrous structures, the string and the parchment. The string, composed of longitudinal fibres, forms along the zone of the vascular bundles on back and "belly" of the pod. The parchment consists of 3 or 4 oblique sheets of sclerous material coating the inside of each valve of the pod. String and parchment appear and develop at different stages of pod development, depending on the variety. Both structures are involved in the process of dehiscence when the pods reach complete ripeness and burst open.
- Pod colour: green pods (various shades of green), yellow pods (wax-pod beans). There are also some varieties with purple,
- mottled or red-marbled coloration.
- Pod shape: pods may be flat (flat beans or slicing beans), or have a round or oval cross section.
- Seed colour: white, black or mottled.

String bean: varieties with string and parchment. The fresh pods are eaten, but only at a young, immature stage.
Bobby bean, snap bean or mange-tout bean: stringless varieties with little parchment. They can be eaten at a later stage, when the seeds have begun to develop.
Shelling bean: varieties with string and parchment, of which only the seeds are eaten.

Classification of dwarf beans (determinate growth)		
Characteristics	**Varietal type**	**Pod**
String and parchment	**Classic string bean**	green, sometimes mottled purple
	Shelling beans	flat
Stringless, reduced parchment	**Bobby bean or mange-tout bean or snap bean**	green, yellow, purple
	Stringless French bean	like classic string bean but paler

Appendix 7: Climatic requirements of French bean (*Phaseolus vulgaris L.*)

Air temperature

Germination:
- optimal between 20°C and 25°C,
- between 25°C and 35°C, problems,
- above 35°C, germination stops.

Growth:
- optimal between 15°C and 25°C,
- above 25°C, problems.

Flowering:
- optimal between 15°C and 25°C,
- above 30°C, flower abortion.

Fruiting:
- optimal between 15°C and 30°C,
- above 30°C:
- String bean: string and parchment form early,
- Bobby bean: young pods fall, seeds appear early, harvest plans disrupted.

Relative humidity

- If too high (e 90% to 100% or dew), conditions are favourable for transmission and development of certain diseases at particular temperature ranges:

→ rust (16°C to 25°C with 10 to 18 h dampness),
→ blight (16°C to 24°C / 25°C): *Pseudomonas* under saturation humidity
(NB walking or driving through wet fields is liable to spread the disease).
→ Rain favours the spread of blight.
→ Sprinkler irrigation should be regarded as rain in this respect.

Soil moisture

- If soil too wet, root and collar rot are encouraged (cf. “soil” and “sowing”).

Wind

- Bean crops are extremely sensitive to wind:

→ rubbing causes mechanical damage to pods, so reducing pod quality and providing an entry point for disease. Leaves are also damaged,

→ hot winds: see § t°, Đwind carrying salt sea spray: reduced yield.

Light intensity

- Beans need a lot of light.
- Do not sow under tree canopies as shade will reduced yields and encourage leaf miner.

Day length

- No effect in West Africa.

Appendix 8: Commercial varieties of French beans available in Kenya

Type/ variety	Maturity approx. days	Resistance	calibration %			Length mm
			6-8mm	8-9mm	9-10.5mm	
Bobby						
Paulista		Anthracnose Common bean mosaic virus *Pseudomonas* Xathomonas	30	60	10	13-14
Xera		Anthracnose Common bean mosaic viru	40	60		13-14
Olivia		Common bean mosaic virus	20	60	20	13-14
RS1391		Common bean mosaic virus - Bean rust	10	50	40	13-14
RS1389		Common bean mosaic virus Bean rust	20	60	20	13-14
Fine bean						
Amy	60	Anthracnose Common bean mosaic virus	70	30		10-12
Tanya	60	Anthracnose Common bean mosaic virus *Pseudomonas* (tolerance)	60	40		11-12
Samantha	60	Anthracnose Common bean mosaic virus	60-70	30-40		12-13
Teresa	60	Anthracnose Common bean mosaic virus Bean rust	60	40		13-14
RS1518	59	Anthracnose Common bean mosaic virus	70	30		10.5-12.5
Extra fine			5-6.5mm	6.5-8mm		
Julia		Anthracnose Common bean mosaic virus	85	15		10-11
Lausanne		Anthracnose Common bean mosaic virus	70	30		11-12
Romano Type					width	
Emelia		Anthracnose Common bean mosaic virus *Pseudomonas*			18-22mm	12-16mm flat pods

Appendix 9: Main pests and diseases of French beans

Alternaria leaf spot or leaf blight

Scientific name:

***Alternaria* spp.** including *Alternaria*

Other host plants: *Phaseolus* spp., *Pisum sativum* (pea), *Solanum melongena* (aubergine).

Symptoms and damage:

Alternaria symptoms are easily identified in the field and generally only occur on the primary leaves, appearing as round brown spots surrounded with a darker ring, or many small regular black spots, depending on the pathogen. Under high humidity conditions, these symptoms can occur on older trifoliate leaves or ripening pods.

Alternaria spp. are latent fungal pathogens that enter the plant via natural openings and only generate symptoms after the latency period.

These fungi are responsible for pod infections, which are sometimes detected in the field, but generally only after harvest.

Conditions conducive to infection:

Infection is promoted by the presence of the primary inoculum (disease spores) in the field where the crop is grown, on storage equipment and in the storage rooms. A minimum of three non-host crop cycles or a 3-year crop rotation is recommended to prevent build up the disease in a field. High relative humidity (above 95% at 6°C) promotes development of the disease and rot onset. Cool and wet weather in which leaves remain wet for periods of 24 hours or longer are essential for spore germination and infection.

Susceptible growth stage of the crop:

Fruiting period.

Preventive control:

Control measures are seldom warranted, but cultural measure such as wider plant and row spacings, and crop rotation are suggested. Cropping in fields recently sown with French bean should be avoided. Rotation cycles should not last less than 3 years. It is also recommended that French bean crops should not be planted near other crops infected with fungal diseases that could infect them.

Non-chemical control:

Alternaria spp. fungi have several biological controls including *Bacillus* spp., *Enterobacter* spp. and the antagonistic fungus, *Trichoderma viride*. *Trichoderma* is registered in Kenya as a crop protection product but efficacy trials have not yet confirmed the role of commercially available isolates against *Alternaria*. This would require efficacy trials to be undertaken in support of an 'extension of use' on the Product Label. Consult PCPB for further information.

No commercial biological control methods are yet registered in Kenya and no systems have been developed for warning or forecasting on sporulation mechanisms, nor on the disease itself.

Control with pesticides:

Monitoring during susceptible growing stages and treat with fungicides if needed.

Halo blight of beans

Scientific name:

Pseudomonas syringae pv. *phaseolicola*

Halo blight is a necrotrophic bacteria (which kills plant cells ahead of the lesion development front and subsequently colonises the dead tissues).

Other host plants:

Phaseolus coccineus (runner bean), *Phaseolus acutifolius* (tepary bean), *Phaseolus lunatus* (lima bean), *Ipomoea batatas* (sweet potato).

Symptoms and damage:

P.syringae pv. *phaseolus* may attack the entire plant, leaves, buds and seeds. After entry through the leaves, the bacteria multiply at an exponential rate within the intracellular spaces.

Symptoms develop within 6-10 days at 24-28°C, but this can be delayed when temperatures are hot. The halo blight bacteria cause leaf necrosis or dieback. Leaf tissues first become translucent and water-soaked due to water uptake in the intracellular spaces. The blight spots that subsequently develop on leaves are sometimes surrounded by a chlorotic, yellow, halo caused by diffusion of the toxin responsible for destroying the plant cells.

Conditions conducive to infection:

Cold (16 to 20°C), cloudy and humid climatic conditions are conducive to the development of halo blight disease.

The pathogen survives in infected seeds and it is important to purchase seeds from a reputable seed merchant with a phytosanitary certificate to confirm the health status of the seeds.

Using self-saved seed increases the risk of introducing halo blight to the growing area.

Halo blight will also survive in crop residue on the soil surface and it is important to identify and rogue out infected plants as soon as they occur in the field to slow down the spread of the disease within the field. A bag should be brought to the infected plant so that it can be placed inside the bag before it is removed from the field. If infected plant material is left on the soil surface in situ, or dragged through the rest of the crop, it is likely to spread the disease. The pathogen can survive for 12 months on dry leaves at 24oC, which makes it essential that composting or burial destroys roughed plants. Rouged plants could be fed to animals as long as there is no pesticide residue on the crop debris. Halo blight multiplies rapidly under suitable environmental conditions. When the weather is highly humid, the pathogen enters the plant through lenticels or stomata.

The disease can be spread between leaves and plants via splashing rain and irrigation water. It can be disseminated as far as 26 m from the primary focus. Overhead and furrow irrigation can spread the disease through water splash. Drip irrigation is recommended to reduce the spread of the disease by reducing the humidity in the canopy and keeping the leaves dry.

Weeds and some non-host species can also serve as a primary source of *inoculum* since the bacteria is able to survive on these plants without inducing symptoms. In uncontrolled conditions (10-27°C), the viability of these bacteria decreases at a rate of 250-fold/year for the first 3 years, with total extinction after some 5 years.

Susceptible growth stages of crop:

Pre-emergence, vegetative growth, flowering and fruiting stages.

Preventive control:

Fields should be cleared of plant debris, crop residue and wild bean plants to reduce primary sources of inoculums. Threeyear (or more) rotations with cereal crops (corn) are recommended. Halo blight disease can be effectively controlled by using disease-free seed and suitable control procedures (field surveys, laboratory inoculation, serological tests and quarantine measures).

Non-chemical control:

Resistant host plants can be used to efficiently control these pathogens, especially by combining plants with specific resistance and plants with non-specific resistance.

Control with pesticides:

Cuprous compounds are widely used for controlling halo blight of beans, despite the fact that they generally do not show very high efficacy against bacterial diseases. Spraying could be done with copper-containing chemicals every 7 to 10 days after first observation symptoms.

Anthracnose of bean

Scientific name:

Colletotrichum lindemuthianum (*Gleosporium lindemuthianum*)

Other host plants:

Cajanus cajan (pigeon pea), *Pisum sativum* (pea).

Symptoms and damage:

This fungus especially attacks leaves of bean plants via conidia produced on free conidiophores in acervuli. Symptoms can also be noted on all other above-ground plant parts. It induces brown lesions, first on the under side of leaf veins. The disease then spreads laterally as lenticular pale brown spots with darker brown borders that are visible on the upper surface of the leaves. Round sunken spots with salient reddish-brown borders may occur on pods. In wet weather, the leaves can bear acervuli that look like gummy pinkish droplets.

Conditions conducive to infection:

Moisture is a key factor for the survival of this fungus. It can also survive for at least 5 years on air dried seed stored at 4°C or on dry infected plant material left in the field and enclosed in watertight polyethylene bags. *C.lindemuthianum* enter dormancy on seeds anywhere and can withstand temperatures of 15- 20°C over a given period of time. Disease development is favoured by temperatures within the 13-26°C range (optimal range 17-24°C). Relative humidity of above 92% is required throughout all conidia germination stages, incubation and subsequent sporulation. A conidium germinates within 6-9 h under suitable environmental conditions. The pathogen survives as long as the seed is viable. After the initial infection, humidity and rain are two factors that promote dissolution of the gelatinous matrix coating conidia that inhabit acervuli. Moderate rainfall at regular intervals, especially when it is windy, and droplet splashing strongly favour conidia dissemination and outbreaks of serious epidemics of anthracnose of beans.

Susceptible growth stages of crop:

Pre-emergence, seed setting, vegetative growth, flowering and fruiting stages.

Preventive control:

Anthracnose-free seed should be sown. Infected crop residue must be buried and rotations conducted with other nonsusceptible crops. 2-3 year crop rotations are often recommended because these pathogens can survive for more than 2 years on infected plant debris. Fields of anthracnose-affected beans should not be cultivated or fertilised by farm workers when the leaves are wet after a rainfall.

Non-chemical control:

C.lindemuthianum can be efficiently controlled by planting resistant bean cultivars. A few resistant cultivars have already been cropped in some African countries. There are six major races of this fungus. Bean cultivars can be resistant to one or several of these races, but generally not all of them.

Control with pesticides:

Bean seed is controlled by fungicide treatment.

During the cropping cycle, treatments are carried out if necessary after the first leaves appear and until pod set.

Fusarium collar rot, *Fusarium* root rot of bean

Scientific name:

Fusarium solani f. sp. *phaseoli*

Other host plants: *Phaseolus* spp. (most legumes).

Symptoms and damage:

Fusarium-infected plants are weak and the seedlings wilt. Longitudinal reddish lesions appear at the base of the stem. The roots become necrotic and the taproot turns reddish. The following table highlights the economic impact of this fungus in beanproducing countries such as Senegal, Burkina Faso and Kenya.

Monitoring and diagnostic methods:

This fungus can be identified by monitoring plant wilt in the field, sampling infected plants and culturing the sampled tissues. Since there are no real fungicide 'controls' for *Fusarium*, it is important to note the fields, and areas within fields, where *Fusarium* has been detected. Often corrective measures to improve soil conditions may reduce the risk of this disease in subsequent crops. Field 'crop histories' are a useful means of identifying areas or fields which should be 'rested' from beans in a crop rotation plan. Ideally, sites, which have heavy *Fusarium* infections, should have at least one maize crop or brassica crop before the next bean crop is planted. Avoid replanting beans in a field, which has suffered badly from *Fusarium*.

Conditions conducive to infection:

Temperatures within the 20-25°C range are optimal for *Fusarium* root rot development. *Fusarium* is a seed and soil borne disease. The use of self-saved seed increases the risk of transmitting *Fusarium* into a clean field. Seed should be purchased from a KEPHIS-registered seed merchant. Ideally seed should be sorted and examined by the grower before planting and any damaged or poor quality seed rejected. If infected seed is planted and *Fusarium* introduced to a clean site, it can remain in the soil for many years.

Excess nitrogen in the soil can accelerate the development of *Fusarium* in infected plants. Care should be taken in the fertiliser programme to avoid excess fertilisation. Any soil factor, which prevents effective root function, such as soil compaction, waterlogging and drought, will increase the stress on infected plants and increase the development of the disease.

The nematodes *Pratylenchus* penetrans or *meloidogyne* spp. And the fungus *Pythium* sp. Also enhance disease severity.

Often, infected plants appear symptom-less until flowering, when the plant's water requirements increase to fill pods. At this time, plants can collapse suddenly, as the water vessels are blocked by *Fusarium* development and insufficient water is delivered to the plant.

Susceptible growth stages of crop:

From the seedling stage until flower bud formation.

Preventive control:

Ideally, crop rotations should be practised, with at least 3 years between each bean crop. On the Equator, where two and a half crops can be grown in each 12-month period, it may not be necessary to have such a long rotation. If bean crops are separated in the rotation with maize and cabbage crops, it may be possible to come back into the same field within 18 months, depending on the severity of any previous infection in that field.

If the organic matter content of soils is actively managed to maintain between 3 –5% organic matter content, by applications of composted manure or crop debris – this will build up beneficial microbes such as *Trichoderma* in the soil which are antagonistic to *Fusarium*. *Trichoderma* can grow on organic matter.

In terms of tillage, preliminary cultivation should be carefully carried out to ensure good drainage and aeration of soils. Avoid compaction and uneven field surfaces, where water may accumulate and cause plant stress. Ensure that any equipment used to cultivate the soil is cleaned thoroughly before it is used to plough the land or prepare beds.

Otherwise soil infested with *Fusarium* may be brought to a clean site from a field which carries *Fusarium*.

Non-chemical control:

F. solani has several natural enemies, including some, which are pathogenic to this fungus, i.e.*Trichoderma viridens*, *Gliocladium virens* and *Pseudomonas fluorescens*. Some of these enemies are antagonists, including *Bacillus subtilis*. These beneficial microorganisms build up in the soil, if the organic matter content is high.

They are also available in some countries as formulated 'biopesticides'.

All these biopesticides would need to be registered as a crop protection agent before use. *Trichoderma* is registered in Kenya as a crop protection product. Seed treatments with *Trichoderma* are recommended on the Product Labels and may make a contribution to crop protection from *Fusarium*. However, the *Trichoderma* is itself a fungus and advice must be sought to integrate the use of *Trichoderma* with fungicides applied to the soil or seeds. *Trichoderma* can also be applied via drip irrigation (see Label).

Control with pesticides:

Bean seed treatment with thiram is the main chemical; strategy for controlling this disease. There are no efficient chemical control treatments after germination, so post-emergence treatments should be avoided. Cultural controls are the most effective treatments (see above).

Ash stem blight or stem rot of bean

Scientific name:

Macrophomina phaseoli (*Rhizoctonia bataticola*)

Other host plants:

Arachis hypogaea (peanut), *Cucumis sativus* (cucumber), *Solanum tuberosum* (potato).

Symptoms and damage:

The entire plant, including the leaves, buds, roots and seeds—but mainly the stems and roots—can be attacked by this fungus. Dry rot symptoms appear on the cotyledons as blackening of growing points and the collar. Small black spots, which are the pycnidia, develop in the infected area. In seedlings, the first symptoms appear as thin irregular blackish lesions on the stem close to the soil line. These lesions develop before or just after plant emergence. The disease spreads from the initial rot site after emergence. The lesions expand, join, begin rotting and can lead to death of the young seedling. The rot areas have clear borders and often concentric rings. Wilting, chlorosis and leaf fall occurs on one side of the infected plant. Many small sclerotia or pycnidia form on the edge of the lesions and several areas in the field can be infected.

Monitoring and diagnostic methods:

Dry blackish lesions can be detected on seedlings close to the soil surface. Rot areas, with clear borders and often concentric rings, develop on the top of the stem and expand and join.

Stem rot is black with many small sclerotia. Chlorosis and leaf death is more marked on one side of the seedling. Clusters of many small sclerotia can also be found randomly distributed in infected root, stem, leaf and fruit tissues. The size of these sclerotic masses can vary.

Conditions conducive to infection:

The main *M. phaseolina* disease agent for most hosts are black microsclerotia that are soilborne or present in plant debris. Sclerotia survival and germination are enhanced in dry soils with a high carbon/nitrogen ratio in their amendments and an oxygen level above 16%. *M. phaseolina* can survive as sclerotia for 16-18 months in plant debris. Soilborne inoculum colonises the bean roots upon contact and hyphae then begin growing along the interface between epidermal cells. In most host plants, the severity of the disease induced by *M. phaseolina* is associated with hot dry climatic conditions (30-40°C). Field experiments revealed that symptoms appeared sooner in water-stressed plants inoculated during the post-flowering stage. The disease intensity increases as the temperatures gradually increased in the fields and while the relative humidity dropped.

The infection peaked at 35°C and 76% relative humidity. The presence of nematodes also accentuated and promoted disease development.

There is a synergetic relationship between the nematode (*Heterodera, Meloidogyne, Rotylenchus*) and the fungus. *M. phaseolina* does not usually produce spores and the main non-biotic means of dispersal is via contamination of vehicles and packing equipment by soilborne microsclerotia. The pathogen spreads in the vicinity of infected fields at high temperatures (> 32°C), especially in areas where the plants are susceptible to infection due to water stress. The risk is lower in temperate climatic conditions. The fungus can be transported in all types of soil and planting material (bulbs, tubers, rhizomes, flowers, leaves, roots, buds, etc.), except for wood and micropropagation material.
Susceptible growth stages of crop: Flowering, fruiting, seed set, vegetative growth and post-harvest stages.

Preventive control:

Efforts to control M. phaseoilina have often been focused on managing microsclerotia populations. Infection by this fungus can be reduced through irrigation. Planting bean varieties that do not require hot dry conditions after flowering is an efficient control strategy. Disease development and severity can be reduced by sowing rows of pure lines that ripen at different periods, e.g. in Asia (Bengal) it was found that the disease incidence can be reduced by sowing beans in November or January. The use of organic amendments and neem oil can also be effective in controlling this disease. Application of a milletbased amendment and compost can reduce soilborne pathogen populations by 20-40%. Mixed results have been obtained in soil solarisation experiments: in Egypt, for instance, solarisation over a long 6-month period increased theM. phaseoilina a population whereas in another case the fungus population was reduced after 30-day solarisation using polyethylene. Tillage also has been found to reduce soilborne fungus populations. (See comments on *Fusarium* controls)

Non-chemical control:

With respect to biological control, *Trichoderma harzanium* is an efficient agent for controlling *M. phaseolina*. Infection rates can be reduced to 14-28% by soil applications of this antagonist.
This fungus can also be applied in seed treatments to efficiently control *M. phaseolina*. Application of T. viride on seed 2 days prior to sowing in acidic soil reduces disease severity.
Seed inoculation with *Rhizobium* (obtained from University of Nairobi) may reduce the growth of the phytopathogenic fungus. Organic amendments have been commonly used with some success to manage infections caused by this fungus when combined with other methods, including seed treatments with biological control agents such as *Trichoderma* spp.

Control with pesticides:

Monitoring from emergence to peak of harvest and treat with fungicides if needed.

Damping off, black leg and *Pythium* root rot

Scientific name:

Pythium aphanidermatum

Other host plants:

Lycopersicon esculentum (tomato), *Arachis hypogaea* (peanut), *Cucumis sativus* (cucumber), *Solanum melongena* (aubergine), *Solanum tuberosum* (potato).

Symptoms and damage:

After sowing, emergence is hampered and the seedlings that manage to emerge have black rotting roots. The plants suddenly wilt and soft and wet rot are noted on the roots, collar and sometimes the stems. Once the plant has emerged and begun growing, infections caused by the pathogen are no longer lethal but they can still have a significant impact on plant growth and yield. Symptoms other than root rot are sometimes also noted, such as nutrient-deficient foliar symptoms due to the root rot. In the post-harvest period, under high humidity conditions, a white fragile mycelium can develop on pods in export packing boxes.

Conditions conducive to infection:

P. aphanidermatum oospores are primary survival structures: they are resistant to drought and can survive in soil for long periods (11 months) when there is no suitable host or organic substrate upon which they can survive as saprophytes.

Oospores germinate between 15 and 45°C (peak germination at 35°C) and when the pH is in the 5-8 range. Germination frequency reaches up to 90% when sufficient moisture and light are available. Sporangia are induced to produce mobile zoospores—the main disease agents—when certain nutrients are present and under high relative humidity. When free water is present, these zoospores are attracted to and penetrate the crop seeds and roots. When environmental conditions are unsuitable for disease development, the zoospores encyst and can remain in the soil for at least 7 years if the soil moisture and temperature are suitable. The disease caused by *P. aphanidermatum* is promoted by high soil moisture and mild to hot temperatures (27°C). Pathogen dispersion is favoured by the presence of a film of water and high humidity. Soil pH is also an important factor with respect to field infections because it alters the ecology (oospore germination) and pathogenicity of this pathogenic fungus. The saprophytic activity of the fungus in the field is markedly reduced when the pH is between 5 and 6. Environmental conditions also have a direct and indirect impact on *P. aphanidermatum*. In field soils, the optimal temperature for disease development is around 27°C, but antibacterial treatment of the soil will reduce bacterial populations and this significantly boosts disease development and oospore germination, thus indicating that the temperature modulates bacteria-fungus interactions.

Monitoring and diagnostic methods:

Infected tissues have wet rot-like necrosis. The diseased plants are weak and their development is slower than that of healthy plants. Oospores can be observed directly on infected tissues, but this depends on how opaque the tissues are and their extent of degradation. Some other phytopathogenic fungi induce similar types of damage, so diagnosis must be confirmed by isolating and identifying the pathogen.

Susceptible growth stages of crop:

Emergence, germination, vegetative growth and post-harvest stages.

Preventive control:

This pathogenic fungus cannot be completely controlled via crop rotations because of the many different possible hosts, but the inoculum load can be reduced through some rotation practices. Postharvest soilborne P. apahanidermatum population densities can be eliminated by conducting 2-3 year rotations. Mineral fertilisers such as phosphorous, potassium, potash, gypsum and dolomite-based amendments can also reduce the disease severity and soilborne propagule densities. Indeed, the resulting modification in the soil pH and ammonia production in the soil atmosphere are toxic to this pathogen. Different mixtures of organic and inorganic compounds are known to reduce the incidence of this disease. The pathogen can thus be controlled for around 25 days after the amendment application and urea seems to be the most effective compound for controlling this pathogen.

The mechanism for suppressing the fungus is linked with a direct effect of mineral fertilisers and an indirect effect of the mixture, which reduces the pH and stimulates microbial activity in the soil. Solarisation can also effectively control the fungus, especially in tomato and cucumber crop fields.

Non-chemical control:

It is known that it is hard to find hosts that are resistant to *Pythium* spp. fungi. However there are some tolerant plants such as ginger, corn and a few bean species.

Some organisms, including many bacteria, have been studied in terms of their potential as *P.aphanidermatum* biological control agents.

Pseudomonas spp. fluorescent bacteria seem to have a positive effect on reducing root colonisation, but the control mechanism is not yet clearly understood. It is thought that these bacteria alter root exudates, thus reducing zoospore attraction to the plant roots. Fungal biological control agents have also been reported. A *Trichoderma harzianum*based powder formulation mixed with the soil amendment can enhance control of this disease. Effective formulations can also be made with *Trichoderma viride* and *Streptomyces* spp. fungi. The use of all biological control agents must be registered before use in any crop; however, good agricultural practice and addition of organic mater to the soil, will increase natural levels of *Trichoderma* in the soil.

Control with pesticides:

Several commercial fungicides have been developed for soil and seed treatments and preventive treatments to control *P. aphanidermatum*. Thiram is the most widely recommended fungicide for bean crop treatments.

Damping off, *Rhizoctonia* black scurf

Scientific name:

Rhizoctonia solani

Other host plants:

Solanum tuberosum (potato), *Fabaceae* (legumes), *Solanaceae* (tomato), *Arachis hypogaea* (peanut), *Capsicum annuum* (pepper), *Cucumis sativus* (cucumber), *Zea mays* (corn), *Solanum melongena* (aubergine).

Symptoms and damage:

R. solani is an economically important pathogen in some African countries.

Early infections lead to seed degeneration and post-emergence decline.

Later infections induce tissue necrosis and yellowing of leaves because of tissue alteration. Typical symptoms include damping off, and plant weakening, yellowing or wilt. Reddish sunken cankers of the collar and dry rot of the taproot and rootlets can also be observed. Sclerotia of various colours and sizes often develop on the plant surface. Small moist concave cankers sometimes develop on the pods during the harvest period.

Conditions conducive to infection:

R. solani frequently inhabits humid soils, where it survives as mycelium or sclerotia. The fungus can colonise different types of dead plant tissues. Survival in the soil is dependent on the soil ecology and competition/antagonism interactions with soil micro-organisms. Dispersal occurs via soil particle displacement, contaminated tools or infected plant tissues.

Basidiospores are rarely produced and are of minor importance with respect to disease dissemination. Temperatures above 24-26°C accompanied by high humidity, in addition to abundant rainfall and excessive sprinkler irrigation, are factors that promote disease development.

Susceptible growth stages of crop:

Germination, emergence, flowering fruiting and post-harvest stages. Plants are more susceptible to damping off in the seedling stage, up to 21 days after sowing, whereas flower bud set to harvest is the most susceptible period for cobweb disease.

Preventive control:

Crop rotations of 3-6 years are recommended and disease-free seed should not be sown too deep or too densely. Excessive irrigation and over-salty irrigation water should be avoided. Drip and furrow irrigation can reduce the risk of pathogen dissemination. Fields should be cleared of crop residue after harvest in order to eliminate sources of inoculum. Rotations with potato should be avoided because this crop is a host for *Rhizoctonia solani*. Foliar fertilisation is also recommended to offset difficulties in plant nutrition via the roots. Calcium superphosphate application and draining fields at suitable times can reduce the disease severity. Row rather than square sowing is recommended to reduce the relative humidity and temperature under the vegetation and increase evapo-transpiration and sunlight penetration– which are conditions that inhibit infection.

Non-chemical control:

Rhizoctonia solani can attack several parts of a broad range of crop plants. The cell walls of this pathogenic fungus consist of chitin, which provides a certain degree of resistance and strength. These cells can, however, be destroyed during the hypha growth phase by chitinase treatment of the mycelium. Seed that naturally expresses a high chitinase level can now be used. The resulting seedlings are more resistant to the fungus in highly contaminated soils (tobacco). The observed resistance capacity is dependent on the fungal pressure, which is typical of quantitative resistance. Some organisms can act as natural enemies of this fungus but experiments are still under way to assess this potential. These organisms include protozoans, nematodes, collembolans and mycoparasitic fungi (e.g. *Trichoderma* spp., *Gliocladium* spp., *Pythium* spp., *Verticillium* spp. and *Fusarium* spp.).

Fungal anatgonists can be combined with organic amendments to enhance *R. solani* control efficacy. All use of biological control agents must be registered.

The seed can also be treated with hot water (around 52°C) for 30 min.

This type of treatment eliminates fungal contamination of seed, and has already been found to be efficient in controlling pepper, tomato and aubergine seed.

Control with pesticides:

Treatment of seed with fungicides is the most suitable chemical control method.
Pre-sowing soil fumigation can be performed with metham-sodium combined with iprodione seed treatment.

Collar rot, collar necrosis, pod rot, southern blight

Scientific name:

Sclerotium rolsfii (*Corticum rolfsii*)

Other host plants:

Zea mays (corn), *Oryza sativa* (rice), *Arachis hypogaea* (peanut), *Sorghum bicolor* (sorghum), *Solanum tuberosum* (potato), *Allium cepa* (onion), *Solanum melongena* (aubergine), *Solanaceae* (tomato).

Symptoms and damage:

At a quite early stage, yellowing appears on the edges of the lowest leaves along with wet rot at the base of the collar just above the soil line. The top leaves then begin yellowing and fall. The pathogen spreads to the stem and roots and destroys the cortex. It sometimes also attacks the vascular tissues and develops in the upper branches and the tissues darken. The plant gradually wilts and dies. A thick white mycelium with spherical white, then beige, sclerotia (1 mm diameter) develops at the base of the stem and spreads into the soil, around organic matter and the roots.

Monitoring and diagnostic methods:

Yellowing and falling of the top leaves is the first sign of this disease. This symptom is often accompanied by soft rot of the stem at the soil line. The most common symptom noted in *C. rolsfii* infections is the development of a whitish mycelium mass at the stem base and on dead leaf litter around the stem. The mycelium develops during hot humid periods and disappears when the conditions become dry. Spherical sclerotia can be seen on mycelium growing on infected plant parts and on the soil surface. They are initially white and then turn brownish-black.

Conditions conducive to infection:

Black microsclerotia in the soil or in host plant debris is the main source of *C. rolsfii* inoculum. The mycelium can survive for 6 months in dry soil. Hot temperatures (26-35°C) and 20- 40% relative humidity conditions are ideal for the survival of soilborne sclerotia. The sclerotia germinate on dry tissues when the relative humidity is around 15-20%. Disease development is accentuated by the presence of *Meloidogyne* spp. nematodes as the injuries they cause to seedling roots provide a gateway for pathogen attacks. Crop rotations have a substantial impact on the survival of *C. rolsfii*. Viable sclerotia populations are higher in soils in which tomato crops have been grown for 3 successive years, as well as in soils in which tomato crops have been grown in rotations with peanut. The pH (range 6.30-6.85) and the clay content of the soil seem to have an influence on sclerotia formation—as the clay content decreases the disease increases. A lack of organic amendments, poorly decomposed organic matter, and nitrogen deficiency in the soil decrease the activity of antagonistic organisms, thus promoting fungal development.

Susceptible growth stages of crop:

From emergence to flowering stages, through vegetative growth and fruiting.

Preventive control:

It is recommended to implement 3-year (at most) crop rotations while avoiding rotations with other crops that host this parasite (e.g. peanut and tomato). Fat-based amendments promote microbial activity and inhibit the development of soilborne sclerotia. Nitrogen fertiliser applications will help to control the disease while enhancing crop yields. It was found (in Mexico) that the disease can be controlled by 70-100% in bean crops by covering the fields with sheets of polyethylene. Moreover, using black plastic mulch reduces disease severity in pepper and tomato crops. Excessive irrigation and application of poorly decomposed organic matter should also be avoided, while removing crop debris after harvest.

Non-chemical control:

Considerable work has been focused on screening for *C. rolsfii*-resistant genotypes and cultivars in different crops. Resistant peanut, sweet potato, tomato, sugarcane, rice and wheat cultivars have been found, but no resistant bean cultivars have been identified to date.

Different fungi have been tested for their *S. rolsfii* biological control potential. Application of a *Trichoderma harzianum*-based nutrient enriched solution reduces the impact of the disease and increases crop yields. All use of biological control agents must be registered.

Control with pesticides:

Fungicide seed treatment is currently the most convincing method for controlling this pathogen.

Angular leaf spot disease

Scientific name:

Isariopsis griseola (=*Phaeoisariopsis griseola*)

Other host plants:

Fabaceae

Symptoms and damage:

This disease develops on the lower leaves of the plant as angular spots that are initially grey, then brown and limited by the leaf veins. The lesions can also be surrounded by a chlorotic halo with no coloured border. Small dark coloured blotches can be noted on the underside of the leaves. The angular shape is a characteristic symptom of *I. griseola* infection. The stem lesions are elongated and brown. Pod lesions are not as common as those observed on the leaves, but they are oval to circular in shape, initially superficial with black edges and a reddish-brown core. The spots vary in width, but they expand and merge to cover the whole pod. Fruiting of the fungus occurs in the lesions and many conidia appear under wet weather conditions.

Monitoring and diagnostic methods:

Lesions caused by *P. griseola* can be observed on the leaves and pods. These spots are circular on the first leaves but typical angular spots are noted on trifoliate leaves. Oval brownish-red lesions with black edges can be detected on the pods.

Severe lesions often appear at flowering.

Conditions conducive to infection:

This disease develops from a primary inoculum source during long, hot and humid periods. Inoculum sources include plant debris, seed and natural or wild host plants. The fungus can survive as sclerotia for several months (4-17 months) in infected plant debris in the soil. New infection particles are produced under very wet weather conditions when temperatures are in the 16-28°C range. The pathogen enters through the stoma, followed by and intracellular phase when necrosis occurs. The disease develops much quicker at 24°C.

Lesions can appear after 3 h under suitable moisture conditions, but it generally takes 24 h for peak lesion development. Sporulation in these lesions requires 24-48 h of constant moisture. Mild temperatures with rain or long highly humid periods are ideal epidemic-inducing conditions.

These periods should be interspersed with dry windy periods to enable spore dispersal. Spores can also be disseminated in splashing rain, but *P. griseola* spores are mainly dispersed via dry winds.

Susceptible growth stages of crop:

From flowering to the end of the harvest period.

Preventive control:

This involves cultural procedures, including immediate elimination of crop debris after harvest, rotations with 2 years between bean crops so that the crop residue has time to decompose, and sowing of top quality disease-free seed.

Non-chemical control:

A few bean varieties are resistant to *I. griseola*.

Leaf resistance is always correlated with pod resistance. The fungus also shows high pathogenic variability (at least 14 different strains). The resistance behaviour of cultivars varies in different geographical areas.

Control with pesticides:

Angular leaf spot disease can be controlled by seed treatments and foliar sprays. A few fungicides are documented to be efficient when applied at the R5 (before flowering) and R7 (pod set) growth stages. Treatments can sometimes be avoided since fungal attacks often occur late in the crop cycle and thus have very little impact on harvests.

Bean rust

Scientific name:

Uromyces appendiculatus

Other host plants:

Vigna spp. and *Phaseolus* spp. plants.

Symptoms and damage:

Damage mainly occurs on the leaves, with the appearance of small (1-2 mm diameter) yellow pustules that soon turn into brownish-red spore masses in the middle of a yellow spot. No yellow halo develops in some varieties, and the symptoms are more discrete in such cases. The leaves wither and fall in highly infected plants. The pods are sometimes attacked. The plant can die if the disease begins developing in the early vegetative growth stages, thus affecting the crop yield. The following table highlights the impact of this disease in some African bean-producing countries.

Monitoring and diagnostic methods:

Symptoms induced by this fungus are easy to recognise so the disease can be diagnosed in the field. If field identification is not possible, diseased plants should be sampled and the tissues cultured under controlled conditions to identify the pathogen on the basis of morphological criteria.

Conditions conducive to infection:

High temperatures reduce the incidence of bean rust, but the harvest can be lost when the disease onset occurs in the initial plant growth stages. Humid conditions and temperatures in the 20-25°C range promote the development of this pathogen. Maximum spore germination occurs between 17 and 22°C, with a lower germination percentage for spores and pustules that have infected older leaves. Relatively cool weather (18-24°C) with high humidity over an extended period, excessive nitrogen fertilisation, and a lack of potash in the soil will favour disease development.

Susceptible growth stages of crop:

From flowering to harvest.

Preventive control:

It is recommended to avoid cropping beans in lowland areas where the dew does not lift until late in the morning because such humidity and temperature conditions are suitable for *U. appendiculatus* infection. Fields should not be watered in the evening or at night because the excess water could promote rust disease development. Well balanced nitrogen and potassium fertiliser applications will facilitate the development of antagonistic microorganisms and enhance the rust resistance of bean plants. Crop residue should be destroyed to reduce potential primary sources of inoculum. Increase plant spacing in the rainy seasons to allow leaves to dry off more quickly after rain. Use a zigzag planting pattern to increase air movement between plants and ensure that the crop is kept weed free for the same reason.

Preferably plant a variety which is resistant to rust. (See Crop Protocol Section for pest and disease tolerance of different varieties).

Non-chemical control:

Bacteria such as *Bacillus subtilis* and *Arthrobacter* spp. can control the fungus on bean crops by more than 95% when applied in a water suspension. Even at low concentration, bean rust can be controlled by 80% when using *B. subtilis* and species of the same genus, and by 70% with *Arthrobacter* spp. Neither of these biopesticides is registered in Kenya, as crop protection agents.

However, a 'bio-fertiliser' is widely used in Kenya in beans, which contains Lacto-bacillus (used in making of yoghurt), *Pseudomonas* and other beneficial, indigenous microbes ('EM' or Effective Micro- Organisms).

Control with pesticides:

The recommended treatment involves weekly preventive fungicides applications in the period between flower bud formation until flowering, or curative treatments conducted as soon as the first rust spots are detected. Early detection of symptoms is crucial, so the regular field personnel (farm workers, watchmen) should well trained in this respect.

Aphids

Scientific name:

Aphis fabae or *Aphis craccivora*

Other host plants:

Arachis hypogaea (peanut), *Vigna* spp., *Fabaceae*.

Symptoms and damage:

Aphids causes direct damage to bean plants during the vegetative and flowering phases. Aphid colonies can attack young shoots, the underside of leaves, petioles and seedlings. Heavily infested plants grow poorly and their leaves shrivel and curl. The concentration of aphid colonies on growing points of the plant leads to a decline in crop yields due to the direct damage these pests cause. This damage is due to the production of honeydew. Honeydew is a rich sweet sticky substance that aphids excrete. It is found as a deposit on plants after being attacked by a high number of aphids, and it acts as a growth agent for a black saprophytic fungus (sooty mould) that hampers the chlorophyll and respiratory functions of the plant. Pods tainted with honeydew or sooty mould are depreciated. This aphid is an important virus disease vector (more than 30 viruses are transmitted by *A. craccivora*, and many host plants are aphid reservoirs since this pest is polyphagous. Bean mosaic is one of the viruses transmitted by aphids and which infects many *Phaseolus* spp.

Conditions conducive to infestation:

They are parthenogenic species. Aphids colonies cluster around growing points of plants. They often have a symbiotic relationship with ants, so the presence of ants is favourable for aphid infestation. Specific climatic conditions are required for aphid development, such as temperatures in the 24-28.5°C range and relative humidity of around 65%. Aphids generally cannot survive in the field under heavy rainfall conditions. Aphids can develop rapidly, the entire cycle lasts around 11 days. The plant metabolism, and especially the reduced hydrocarbon translocation, have an impact on the development of winged aphids, which in turn prefer to attack water stressed plants.

Susceptible growth stages of crop:

All stages, especially during flowering and pod set.

Preventive control: Ensure that consecutive plantings of French beans are not planted down-wind of older crops, which could be heavily infested with aphids. Monitor the edges of new plantings very carefully to identify early invasions of aphids, which often occur at the edges of fields. This will ensure timely control methods are applied when the aphid population is low and crop canopy has not developed to densely (which will hamper penetration of sprays).

Non-chemical control:

For biological control, some pesticides can be detrimental to aphid predator populations. Integrated aphid management programmes should use pesticides that are as harmless as possible to parasitic wasps such as *Aphidius*, syrphid flies and ladybirds, which are natural enemies of aphids (see Pesticide Sensitivity charts in Appendix).

Parasitoid wasps are particularly useful biological control agents since they lay many eggs and can quickly parasitise aphid colonies. Local Kenyan species of *Aphidius* have proved to be very useful in the control of black bean aphid. This wasp lays eggs inside the body of a wide range of aphids. The aphid host does not die immediately and remains attached to the leaf where it is feeding. The *Aphidius* eggs hatch inside the body of the aphid and feeds on the aphid's body fluids. As the *Aphidius* larvae develop within the host's body, it pupates and spins a cocoon inside the aphid body. The aphid is still attached to the leaf and takes on a papery 'mummified' appearance. The *Aphidius* continues to develop into an adult *Aphidius* wasp within the aphid 'mummy'. Eventually it bites a circular hole in the aphid body, which it then pushes open like a trap door and emerges as a fully mature *Aphidius* wasp.

Sometimes hyper-parasites attack the developing *Aphidius* within the 'mummified aphid' and lay their eggs in the *Aphidius* larvae. It is possible to distinguish a mummified aphid, which has been 'hyper-parasitised', because the 'exit hole' for the hyper-parasite is usually a torn, split aphid body, instead of a neat circular trap door-like exit hole. The indigenous parasitic wasp, *Aphidius transcaspinus* is registered by PCPB as a biological control agent in Kenya. It has been mass-reared commercially in Kenya.

Control with pesticides:

Many active ingredients have been used to treat aphids, including halocarbon, organophosphorous, carbamate and pyrethroid compounds The persistence and efficacy of these pesticides on plants are essential factors. Systemic active ingredients are efficient for killing aphids but unfortunately these pests have time to feed and transmit viruses before they die.

Aphids are readily visible on plants, especially on leaves and buds. It is essential to detect them as early as possible to avoid heavy aphid infestations on the plant organs. It is important to ensure quick control of early aphid infestations, since the longer it takes to eliminate the aphid population, the larger the aphid colony will develop. IPM scouting will determine the relative levels of aphids and aphid predators and parasites in the crop. If the ratio of aphid predators/parasitoids to aphids is less than 1:20 (ie for every 20 aphids there is one aphid predator or parasitoid), then it may be advisable to use a pesticide to quickly bring down the level of aphids. This will avoid any damage due to high aphid populations and the honeydew they excrete. If the aphids are detected early, then there may be less pressure to resort to chemical controls, even if the ratio of aphids preadators/parasitoids to aphids is greater than 1:20, since there is still some time before flowering to allow the ratio to develop in favour of controlling the aphid colony. The speed of the control achieved can be accelerated if the grower collects aphid predators and parasitoids from older crops and moves them into the new crop. The key to success is to identify aphid colonies as soon as they appear and to introduce beneficial insects to these 'hot-spots' as quickly as possible.

As resistance to pyrethroids has been detected, some operators use natural substances such as neem oil or Parkia roxburghii plant extracts.

Whiteflies

Scientific name:

Trialeurodes vaporarium (greenhouse whitefly) and *Bemisia tabaci* (sweet potato whitefly)

Other host plants:

Brassicaceae, Cucurbitaceae, Fabaceae, Malvaceae, Solanaceae.

EU Notifiable Pest:

Bemisia tabaci is a notifiable pest in the EU, which means that it must not be imported on produce to the EU. However, it is unlikely that this would occur with French beans, since it would be extremely rare for a whitefly scale to be present on a harvested bean.

Bemisia is however, a serious pest, since it can transmit many viruses and growers should learn how to distinguish between *Trialeurodes* and *Bemisia*.

The greenhouse whitefly is known to attack 249 plant genera in 84 plant families.

Symptoms and damage:

Direct feeding damage from whitefly adults and nymphs causes chlorotic leaf spots, which can be seen on the upper surface of leaves. Depending on the extent of whitefly colonisation, these spots can merge until the entire leaf is yellow. When whiteflies are not controlled, and their feeding is excessive, leaves can become brittle and eventually dry up and fall off.

B. tabaci can acquire and transmit a number of viruses (*Geminivirus, Closterovirus, Nepovirus, Carlavirus, Potyvirus*) that induce different symptoms depending on the host species. A virus can present one or several of the following symptoms: infected leaf veins, yellow leaves, yellow mosaic on leaves, leaf curl and thinning, etc. This pest has a relatively high impact in Africa. *B. tabaci* colonisation is often involved when plants are infected by virus transmission, even though plants can be infected as a result of the migratory feeding movements of this pest.

As the whitefly larvae suck sap from the leaf, excess sugary plant sap drips from their bodies onto the leaf surfaces beneath the one where they are feeding on the plant. Sooty moulds readily grow on this sugary solution causing the characteristic 'black sooty mould'.

Conditions conducive to infestation:

Each female can lay up to 160 eggs after 5-9 days at 30°C depending on the temperature and humidity conditions. From 11 to 15 generations per year are possible. Whiteflies can reproduce easily in a humid sheltered biotope and subsequently attack host plants. Dry winds are not favourable to these pests.

In Kenya *Trialeurodes vaporariorum* is prevalent mainly in highland conditions and the prevalent species on beans at present. However, *Bemisia tabaci* has expanded its range of occurrence and is more frequent in highland conditions than it used to be.

Susceptible growth stages of crop:

From emergence to flowering, including vegetative growth.

Preventive control:

Whitefly has developed resistance to many chemical pesticides. Therefore, it is very important to use all new active ingredients, aimed at controlling whitefly, as part of an IPM programme – to safeguard these products for future use. Continuous, prophylactic insecticide programmes for whitefly has lead to resistance developing all over the world. Integrating biological controls, such as the parasitic wasp, *Encarsia*, will protect the efficacy of new active ingredients. Once resistance is allowed to get a foothold because of over use of pesticides, whitefly populations will increase dramatically and can become uncontrollable. If the whitefly also carries a virus, it may even be uneconomical to continue growing the crop in that region!

Crop rotations have long been used to control this pest. However, other crops in the rotation cannot be *B. tabaci* hosts. Weeds growing along or between the sowing lines and crop residue can harbour whitefly populations. It is therefore important to weed the field and clear the residue before sowing and during the growing period.

If, for economic reasons, it is not possible to benefit fully from crop rotation to keep local whitefly populations at bay, then the grower should plant younger crops, upwind from the older crops. This will reduce the migration of whitefly from old crops, when they are puled out – onto young, vulnerable crops, down wind.

Although whitefly adults are highly active during the day time, they cannot fly at all in cold conditions. In Kenya, at high altitude, the night temperatures can crop quickly to as low as 15 to 5°C. At these temperatures the adult whitefly do not fly and crops can be removed without the adult whitefly being disturbed. This will reduce the migration of whitefly from old to young crops to negligible levels.

If a heavily infested crop is removed during the day time, in hot conditions, the adult whitefly are very active and will fly off, in 'clouds' onto adjacent young crops.

Non-chemical control:

If there is no virus present, it may be possible to tolerate a certain level of whitefly scales on a leaf, as long as any honey dew produced by them is not causing excesive sooty mould build up.

Since French beans are only in the ground for 10 weeks, it does not build up as much whitefly as a runnerbean crop for example, which is in the ground for twenty weeks and produces three times as many leaves. This is the '*economic threshold*' and should be determined by the individual grower by observation of the crop at the time (eg vegetative vigour and quality of leaf – extent of sooty mould etc) – and taking into consideration the length of time remaining before harvest is completed.

The most important natural enemy of whitefly is a minute parasitic wasp, called *Encarsia*, which lays its egg in the whitefly scale. When the whitefly scale is parasitised, it turns black so the percentage parasitism is easily monitored in an IPM programme.

Encarsia formosa is registered by PCPB in Kenya for the control of whitefly and it is mass reared for application to commercial crops.

Encarsia is one of the most widely used commercial biological control agents in the world and is the preferred method in many protected crops in the EU (tomatoes, gerberas etc) because whitefly has developed resistance to many of the pesticides formerly used to control this pest. The egg and pupa stages of the whitefly are 'non-feeding stages' and are not killed by pesticides – therefore a routine, prophylactic pesticide programme, is required to control the vulnerable adult and larval stages, as they continuously develop. This in turn leads to resistance to the pesticide and the treadmill commences.

The biological control strategies for whitefly on outdoor crops are still under development. However it is possible to devise a prophylactic IPM programme using adult *Encarsia* wasps for outdoor crops. The introduction rates for *Encarsia* are, based on an estimated number of whitefly scales which could be present per tri-foliate leaflet, if NO other controls are used, and natural migration of the pest occurs unhindered (e.g. worst case scenario) Over a period of time, if effective control occurs, the level of natural migration of whitefly into the crop, shortly after planting, is likely to decrease and therefore the introduction rates required for *Encarsia* would also decrease.

An efficient IPM scouting system, will help growers to measure the control which is being achieved, by estimating the average numbers of whitefly scales and adults per leaflet, over time.

In Europe and elsewhere, *Encarsia* is normally purchased from biocontrol companies as black parasitised whitefly scales which contain a young *Encarsia* pupae that later emerges from this as an adult *Encarsia* wasp. This adult *Encarsia* is the 'biological control agent' since it flies off to lay eggs in more whitefly scales on the crop. This method of application has advantages in that pupae are cheaper to produce and distribute than adult wasps and pupae can also be stored for longer than an adult wasp, before use. This suits growers in the EU who are producing crops in greenhouses.

Very little work has been done using *Encarsia* on outdoor crops. However, adult *Encarsia* wasps are preferred to *Encarsia* pupae (ie parasitised whitefly scales) for outdoor crops in Kenya because in field conditions, the *Encarsia* scales are liable to be eaten by ants, dehydrate or be blown away, if they are applied loose, into an outdoor crop. Whereas, adult *Encarsia* wasps will fly directly to the underside of leaves, in search of whitefly scales to feed on the scales and to lay their eggs into them.

It is also easier to integrate adult *Encarsia* wasps with the timing of applications of other compatible fungicides and insecticides, since the grower knows the exact date when the adults were applied to the crop. If the grower had applied the *Encarsia* as scales instead – he would not know the exact date when they hatched from the black scales – which makes it difficult to time other pesticide sprays and ensure that the *Encarsia* adults are not killed. *Encarsia* is very sensitive to pesticides and even fungicides. (See Appendix for pesticide sensitivities) Technical advice should be sought in the use of biological controls for whitefly. However, the following guidelines will assist growers who want to develop biological control on outdoor crops. One week courses are available to provide the necessary scouting and management skills to implement these programmes.

The 'conventional' method for use of *Encarsia*

Commercial use of *Encarsia*, the widely used parasitic wasp for whitefly, is normally limited to protected crops because of the cost of these natural enemies which would make it uneconomic to use in outdoor crops. However, *Encarsia*, like all natural enemies comes from 'outdoors'! It is not biology, but economics, which prevent it from being used effectively outdoors ! They can be produced very cheaply in Kenya and sued in much higher rates than is economically possible in the EU.

The conventional way to use *Encarsia* is to purchase parasitised whitefly scales (that are black when parasitised). These are stuck onto cards which are hung in the crop. The adult *Encarsia* wasps then hatch (or don't hatch) from these scales and search the crop for whitefly scales of sufficient size (L3 stage and above) in which to lay an egg. If the *Encarsia* egg is laid into a large whitefly scale, it will eventually develop into another adult *Encarsia* inside the parasitised whitefly scale (because there is enough food inside the large scale). If there are no large scales present in the crop, the *Encarsia* will be forced to lay an egg in a smaller scale – which will not have sufficient 'flesh' in it, to feed the full development of the *Encarsia* into adulthood. The result is that both the developing *Encarsia* and the scale die and the *Encarsia* population in the crop will not be able to build up. However, the whitefly scale dies . . . which is the objective of the grower.

It is the crucial nature of the timing of the introduction of the to coincide with the presence of large whitefly scales, which underlies the success of the 'dribble' method for introducing *Encarsia*. This is a 'little and often' weekly introduction at a fixed rate per hectare which attempts to overcome some of the above problems. The weekly, prophylactic introductions of *Encarsia* generally stop once 95% parasitism of whitefly scales is observed (e.g. 95% black scales on the crop leaves)

Prophylactic - preventative programme using *Encarsia*.

A different way of using *Encarsia* is a prophylatic high rate programme.

In ornamental pot-plants (eg poinsettias) in Europe, a high level prophylactic programme of *Encarsia* introductions is used instead of the low level weekly, routine programme (the 'dribble' method described above) which is used in crops such as tomatoes, because the consumer does not want to buy ornamental poinsettia plants with black scales on the leaves. In tomato crops, it does not matter if the tomato leaves have black scales on them.

In poinsettias, a routine introduction of *Encarsia* is made, **before** whitefly eggs have even hatched on the plant's leaves, so that the *Encarsia* actually kills the whitefly scales, as they develop, instead of parasitising them. This happens because the *Encarsia* adults also feed on young scales - excessive feeding damage will kill the scale and it will fall off the leaf. The scales also die beacsue the *Encarsia* has laid an egg in the scales – even if the scales are too small to support the full development of the *Encarsia* pupae. Hence, there will not be a high level of conventional parasitism, and few black scales in the crop, since the development of the whitefly population in the crop is arrested at the L2 stage. This technique is called '***stinging out***'.

Stinging out will often occur when the ratio of *Encarsia* adults to whitefly scales in the crop is closer than 1:30 (e.g. one *Encarsia* adult for every 30 whitefly scales).

This type of 'stinging-out' programme will inevitably use more *Encarsia* than the conventional dribble programmes above and is normally only used in high value crops, such as ornamentals. However, if the cost of *Encarsia* can be reduced by mass rearing them on-farm, then the higher rates of adult *Encarsia* can be used economically.

The general principle of biological control is that the more beneficial insects which are present (or introduced) in relation to the number of pest present – the quicker control will be achieved.

Therefore, the introduction rate for *Encarsia* should be in relation either to the number of whitefly actually present or the number which are anticipated to migrate into the crop.

In order to calculate the possible number of *Encarsia* required, the grower should first obtain a good estimate of what the likely weekly build up of the whitefly scales would be on the crop if NO controls were applied. This could either be estimated from the grower's experience of the average number of whitefly scales per trifolaite leaf at a given age of crop - or may have to be done by setting up an unsprayed plot on the same farm as the crop, which allows whitefly adults to migrate into the plot. Scouting this plot weekly will obtain the average number of:

- whitefly scales per leaf per week (build up of scales),
- number of leaves per plant per week (build up of leaves). (see the table below to understand how this information can be used)

The weekly introduction rate of *Encarsia* adults (not the black parasitised scales) would be determined by dividing the estimated weekly number of whitefly scales per hectare (*) by thirty. This will determine how many *Encarsia* adults would be required to establish a 1:30 ratio of *Encarsia* adults to whitefly scales, in the crop canopy. At this ratio, stinging-out should occur. If the grower can afford to put even more *Encarsia* adults into the crop, this would provide even pbetter control (but would cost more).
*estimate of total whitefly scales per hectare = (average whitefly scales per leaf x total leaves per plant) x total plants per hectare

Calculations for prophylactic introduction rate (*Encarsia* in French beans)

This high rate would only be needed during the period when the farm whitefly population was being forced down to a more manageable level. Future introduction rates would be adapted to the actual average number of whitefly scales present (not the high average of 20 scales per leaf used in the calculation below).
Table 1: Guidelines on calculations for *Encarsia* adult introductions in to outdoor French beans, Plants/ha = 200,000. Use a level of 20 scales per trifoliate leaf to calculate maximum total whitefly/ha (worst case scenario) – for initial programme As long as no harmful chemical sprays are applied during this phase and there is not a massive influx of whitefly adults from an adjacent crop – it should not be necessary to make further introductions of *Encarsia* adults beyond week 6. (see pesticide sensitivity chart in Appendix). There will be some build up of black, parasitised, whitefly scales using this technique, as a proportion of the whitefly scales would have developed beyond L3 and could be properly parasitised by *Encarsia* and turn black.
Scouting will determine whether *Encarsia* introductions need to continue. Introductions of *Encarsia* adults should continue if weekly scouting reveals that:

- the average number of whitefly scales are continuing to rise each week to an *unacceptable level* or,
- the percentage parasitism of the larger scales on the older, lower leaves is less than 50 percent.

The grower needs to determine if the level of scales present is 'acceptable' (economic threshold). He would take into account how many weeks the crop has left in the ground and whether the scales present are causing too much honey dew damage to the beans, or if the crop is not growing vigourously enough due to heavy feeding presure from the whitefly. However, at £5 per thousand (the commercial cost in EU for parasitised scales) – an introduction rate per hectare of around 3 million *Encarsia* adults would cost about £15,000 – which is prohibitively expensive.

Wk after planting	wk 3	wk 4	wk 5	wk 6	wk 7	wk 8	wk 9	wk 10
trifoliate leaves per plant total tri-foliates per ha ('000 s)	1 200	3 600	9 1 800	12 2 400	18 3 600	22 4 400	26 5 200	26 5 200
estimated total scales per ha	4 million	12 million	36 million	48 million				
intro. rate per ha *Encarsia* '000 s' ratio of 1 to 30 (rounded up)	140 000	400 000	1,2 million	1,6 million				

The only way to achieve this, is to breed the *Encarsia* on the farm to reduce the cost. The whitefly scales can also be destroyed by using detergent based sprays such as Teepol but again advice should be sought from the Pesticide Regulatory Authorities to determine if this use is exempt from the need for Registration as a crop protection agent. In many countries, this type of crop protection agent is exempt because it kills by physical means, by dissolving the cuticle and allowing the scale to die of dehydration. Other controls agents include substances such as starch, which if sprayed onto a leaf with whitefly scales will prevent the scales from hatching as it forms a surface coating which either suffocates the scale or dehydrates it due to osmosis. Similar effects can be achieved by spraying vegetable or mineral oils. Again, these types of substance are exempt from registration in other countries because of their physical mode of action. Guidance needs to be obtained on local registration requirements.

Control with pesticides:

Both species can be regarded as induced pests, triggered by injudicious pesticide applications.

If only chemical pesticides are used an intensive pesticide programme may be required because no pesticides are available which will kill whitefly eggs or pupa of whitefly (as they are non-feeding stages). The eggs are unaffected and hatch into whitefly larvae (which require another spray); - the pupae hatch into whitefly adults (which require another spray).

The need for an intensive programme leads to resistance to the limited number of pesticides available.

It is recommended to conduct preventive control treatments from the beginning of the cropping cycle until flowering only if risk of viruses transmission is known. If there is no risks of viruses scout the field and treat only if necessary.

Preferably crops should be sprayed at night, late afternoon/early evening or early in the morning – before temperatures are high enough for whitefly to fly. In cool temperatures, the whitefly will not move off during the spray application (possibly to other blocks) and are more easily contacted by sprays.

Monitoring methods:

Whitefly adults are very active and easily disturbed during the daytime. The immature stages are less mobile and usually found on the undersides of the foliage. Adult whiteflies feed on the lower leaf surfaces where they lay their eggs, but may rest on other areas of the host plant.

Leaf curl and mosaic lesions along the leaf veins are signs of the presence of whitefly-transmitted viruses. Close observation of the upper surfaces of infected leaves reveals the presence of minute pale yellow larvae and adults can also be noted when colonisation is severe. The eggs, which are white and then gradually turn brown, are held in position by a thin stalk produced by the female. Adults are 1 mm long with a yellow body and white wings.

Adult whiteflies are strongly attracted to yellow and sticky traps can be made from yellow plastic covered in glue or other sticky substances such as grease. However, it these 'traps' should not be used routinely as part of an IPM programme since they also trap and kill beneficial insects such as *Diglyphus* (parasitoid of leafminer) as well as *Encarsia*, which attacks whitefly. Sticky traps should only be used as a monitoring tool to observe general trends in field populations of pests. Yellow sticky traps are attractive to thrips, aphids, leafminer and thrips, to varying degrees.

Differences between adult stages of Trialeurodes and Bemisia

Trialeurodes

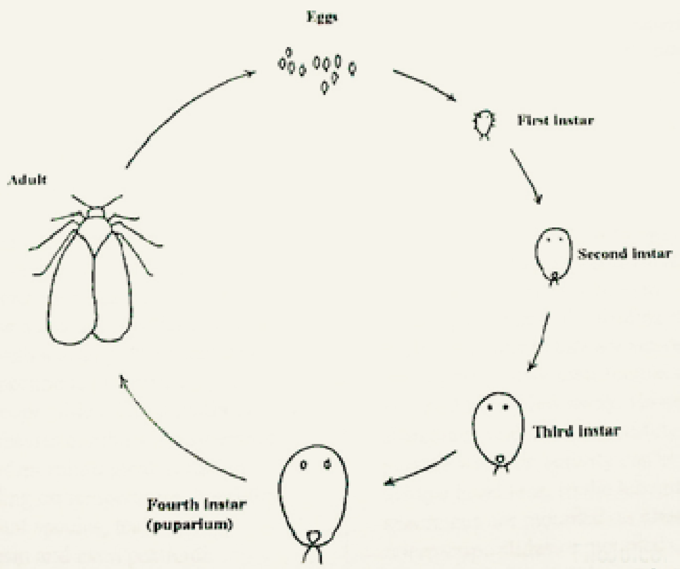
Bemesia

Adult *Bemisia* hold their wings over the body with a steeper pitch (like a tent) and it is possible to see more of the yellow abdomen of *Bemisia*.

Mature whitefly eggs are grey in colour. *Bemisia* tend to lay their eggs haphazardly over the surface of the leaf whereas *Trialeurodes* will lay eggs in semi circles.

Whitefly life cycle:

Whitefly adults commence egg laying during the day,
about 1 - 3 days after emergence from the whitefly scale on the leaf.
Eggs are attached to the lower leaf surface and egg hatch occurs 7 - 10 days later. This stage, known as the "crawler", is the only mobile immature stage. It moves only a short distance, inserts its needle-like mouthparts into the leaf, and begins to feed on plant sap.



For approximately 7 days, the insect remains sessile, but goes throug h 3 molts. The second and third instars also feed on plant sap with each stage being 3 - 4 days depending on temperature. The insect then molts into a fourth stage nymph or resting stage called the pupa. No feeding takes place during the pupa stage.
Approximately 1 week later, the adult whitefly emerges from the pupa, usually in the morning. Even though adults may fly up to 50 feet in a 24 hour period, most remain within 8 - 10 feet of their hatching site.
The entire whitefly lifecycle may average 32 days at temperatures of 20° - 25° C and are favoured by temperatures averaging 25° C .

Corn Ear Worm, Tomato Grub, Tobacco Budworm, Cotton Bollworm

Scientific name:

Helicoverpa armigera (*Heliothis armigera*) Other host plants: *Gossypium* (cotton), *Lycopersicon esculentum* (tomato), *Solanum tuberosum* (potato), *Sorghum, Arachis hypogaea* (peanut), *Brassicaceae* (crucifers), *Allium, Capsicum annuum* (pepper), *Pennisetum glaucum* (millet), *Phaseolus*, *Pisum sativum* (pea), *Solanum melongena* (eggplant)...

EU Notifiable Pest:

Heliothis armigera is a notifiable pest in the EU, which means that it must not be imported on produce to the EU. This is one of the most frequently intercepted pests from Kenya to the EU.

Symptoms and damage:

H. *armigera* is an important pest of many crops throughout most of the world. It is especially well adapted to artificial ecosystems such as crop fields because of the following features:
highly mobile, polyphagous, rapid reproduction capacity and diapause. As this pest shows a preference for flower-derived plant parts (pods, seeds, etc.) of high added value crops (cotton, tomato, bean, etc.), it has a substantial economic and socio-economic impact, especially in subsistence farming systems.
The bollworm nibbles on the pods and leaves and eats the seeds. Adult females lay their eggs in the bean pods. These eggs and young caterpillars are hard to detect during bean sorting operations, so the pods can subsequently be damaged in the export packing boxes.

Conditions conducive to infestation:

A H.*armigera* female can lay (mainly at night) up to 3000 eggs during its life cycle. These eggs hatch after 3 days of incubation at temperatures around 25°C. These temperature conditions also promote the development of first and second instar larvae which pupate in the soil. The adult life-span of these worms is about 3 weeks. Their longevity, however, depends on food availability (sucrose, nectar). For this reason, bollworm tends to peak in populations after the rains in Kenya, when the adults emerge from pupae in the soil and there is an increased likelihood that suitable host plants will have emerged after the rains.
In countries like Senegal, this pest is dangerous throughout the year, especially from December to March-April, and its development is favoured by a succession of host crops: tomato, bean, aubergine, cotton, etc.

Susceptible growth stages of crop:

From fruit set to harvest, including the vegetative growth, flowering and fruiting stages.

Preventive control:

It is not very effective to try to manage populations of this pest in the crop fields because of its high mobility and dispersed habitats. Adapted cultural techniques, such as reducing the cropping period, can be a useful control strategy but there should be no wild host plants in the vicinity, or those that are present should be isolated. Other crop management techniques using bait plants such as chickpea, have been set up, but they have some limitations, since they may serve as a breeding ground, unless they are carefully and regularly inspected and the caterpillars present are removed. Even one caterpillar being destroyed may prevent many hundreds of a second generation from developing (since an adult can lay up to 3000 eggs each). Crop rotations without a spatio-temporal succession of crops that host this pest are recommended for preventive control. It is also recommended to carefully choose cultivars that are to be planted, to space and fertilise the crop so as to increase the crop yield, and to specifically target the larval stages in control operations since they are the most susceptible to conventional treatments with pesticides and microbial formulations.

<u>Non-chemical control:</u>

Trichogramma is a minute parasitic wasp, which lays eggs in the eggs of caterpillars, including bollworm. Kenyan companies have developed mass-rearing systems for *Tricho-gramma* but have not yet completed Registration of this biological control agent with PCPB. *Trichogramma* is the most widely used natural enemy in the world and it is mass released over millions of hectares each year for maize stalk borer control in the US, China, southern Europe and Russia.

Trichogramma wasp laying and egg into a caterpillar egg

A virus which infects bollworm is also well researched and being massproduced in a pilot scheme for small-scale farmers in East Africa, with DFID funding. This system has been used in other parts of the world and involves collecting bollworm caterpillars in a bucket from the wild and introducing one or two infected caterpillars. The virus then spreads very quickly throughout the collected caterpillars and when they have died, their bodies are macerated and sprayed onto the crops to kill other bollworm pests. This is called a 'biopesticide' and should be registered in Kenya with PCPB, even if the homemade formulation is for own use onfarm.

There are also commercial virus based biopesticides registered for this pest elsewhere in the world, based on similar microbes to that described above. In Kenya PCPB will confirm how these can be legally imported with permission from the Kenyan Standing Technical Committee for Imports and Exports (KSTCIE) for an experimental permit to develop registration data for a Kenyan Label.

Formulations of *Bacillus thuringiensis* (Bt) are registered for use in Kenya by PCPB. It is important to use these sprays in the late afternoon or early evening because the Bt is broken down by UV light during the daytime.

This has to be injected by the caterpillar in order to kill it and it works best on young caterpillars as high doses are needed to kill mature caterpillars.

Early applications are essential when the newly laid eggs have just hatched to make the Bt spray effective. Since it is very difficult to see these small larvae or to find the bollworm eggs on leaves, it is best to begin a weekly spray when the adult moths are seen. Adult moths can be caught in light traps and their numbers recorded to determine when the peak migration has occurred. This will help to time the Bt application to when the first small young (susceptible) larvae are present.

Planting H. ***armigera*** tolerant or resistant varieties has long been and still is an important focus of research (cotton, pea). Several plants have a genetic potential that could be tapped to develop varieties at are less susceptible to pests. However, developing one specific trait sometimes weakens the plant's defence against another pest (e.g. glabrous cotton, which reduces egg laying but increases susceptibility to jassid infestation). In recent years, advances in genetic technology have made it possible to introduce genes responsible for the secretion of *Bacillus thuringiensis* toxin in some crop plants (cotton, corn). However, these plants should be mixed with susceptible varieties to avoid placing high selection pressure on the pest populations.

As an IPM strategy, considerable research has been focused on achieving a suitable level of control by introducing natural enemies or increasing predator and parasitoid populations in association with other pest control methods. As it is essential to produce a high quantity of parasitoids or predators, research has also been focused on *Trichogramma* spp. which can be mass propagated easily. There are other natural enemies of H. ***armigera*** (lacewings, ladybugs, *Bacillus* spp., braconid wasps, etc.), but the results have not always been very promising, especially for systems in which pesticide treatments are necessary.

Micro-organism-based pesticides are quite useful for IPM on account of their relatively high specificity, potential activity, environmentfriendliness and pesticide immunity. These are *B. thuringiensis*- and virus-based formulations. They are not widely used, however, because of their high light degradability, the fact that larvae do not ingest sufficient quantities, and their virulence is sometimes not very high.

Monitoring methods:

This worm can reach 40 mm long at full development. Its colour varies markedly, ranging from very dark brown to green or yellow. Black and white sinuous lines run along the entire length of its body. Feeding larvae can be noted on the plant surface but they are often hidden in the flowering and fruiting organs. During pest monitoring, some of these organs should thus be cut off, opened and the internal parts carefully inspected. These worms can also be detected by the presence of organic waste outside of or on the bean pods which is produced by feeding larvae. Exit holes made by mobile larvae, which subsequently pupate into nymphs in the soil, can also be observed.

Control with pesticide:

H. ***armigera*** is mainly managed with pesticides, alone or combined with other control methods. Clearly, to get the best results, these pesticides should only be applied when the economic threshold has been reached, but operators do not always comply with this rule. Most recommended pesticides target larva, but are actually only efficient against first instar larva. Young larvae are hard to find and older instars are often well hidden in the bean pods, thus reducing their accessibility for treatment and forcing operators to increase the active ingredient dose. Moreover, larvae from resistant populations are only susceptible when they are less than 4 days old, so targeting neonate larvae is the most efficient approach for controlling such pests. As preventive control, it is recommended to conduct treatments weekly after fruit set and throughout the harvest period. As curative control, treatments should be undertaken as soon as 1% of the pods have been attacked. Preventive control is preferred because batches of French beans can be turned away by importing countries if any worms are detected.

Resistance phenomena due to selection pressure induced by the use of pesticides such as pyrethroids were already noted in the 1980s in H. ***armigera*** populations. The high dispersal potential of this pest could lead to dilution of this resistance, but the same mechanism also facilitates the spread of resistance genes beyond the initial region.

Based on the importance of the dispersal and migratory behaviour of this pest, its movements could be monitored by a trapping system so as to be able to forecast infestations in a given region. This would only be qualitatively useful for indicating the onset of infestations and the location of the migratory front, and preventive treatments should still be conducted during the initial vegetative stages.

This monitoring is required to determine exactly when the economic threshold is reached and surpassed so that control measures can be initiated. It is hard to get accurate data on this threshold, some are based on egg numbers (1 egg/2 plants, 2 larvae/18 plants, 2 eggs/1 m row).

Leafminers

Scientific name:

Liriomyza huidobriensis (South American leafminer), *L.trifolii* (American Serpentine leafminer) and other *Liryomyza* spp.

Other host plants:

Cucurbitaceae (cucumber), *Gossypium* (cotton), *Lycopersicon esculentum* (tomato), *Solanum tuberosum* (potato), *Solanum melongena* (aubergine), *Arachis hypogeae* (peanut) and various weed species.

EU Notifiable Pest:

Liriomyza bryonae, *Liriomyza huidobriensis* and *Liriomyza trifolii* are notifiable pests in the EU, which means that they must not be imported on produce to the EU. This is one of the most frequently intercepted pests from Kenya to the EU. It is more of a problem on the pods of mangetout and sugarsnap peas than in French bean pods as mines are not often seen on French bean pods – possibly because the crop growing period is much shorter than in pea crops.

Symptoms and damage:

Feeding damage caused by leafminer appears as tunnelling (0.13-0.15 mm diameter) on the upper side of leaves. The shapes of these tunnels varies according to the attacked plant, but they are long, linear, and not very wide when sufficient leaf area is available. They are generally greenish to white. A sac forms for pupation at the end of feeding tunnels on the smallest leaves.

Conditions conducive to infestation:

The eggs are laid just under the leaf surface and hatch within 4-7 days at 24°C. The larval development time also depends on the temperature– several generations a year are possible under suitable temperatures and when growing host plants are available. Leafminer pupate in the soil near the plant. The adults emerge 1-2 weeks thereafter when temperatures range between 20 and 30°C, with peak emergence occurring at midday but earlier for males.

The lifespan of these pests is 15-30 days. When temperatures exceed 40 deg C, leafminer lay fewer eggs.

Susceptible growth stages of crop:

From the seedling stage to the first harvest, including the vegetative growth, flowering and fruiting stages.

Preventive control: Cropping should be avoided in or near fields where there have been heavy leafminer infestations. Runnerbean crops can produce millions of leafminer if not properly protected.

To avoid *L. trifolii* introductions, international authorities (EPPO) recommend monthly inspection of propagation material (except seed) from other host plants, such as pepper, cucumber, lettuce and tomato from other countries where this pest prevails, over a 3-month period. The plants should be exempt of this pest. A phytosanitary certificate is required for leafy plants.

Destroying host weed plants growing along the edges of the crop fields is recommended, unless biological controls are used, in which case, the natural enemy will migrate into the weedy areas and kill any leafminer larvae present.

Since leafminer pupates in the soil, deep ploughing can bury the pupae and prevent them from emerging. However, take care to ensure that there is sufficient topsoil to do this without bringing sub-soil up to the surface.

Crop debris should also be quickly destroyed after harvest is completed, if there has been a heavy infestation of leafminer – to prevent more adult leafminer from hatching from the crop debris. However, crop debris is not always a problem…since if biological control has been good, it may be possible that more *Diglyphus* than leafminer will hatch from crop debris! (see below).

Non-chemical control:

The indigenous parasitic wasp, *Diglyphus isaea*, is the best method of control for leafimer since it lays eggs prolifically and actively flies in search of leafminer lavae in which to lay its eggs. *Diglyphus* will naturally migrate into crops, if they are not sprayed and it is important for the scouts to be able to identify this parasitoid wasp.

An effective IPM scouting system will determine the ratio between the *Diglyphus* and the leafminer adults.

If the ratio is 1:3 or below (ie one *Diglyphus* adult for 3 leafminer adults) then the leafminer is under control and no actio needs to be taken.

Diglyphus is registered as a crop protection agent with PCPB in Kenya and it is mass reared locally.

The wasp lays eggs inside the leafminer larvae within the leaf. The leafminer larva eventually dies and the *Diglyphus pupates* within the leaf, to emerge later as an adult wasp.

Mass rearing courses are available in Kenya and advice about how to harvest the naturally occurring *Diglyphus* from old crop debris.

Trichogramma wasp

Control with pesticides:

Chemical control is quite problematic because the larva is endophytic (develops within the leaf sheltered from pesticide treatments). Actual effective pesticides are very few and pesticides harmful for natural enemies must be avoided. Curative treatments are scheduled according to the intervention threshold. Scout the field mainly from emergence to beginning of harvesting.

Monitoring methods:

Flies of this species are black and yellow, so they can be clearly seen flying around host plants and above the leaves. They feed on the leaves, leaving small round feeding marks which can be distinguished from the eggs which they lay in the leaves, as these are oval shaped white marks. The eggs hatch into leafminer larvae, which feed on the leaf tissue and make tunnels or mine in the leaf blade – hence their name…'leafminer'.

The leafminer larva exits from a tunnel to pupate in the soil. Pupation casings can sometimes be found on the leaf surfaces, but in most cases the satiated larva will quickly find its way to the soil. This behaviour is often noted under dry weather conditions as the larva-pupa must seek shelter to avoid drying out on the leaf surfaces.

Tunnel damaged leaves should be collected in polyethylene bags and transferred to a press as quickly as possible. Leaves containing larvae that are to be kept for rearing should be placed in individual bags that are then filled with air and sealed. Pupae should be transferred into separate tubes where they are kept until emergence of adult flies. These adults are retained in the glass tubes for at least 24 h. Condensation within the tube should be avoided because the flies could stick to the walls after emergence. Adult flies are collected in the field by net trapping.

The use of yellow sticky traps, which are placed around the crop plant, is a very efficient sampling and infestation assessment method.

However, it is not advisable to use these routinely or for mass trapping except in severe infestations, since the yellow sticky traps also catch *Diglyphus* which is a very efficient parasitoid wasp that controls this pest without the need for any pesticides. Leafminer prefer to sit on horizontal surfaces rather than vertical surfaces and will therefore be more effetive if placed horizontally in the crop.

Legume pod borer

Scientific name:

Maruca testulalis (*Maruca vitrata*)

Other host plants:

Fabaceae, Cajanus cajan (pigeon pea), *Phaseolus lunatus* (lima bean), etc.

Symptoms and damage:

M. vitrata belongs to a group of lepidopteran pod borers. It is broadly distributed in tropical areas, especially in West and East Africa. Other pests such as *H.* ***armigera*** or dipterans can occur simultaneously in crop fields. The crop damage caused by *M. vitrata* is usually not distinguishable from that caused by other pests of the group present, but this insect is generally considered to be one of the major pests of the group (especially in India, but less in Kenya for instance).

Yield losses range from 33 to 83% (Tanzania), but are often around 60%.

The larvae bore circular holes in the corolla of flowers; the pods become deformed because of the larger larvae that they contain. The damage caused by this pest includes round bore holes in the corolla, which can turn the flowers into a brownish mass within 24 h.

Conditions conducive to infestation:

This nocturnal lepidopteran insect requires high relative humidity conditions. The egg stage lasts around 3 days at 24-27°C. When flowers are present at the onset of the rainy season, a few first instar larvae, which are initially grouped, are able to disperse later. Young larvae feed on leaves and pods during the 13-14 day larval stage at 24-27°C. The pupa stage lasts around a week. The adults are inactive during the day and can be found roosting on the lower plant leaves. Several generations a year (up to 7) are possible. The alternating flowering patterns of the different host plants along a south-north gradient induces *M. vitrata* migration from the coast towards the West African savanna regions. During this migration, the pod borers find suitable reproduction conditions on different crop plants, thus boosting the size of each new generation. Up to 1500 adults can be captured per night in light traps during the growing season, with peak captures of 5000 butterflies a night reported in northern Benin.

Susceptible growth stages of crop:

Flowering and fruiting phases (fruit set to harvest).

Preventive control:

Studies carried out for 10 years on crop rotations in Kenya revealed that the sorghum-pea association is the most effective in reducing pod borer populations. This also applies to the corn-sorghum succession, whereas the corn-sorghum succession was found to be the most detrimental combination.

Non-chemical control:

The introduction of resistant or tolerant varieties or late flowering cultivars is an alternative strategy for controlling these pests, especially when bean varieties are cropped in alternation with corn varieties (Tanzania). Tests were carried out to assess the impact of introducing natural enemies (Mauritania, 1950) and, on the basis of the results, two species, i.e. *Bracon cajani* and *Eiphosoma dentator*, were subsequently introduced in this geographical area.

Control with pesticides:

Preventive chemical control treatments should be carried out weekly from fruit set onward and throughout the harvest period. There is currently less dependence on chemical products for controlling this pest, partially because of the development of resistance phenomena, especially in Nigeria where pod borers have shown resistance to cypermethrin, dimethoate and endosulfan.

Alternative control methods are thus recommended, and these products should only be used when there are no other options. Pesticide foliar spray treatments with cypermethrin, endosulfan and monocrotophos, beta-cyfluthrin and deltamethrin have, nevertheless, been widely used in the past (1990s). Alternative pesticides such as neem (*Azadiracta indica*) oil extracts are sometimes more efficient for controlling pod borers than some other products such as carbaryl or lambda-cyhalothrin, i.e. providing protection against third instar larvae within 2 days posttreatment.

Monitoring methods:

The adult is a pyrallid moth measuring around 25 mm that keeps its wings spread when roosting. The moths can be observed on the lowest leaves during the day, but it is more efficient to attract them at night with a light trap. The wings of adults are brown with white markings. They have a brown head. The eggs are yellowish-white, translucent and look like fine separate water droplets. The size of the pupae ranges from 2.5 to 11.5 mm. The flowers should be examined to detect circular holes bored by the larvae and signs of pod deformation.

Mylabris beetles

Scientific name:

Mylabris spp.

Other host plants:

Arachis hypogeae (peanut), *Sorghum* (sorghum), *Solanaceae* (tomato, pepper, etc.), *Cucurbitaceae* (cucumber), etc.

Symptoms and damage:

Adult beetles are 25-35 mm long. They are blackish with wide yellow or reddish transversal stripes on the elytra.

The tips of the antennae are also yellow or orangy. They consume the flowers (which leads to abortive pod set) and sometimes bore wide holes in the leaf blades. Entire fields can be quickly defoliated by these beetles since they often massively colonise crop fields.

The *Mylabris* beetle is not a common pest in Kenyan French beans but this information is included for completeness as pest profiles of crops can change and it is useful to be able to identify potential pests.

Conditions conducive to infestation:

They mainly occur in the rainy season (from August, but also in November and December in Senegal).

The eggs are laid in the soil by groups of at least 100 after 2 weeks. The larvae live underground and feed on grasshoppers. The adults emerge just after flowering of the bean plants. They assemble around the flower organs and live for 2 weeks.

Susceptible growth stages of crop: Mainly the flowering stage.

Preventive control:

It is especially important to thoroughly till the soil in order to expose the larvae so that they will subsequently dry out or be killed by the cultivating implements. Measures should also be taken to avoid permanent soil moisture due to rainfall. Crop rotations are also recommended.

Non-chemical control:

It is possible to collect these insects manually, especially when many farm workers are available.

Control with pesticides:

It is generally hard to control these beetles with chemical pesticides because they are highly resistant to such products, which means that more powerful active ingredients would have to be used and high doses—which is not possible when treating crops that are to be marketed for human consumption.

Monitoring methods:

The adult beetles can be trapped in yellow containers or by other methods, such as wrapping a piece of cloth around the base of a plant which is shaken so that the beetles will fall onto the cloth.

Red spider mite or two-spotted spider mite

Scientific name:

Tetranychus spp.

Other host plants:

Gossypium (cotton), *Citrus, Abelmoschus esculentus* (okra), *Lycopersicon esculentum* (tomato), *Cucurbitaceae* (cucumber), *Arachis hypogaea* (peanut), *Carica papaya* (papaya), *Citrullus lanatus* (watermelon), *Ipomoea batatas* (sweet potato), *Solanum melongena* (aubergine), *Solanum tuberosum* (potato) commercial flower crops and local weeds…

Symptoms and damage:

Yellow spots are noted on the upper side of leaves, while small mobile mites (0.5 mm) are found on the under side. A very fine web may be noted when these mites occur in high numbers.

Plants grow poorly when they are heavily infested, and the leaves become deformed and often fall. Infestation occurs in concentrated patches, with mites often migrating from heavily attacked neighbouring crops.

Conditions conducive to infestation:

This pest can increase dramatically during dry weather (in Senegal, especially from March to August), whereas high rainfall quickly reduces spider mite outbreaks. Red spider mites develop very rapidly, particularly under high temperature conditions, i.e. around 9-12 days at 30°C.

Susceptible growth stages of crop:

Before flowering and especially from flower bud formation until harvest.

Preventive control:

If local spider mite control is not good, it is recommended to avoid growing beans in or near fields that have undergone heavy previous spider mite infestations, or where susceptible trees (papaya, etc.) are growing. Since spider mite moves on wide currents, it is useful to ensure that young plantations are planted upwind of older infested crops, to minimise the migration of spider mite in the wind onto new crops. Windbreaks can also be used to slow migration.

Excessive nitrogen fertilisation and enclosed fields without aeration should also be avoided. Crop residue should be collected and burned immediately after harvest if the spider mite infestation has been very high. However, if biological control has been used, the leaves at the end of a crop's life should be checked before they are destroyed, since they may have more *Phytoseiulus* on them than spider mite and the leaves could then be used to transfer the *Phytoseiulus* to other crops. It is important to use a hand lens for this purpose because the leaves may be severely damaged by the spider mite feeding, but this could just be 'historical' damage, since there may not be many spider mite left if the *Phytoseiulus* has developed in this crop. The grower may even decide to leave the crop in the ground and even water the crop, to allow the *Phytoseiulus* population to develop to a stage where there are very few spider mite but a preponderance of *Phytoseiulus*.

Good weed control will allow more effective spray penetration to the underside of the crop's leaves. Many weeds are also a host for spider mite.

Finally, sprinkler irrigation will limit damage.

Non-chemical control :

The predatory, Phytoseiid mite *Phytoseiulus persimilis* has been successfully used to control spider mites in both field and greenhouse crops. It is very specific in its host range, feeding almost entirely on spider mites. If the prey population is eliminated, the *Phytoseiulus* will either move out of the crop and into the surrounding area in search of spider mite, or it will become cannibalistic and attack other *Phytoseiulus*. There is no negative environmental impact from *Phytoseiulus*, which is used in most countries of the world as a commercial means of controlling spider mite.

Phytoseiulus is a predatory mite, which moves much faster on leaves than spidermite.

It has a red, pear-shaped body with a glossy appearance and is slightly larger than spidermite.

Phytoseiulus is registered in Kenya by PCPB as a biological control agent for spider mite and it is mass reared commercially in Kenya.

At a temperature of about 18°C an adult *Phytoseiulus* female lays 50-60 eggs; these will hatch in five days and the life cycle is completed in 9-11 days. This progress from egg to adult is twice as fast as spider mite which takes about 21 days from egg to adult at 18°C. The predator can live up to 26 days.

Although red spider mite can reproduce very rapidly as temperatures rise, *Phytoseiulus* will complete its life cycle twice as fast as spidermite is able to do so at the same temperature.

The daily multiplication rate of *Phytoseiulus* is 1.25 times. Multiplication per generation is 44 times. At 20°C predator populations will increase 300 times in 30 days. At 26°C predator populations will increase 200,000 times in 30 days. With an introduction rate of 30,000 *Phytoseiulus* per hectare in field crops it is possible to build up phenomenal numbers and the build up of predators can be easily monitored.

It is this speed of reproduction and the morphology of *Phytoseiulus*, which enables it to get underneath the webbing that makes this predator more effective at controlling spidermite than pesticides.

However, if the introduction rate of *Phytoseiulus* is properly matched to the field spidermite population, the problems caused by excessive temperatures can be minimised.

Predatory mites have the advantage over pesticides in that they will actively move to the underside of leaves in search of spidermite. It is not possible for spidermite to become resistant to attack from predators.

If the grower has access to sufficient *Phytoseiulus* at a reasonable cost, it is feasible to apply enough predatory mites to 'clean-up' a farm and reduce the 'pest status' of spidermite.

Types of *Phytoseiulus* 'Products':

Phytoseiulus can be supplied to growers either in a bottle of vermiculite (an expanded clay particle used simply as a carrier) or on freshly harvested bean leaves. The *Phytoseiulus* are actually reared on bean plants, so the leaf will have all stages of the *Phytoseiulus* present (adults, juveniles and eggs). There may also be a small amount of spider mite on the leaf as well. This is not a problem and should be considered a 'packed lunch' for the *Phytoseiulus*! If it does not have something to eat --it has less chance of establishing in the crop.

Extreme care must be taken with the *Phytoseiulus* in transport to the farm. They will not establish if they die. If the bottle with vermiculite in it gets too hot the vermiculite will dry out and even dehydrate the *Phytoseiulus* inside the bottle – killing them. If condensation arises inside the bottle, the *Phytoseiulus* in the bottle will drown.

Phytoseiulus, which is provided on a fresh bean leaf, should remain alive as long as the leaves are stacked carefully on top of each other in thin layers and held between sheets of tissue paper. It is easy to see if the leaves are 'old' because they wil be brittle and dehydrated. It is easier to examine the number of *Phytoseiulus* on a bean leaf rather than in a bottle of vermiculite.

Never store *Phytoseiulus*. Always apply it as soon as it arrives on the farm, having already checked that the spray programme is compatible.

Establishing *Phytoseiulus* in a crop :

Introduction strategies

Never apply *Phytoseiulus* to a crop, which is heavily infested with spider mite. Always apply a prophylactic introduction of *Phytoseiulus*, early in the life of the crop - whether scouts see spider mite in the crop or not. Make a minimum of two applications between two and four weeks apart. The minimum individual application should be 15,000 *Phytoseiulus* per hectare.

If a prophylactic programme is adopted – the *Phytoseiulus* applications should begin before spider mite is observed in the crop. In this case – the introduction rate for *Phytoseiulus* does not need to be calculated, based on the total spider mite population in the crop – as there is not likely to be much present. The grower would just apply a minimum of 15,000 *Phytoseiulus* per hectare.

However, a grower will need to assess spider mite populations before applying *Phytoseiulus* only if:
The introduction is made LATE to a crop and spider has already become a problem (not ideal – as you will need a lot of *Phytoseiulus*)

OR

the *Phytoseiulus* do not establish (because of a harmful spray or lack of food) and you want to re-introduce *Phytoseiulus* and need to know how many to apply. (see section on remedial action and how to estimate total field populations)

If the risk of spider mite build-up is high (hot weather coming or a flower crop with low tolerance of pest damage) – then modify the introduction strategy as follows:

- reduce the time between applications (one to two weeks apart),
- continue making applications until scouting indicates that the ratio is less than 1:5 (*Phytoseiulus* to rsm). If you have plenty of *Phytoseiulus*, try to bring this down to 1:1.

OR

- assess the total spider mite population per hectare by sampling and calculate introduction rate for *Phytoseiulus* which ensure a ratio of at least 1:10 or lower – in one application.

Field guide – application methods :

Phytoseiulus may be available either as a freshly harvested product on leaves or in a plastic bottle with vermiculite inside (this is just used to help distribute the *Phytoseiulus* and it is inert) Never store *Phytoseiulus*, always use it as soon as it arrives on the farm.
If it has to be stored, do so in a domestic fridge at 5 deg. C for no longer than 24 hrs.
Only order the *Phytoseiulus* when you are ready to apply it, having organised the spray programme to ensure that no harmful sprays have been applied recently and there are not plans to apply harmful sprays within 2 weeks after the application of the *Phytoseiulus*. (See Appendix for pesticide sensitivity charts) It is important to apply predators as evenly as possible. If predators are applied unevenly into a crop, the spider mite on plants between those, which received *Phytoseiulus*, will remain untreated until the predators have eaten the entire spider mite on the plants to which they were originally applied. This may result in hot spots of high spider populations, which` will be more difficult to control biologically.
Biological control of red spidermite may take several weeks to complete.

To avoid damage to the crop the manager must make this process as quick as possible by:

1. applying *Phytoseiulus* on a prophylactic programme early in the life of the crop (minimum strategy is - 15,000 per hectare in wk 3 and 15,000 again in week 6),
2. distributing *Phytoseiulus* as evenly as possible (a piece of transfer leaf at every meter along the planting row – so the distribution can be checked easily by the supervisor),
3. applying small amounts of spider with the *Phytoseiulus* (these will come on the transfer leaf),
4. if some spider is already present in the field, ensure the *Phytoseiulus* is applied to these areas without fail. (train staff to recognise spider mite damage on the leaf – as well as applying to every meter along the row – these areas should also receive extra *Phytoseiulus*),
5. apply the leaves with the *Phytoseiulus* on them, with the underside of the transfer-leaf, facing the ground – so the *Phytoseiulus* eggs do not dry out in the sun,
6. wedge the transfer-leaves between leaf stalk and the stems, lower down in the canopy – so they do not blow away before the *Phytoseiulus* have walked off the transfer-leaf on to the crop.

Measuring biological control

It is possible to measure biological control by weekly monitoring of leaf samples to determine the ratio of predator to pest – just as advised with leafminer and *Diglyphus*.

In this way, if historical weekly records are kept, the progress of the ratio (*Phytoseiulus* to spider mite) over a period of time can be measured and the success of the biological control programme is determined.

The ratio of *Phytoseiulus* to red spider mite at the time of introduction and the average temperature at that time will influence the time it takes for the *Phytoseiulus* to eliminate the red spider mite.

If the ratio of *Phytoseiulus*:rsm is 1:500, it will take longer to get control, than if the ratio was 1:50 or even 1:5. This is logical.

Assuming a prophylactic introduction of *Phytoseiulus* has taken place early in the crop, before spider mite is present – the following scouting method should be used.

After introduction, the *Phytoseiulus* will actively search for spidermite – therefore when monitoring check only the leaves with spidermite damage – this is where the mites are – so this is where any *Phytoseiulus* will be.

Compatible spray programmes

If an IPM programme is adopted for spider mite – all prophylactic sprays for spider mite must be removed from the programme immediately.

Acaricides will kill *Phytoseiulus*.

Other sprays, including fungicides will also kill some Phytoseiulus.

However, scouting will indicate if further introductions are required to compensate for any negative affect of the fungicide/pesticide programme. (See Appendix for pesticide sensitivity of *Phytoseiulus*) A successful IPM programme needs:

- The absence of harmful pesticide residues on the leaves from the previous spray programme. NB: This is NOT the same as the Pre- Harvest Interval.
- A compatible spray programme after introduction of *Phytoseiulus*. Bear in mind that even a 'safe' pesticide is likely to kill 25% of *Phytoseiulus*.

Always organise the introduction of Phytoseiulus to take place AFTER a spray application (including fungicides) – as these will kill some *Phytoseiulus*. Never apply *Phytoseiulus* just before a spray application – give them a chance.

In a successful IPM programme, the crop itself is a good breeding ground for beneficial insects, It has been possible to produce about 100 million in half a hectare over seven weeks – by putting *Phytoseiulus* into a badly infested crop in about week 8.

These can then be moved around the farm, to introduce *Phytoseiulus* into young blocks.

Amblyseius californicus

Another predatory mite is regsitered in Kenya by PCPB as a biological control agent for spdier mite. Amblyseius is indigenous to Kenya and it has the advantage that it is generally more resistant to pesticides than *Phytoseiulus*. It can also survive for longer without spider mite being present since it can also feed on pollen. If spider mite is not present it will prey on the very young stages of thrips.

Control with pesticides:

Preventive or curative treatments should be conducted during the vegetative phase to ensure that infestation levels are very low at the beginning of harvest.

Acaricide resistance phenomena have also been documented in spider mites. Resistance can quickly develop within a relatively small number of generations along with cross-resistance to other acaricides. These products should therefore be carefully chosen and only used when absolutely necessary. A resistance management strategy drawn up by IRAC (Insecticide Resistance Action Committee) involves changing active ingredients belonging to different chemical families with the aim of extending their efficacy time.

Monitoring methods:

Spider mites can be detected on the basis of leaf symptoms, but it is better to pinpoint them prior to symptom development.

Regular sampling of leaves is required and they should be examined under a magnifying glass or microscope.

The eggs are spherical (0.15 mm diameter), initially translucent, and then take on a pearl-like quality, sometimes with a pinkish tint. The larvae are beige in colour and as they feed they develop two black spots in the abdomen (hence their name). These spots are their guts filling up with the plant sap, which is dark green when concentrated and eventually looks black. The two spots can merge into one if the spider mite has bee feeding excessively.

Each nymphal instar has eight legs. On the equator, in Kenya, the spider mite does not enter diapause (hibernation) like it does in Europe where the growing season is broken by a long, cold winter. However, it can exhibit symptoms similar to the European 'summer diapause' and it will turn red if it is stressed for some reason. This will happen when the spider mite population on a plant is very high. This causes the plant to suffer and the nutritional quality of the plat sap goes down – this stresses the spider mite because this is its sole food source. It turns red because its slows down its development rate in relation to the quality of the sap.

The red pigment is a feeding deterrent to potential predators and it is important to take this into account if the grower is using biological controls for this pest – as *Phytoseiulus* may not be so efficient if there is a preponderance of red spider mite. In this situation the spider mite may also migrate to the top of the plant, form a silken strand to dangle itself in wide currents. This is how it migrates to find other host plants.

Armyworm

Scientific name:

Spodoptera exigua

Other host plants:

Zea mays (corn), *Gossypium* (cotton), *Lycopersicon esculentum* (tomato), *Oryza sativa* (rice), *Pisum sativum* (pea), *Solanum tuberosum* (potato), *Solanum melongena* (aubergine), etc.

Symptoms and damage:

Young larvae feed on the superficial layer of leaves, often leaving the epidermis and large veins intact. Later instar larvae pierce irregular holes in the leaves and fully developed larvae can consume all of the leaves, leaving only the main leaf ribs.

Conditions conducive to infestation:

The eggs are deposited at night on host plants on the under sides of the lowest leaves. The 6-stage larval development process is determined by a combination of diet and temperature conditions, with temperatures required to go from the egg to the larva and then pupa stages being 13, 15 and 15°C, respectively. This development period lasts from 10 to 12 days at 28°C, but can last for 35 days at 16°C. The larvae vary in colour but are often green and range from 20 to 30 mm in size. The adults emerge at night and live for 8-11 days.

This a tropical and subtropical butterfly species that is adapted to hot regions, with an optimal temperature of 28°C for larvae. There can be 4- 6 generations annually in these regions. Activity and development are stalled at lower temperatures, and all stages are killed during cold periods. *S. exigua* winters in hot regions of the Mediterranean Basin and Africa.

Susceptible growth stages of crop:

All stages, from sowing to harvest, but the worm shows a preference for the flowering, fruiting and vegetative development stages.

Preventive control:

One control technique involves exposing larvae and pupae on the soil surface so that they will dry out and die. Weeding is also recommended in order to destroy all potential shelters for this pest.

Non-chemical control:

The importance of natural enemies has been demonstrated, with a wide range of arthropod predators (ground beetles), parasitoids (braconid wasps, *Ichneumonidae, Trichogramma*, etc.) and pathogens (*Bacillus* spp., viruses, etc.). A molecule called volicitine is secreted by *S. exigua* larvae and can be applied on damaged leaves (corn) to trigger the release of volatile compounds that attract the female pests along with the parasitoid *Cotesia marginiventris*.

Improvement programmes have been set up to boost resistance to *S. exigua* in corn–leaf hardness was thus enhanced and the leaves were induced to secrete *B. thuringiensis* toxins that are harmful to armyworm larvae.

Control with pesticides:

Scout the field and treat if necessary.

Monitoring methods:

Detection of this pest is facilitated by looking for signs for feeding damage caused by the larva. Pheromone and light traps can also be used.

Thrips

Scientific names:

Frankliniella occidentalis (Western Flower Thrips),

Megalurothrips sjostedti (African bean flower thrips), *Calliothrips impurus* and *Sericothrips occipitalis*

EU Notifiable Pest Note that Thrips palmi is a notifiable pest in the EU and scouts should be trainined to distinguish this species. There are also some predatory thrips species.

Other host plants:

Zea mays (corn), *Oryza sativa* (rice), *Arachis hypogeae* (peanut), *Gossypium hirsutum* (cotton).

Symptoms and damage:

Punctures caused by thrips induce tissue discoloration and metabolic disorders in the plant, which thus weakens and wilts.

Conditions conducive to infestation:

These pests are well adapted to the hot climate (25-30°C) of tropical and Sahelian countries. Their development is also favoured by the presence of weeds and secondary host plants.

Both species, the African bean flower thrip (ABFT), *Megalurothrips sjostedti* (Trybom) and the western flower thrip (WFT), *Frankliniella occidentalis* Pergande, have almost identical ecological requirements, however, under hot and dry conditions, WFT out-competes ABFT and displaces it almost completely.

Susceptible growth stages of crop:

From the seedling to the flowering stage.

Preventive control:

It is often virtually impossible to eradicate secondary host plants that could be virus reservoirs or harbour thrips. It could, however, be useful to plough and harrow the fields after harvest in order to kill larvae remaining in the ground and adults on the vegetation.

Sowing could also be done at an earlier date and sowing rates could also be modified.

Non-chemical control:

In Kenya, thrips are mostly of commercial significance during the dry seasons, which constitute almost six months of the year – and may cause down grading losses of up to 20%.

Thrips control strategies may benefit from the following additions.

- In many crops, there is a pattern in the activity of thrips on crops. In some areas, it has been observed that thrips emerge onto the outside of flowers and the upper surface of leaves from about 7.30 to 8.30 am and from 4.30 to 5.30 p.m. It is possible to confirm this locally if scouting is undertaken every half hour from 6.30 am onwards. Thrips do this for social reasons, and are otherwise either flying or tucked very tightly inside flowers or on the underside of elaves. They are difficult to kill when they are hiding , so it is best to spray when they are exposed, on the upper surface of leaves and on the outside of flowers. Contact insecticdes could then be used instead of the systemic organophosphates which tend to be more harmful to operators and the environment.
- After very hot dry spells, thrips become very thirsty and feeding damage will increase on the plant as they scrape moisture from leaves and petals. If during the dry spell, there is a heavy downpour of rain in the late afternoon, this often brings thrips out onto the outside surface of leaves and flowers during the evening. If this happens, this would be a good time to spray, as more would be killed.
- Providing the top-soil depth is adequate, deep ploughing of heavily infested thrips blocks will bury the thrips which pupate in the soil. Do not deep plough, if sub-soil is brought to the surface, as this will reduce subsequent yields.

- Varieties could be used that are tolerant or less susceptible to thrips, but this is often a difficult practice to apply on account of the high price of the seed.
- Thrips parasitoids and predators, including some Hymenoptera, can also be used. Amblyseius californicus is registered in Kenya as a biological control for spider mite but it will also eat the younger stages of thrips.
- Other predators such as Orius are very common in Kenya and can have a significant impact on thrips numbers. Scouts should be trained to recognise this natural enemy. Mass production systems for this natural enemy have been developed and training is available in mass rearing systems.

Adult *Orius* feeding on young thrips larvae

Planting sunflowers and maize in windbreaks will increase the number of *Orius* in the locality.

Control with pesticides:

Scout the field and treat if necessary.

WFT has developed very high levels of resistance against most pesticides while ABFT is easily controlled and pesticide resistance is not known in East Africa.

Monitoring methods:

Thrips are very small and therefore hard to detect, and this is also problematic with respect to taking quarantine measures.

The larvae and adults are gregarious feeders that first attack the leaves along the veins. On stems, they especially attack the terminal buds but they are also sometimes detected on the petals. Feeding stains also indicate the presence of this pest.

There are two major thrips species affecting French bean production in Kenya: the African bean flower thrip (ABFT), *Megalurothrips sjostedti* (Trybom) and the western flower thrip (WFT), Frankliniella occidentalis Pergande. The former is considered endemic while the latter is an introduced species and originates in the New World. The species are easily distinguished in adult stage (ABFT is black and much larger while WFT is pale brown), however, thrips larvae are difficult to distinguish and therefore always counted together.

The biology of the two species is rather different: WFT can be found in the bean crop at low numbers from germination as it can feed on young leaves. ABFT only appears in the crop from flower bud formation, as it does not reproduce on the leaves. However, at the onset of flowering, all thrips move from the canopy to the flowers, which are therefore the most suitable crop organ for assessing populations.

Looper caterpillar

Scientific name:

Trichoplusia ni

Other host plants:

Brassicaceae, Malvaceae, Cucurbitaceae, Solanaceae

Symptoms and damage:

Large irregular holes on the surface of leaves is a sign of looper caterpillar feeding.

Conditions conducive to infestation:

The adult moths fly at night and roost on crop residue when it is present. They feed on plant nutrients from different hosts. The eggs are deposited individually on the plants, and there can be up to 5 larval instars depending on the temperature conditions. The larval stage normally lasts 2-4 weeks and pupation lasts 2 weeks.

Susceptible growth stages of crop:

All stages, especially during vegetative growth.

Preventive control:

Residue from bean crops and other nearby crops that could be possible hosts for T. ni should be destroyed in order to eliminate refuge areas for the moth.

Non-chemical control:

Many micro-organisms of potential interest for biological control of this pest have been isolated in the field. Commercial preparations with *B. thuringiensis* and other fungi can also be applied in crop fields. There are at least 68 species of T. ni parasitoids, including *Trichogramma* wasps, which are very promising because they prey on and kill T. ni eggs, thus avoiding potential larval damage to crops.

Parasitoids and predators can be introduced by small-scale releases with the hope that these beneficial organisms will subsequently propagate. Many studies have focused on assessing different cultivars that host T. ni larva, but so far no resistant cultivars have been developed with the aim of reducing economic losses.

Control with pesticides:

Scout the field during vegetative phase and treat if necessary.

Monitoring methods:

Methods for detecting T. ni vary according to the development stage of this insect. The larvae, like most defoliating insects, can be sampled by inspecting leaves in the field. However, a minimum level of knowledge on the spatial distribution of these pests and on the larval traits is necessary. The intervention threshold can be set on the basis of the sampling results. Pheromone traps can be used to sample the adult moths.

Bean fly

Scientific name:

Ophiomyia spencerella, O. phaseoli and *O. centrosematis*

Symptoms and damage:

Adult flies are more active in the late evening or early morning lay eggs in the leaves of young plants, near to the leaf petiole. The eggs hatch into a small white larvae which tunnels it way from the leaf , down through the leaf petiole and into the stem. It burrows through the stem and pupates inside the stem near to the base of the plant. Adult flies emerge from the pupae in the stem. The stem tunnelling causes death of young plants and heavy and early infestation often result in complete crop loss.

Conditions conducive to infestation:

Young plants are the most vulnerable stage and are particularly vulnerable during dry weather, when water requirements of the plants are higher and the damage caused to the stem limits the amount of water the plant can take up.

Plants on the outside edge of a plantation are more exposed to attach from bean fly.

The beanfly larvae feeding in the main stem causes affected plants to yellow and suffer stunted growth. The stem often thickens and cracks lengthwise at the base and affected plants usually die. Young plants are most susceptible though older plants may also be attacked. Late plantings are usually at higher risk. In Kenya, damages are especially serious in December and January but can always be a problem during the first sunny days after a period of rain.

Susceptible growth stages of crop:
They attack beans from the time of germination.

Preventive control:
It is easier to control this pest preventatively by insecticide seed treatment. Removal of leaves which have egg laying marks on them will reduce the number of larvae produced and subsequently reduce the number of egg-laying adults which would otherwise have emerged from the stem in the second generation.
Plants, which have died from bean fly attack, should be thoroughly rougued from the plantation so that the flies do not emerge and re-invade the crop. This is particularly important if the grower is re-planting part of his crop due to bean fly attack, since he will be providing more of the most vulnerable stage of the plant (seedlings) when the second generation emerge from the first planting. Plants should not just be pulled out and left to dry out by the side of the crop, since the bean fly can still emerge from a dried out stem. The old plants should either be fed to animals (if there is no pesticide residue) or buried. Even if the plants are kept in a plastic bag and left in the heat for a couple of weeks this should kill any flies that emerge from the stems.
Sometimes ridging up the infested plants around the site where the bean fly pupae are obvious, can reduce the number of adult flies which emerge, since they are blocked in by the heaped up soil.

Non-chemical control:
There are natural enemies, parasitoids, for bean fly but they are not mass produced.

Control with pesticides:
In Kenya, the best method of control is seed treatment. If this is expensive, it may be economic just to treat seeds during the peak periods of the year when bean fly is anticipated.

Monitoring methods:
Newly planted crops need to be closely monitored for signs of egg laying on leaves. Stunted wilted plants will also indicate presence of bean fly. However, these plants are hosting the next, larger, generation of bean flies and action needs to be taken quickly.

Bean seed fly

Scientific name:
Delia platura

Other host plants:
Phaseoulus beans (esp. runnerbean), cabbage, onion, pea, potato, radish, cauliflower and sunflower.

Symptoms and damage:
The larvae feed on the germinating seed, often hollowing it out completely. The seedlings may fail to emerge or be very stunted. Gaps will appear in the planting. The larvae feed for 1 – 3 weeks and then pupate near the soil surface. Adults emerge from the soil. Females lay about 50 eggs each.

Conditions conducive to infestation:
The adult fly lays eggs in the soil near to germinating seedlings. Areas of the field where there is higher organic matter or where water lies and the soil is therefore more moist, are more attractive to bean seed fly. Plants on the outside edge of a plantation are more exposed to attach from bean seed fly.

Susceptible growth stages of crop:

Germinating seedlings.

Preventive control:

It is easier to control this pest preventatively by insecticide seed treatment

Non-chemical control:

There are no mass-produced natural enemies for this pest. If plants that fail to germinate are checked and the damaged seeds and the larvae removed this will prevent fifty more flies from being produced for each seed removed.

Control with pesticides:

The best method of control is seed treatment. If this is expensive, it may be economic just to treat seeds during the peak periods of the year when bean seed fly is anticipated.

Monitoring methods:

Bean seed fly is easily found if the areas where plants have failed to emerge are examined. The damaged seed will have a white larva within it near to the seed.

Root-knot nematodes

Scientific name:

Meloidogyne spp.

Other host plants:

Arachis hypogaea (peanut), *Musa* (banana), *Oryza sativa* (rice), *Solanum tuberosum* (potato), *Lycopersicon esculentum* (tomato); almost all market-garden crops except onion, mint, strawberry, garlic and leek.

Symptoms and damage:

The larvae penetrate the roots and settle in the vascular area, inducing swellings or galls. The shape, size and appearance of the galls varies with their age, number, the host plant, extent of attack, *Meloidogyne* species involved, and environmental conditions. Under heavy infestations, the roots can become swelled and stunted. The decreased branching of the root system and metabolic problems resulting from the presence of root-knot nematodes lead to poor plant development and gradual reductions in yield. The root injury caused by *Meloidogyne* nematodes also facilitates attacks by other phyto-pathogenic micro-organisms *(Pythium, Fusarium, Rhizoctonia)*.

Root knot nematode is often confused with the normal nodulation of legumes by the nitrogen-fixing *Rhizobium* bacteria. *Rhizobium* nodules are round and attached to the outside of the root, whereas root knot nematode is a swelling within the body of the root.
Rhizobium nodules are often pink inside if they are actively fixing nitrogen.

Conditions conducive to infestation:

The lifespan of one generation of *Meloidogyne* spp. nematodes is highly dependent on the temperature conditions. At very high temperatures (above 29°C), the cycle lasts around 3 weeks but it can last as long as 3 months at low temperatures.
Crops are at risk of nematode attack throughout the year but especially during hot periods, with cardinal temperatures of 14°C-28°C-32°C.
Excessive irrigation promotes the dissemination of root-knot nematodes.

Susceptible growth stages of crop:

From emergence to flowering.

Preventive control:

The soil should be tilled and it is especially important to carefully eliminate infected crop residue from the previous season.

Successions of bean crops, or of bean crops with other crops that also host root-knot nematodes, should be avoided.

Soil infestation levels can be reduced by flooding irrigable fields to asphyxiate larval and adult nematodes, by introducing bare or tilled fallows in the dry season, or by implementing suitable crop rotations.

Infestations can be reduced by applying well decomposed organic matter along the sowing lines. It is obviously highly recommended to uproot and destroy the bean plants right after harvest. Susceptible windbreaks should also be avoided (*Euphorbia, Prosopis*) as well as associations of susceptible plants with different cycles (papaya, etc.).

Non-chemical control:

There are some biological control agents under development in Kenya (*Pasteuria, Pochonia*) as well as registration in progress of imported biopesticides for nematode control. In Kenya, PCPB should be contacted for further information as the Registrations are approved. Root knot nematode (*Meloidogyne incognita*) can become a problem if the crops grown on that ground which are a host to root knot nematode (okra, beans, chilies etc) and the non-host crops (brassicas and babycorn) are not in balance with these in the planting programme.

Dwarf Mexican marigold as a trap crop for root knot nematode (rkn) is a useful break crop if there are many rkn-susceptible crops grown on the land. Root knot nematode will enter the roots of the marigold but does not complete its life cycle effectively. Therefore the marigold acts like a sponge – mopping up levels of root knot nematode in the soil. However they will only attract nematdes which have hatched from egg masses and do not kill the egg masses which may have been dislodged when the previous infested crop was removed.

The relative levels of rkn per block should be ascertained so that the blocks with high rkn levels are identified and appropriate management can be implemented in a timely fashion. Non-host crops could be planted or other cultural operations, described below, could be prioritised in these blocks.

- Scouts may need training to ensure correct sampling procedures are used for collecting soil samples to asess rkn levels in fields. If the soil samples are too dry or stored incorrectly prior to dispatch to the lab for assessment of rkn levels – misleading information may be provided regarding the levels of rkn in the soil. This is because the extraction of nematodes from the soil sample relies on them being alive to swim out of the soil into water. The nematodes in the water are then counted and identified. If the beans are grown in a hot climate and are a long distance from soil labs, it may be useful to train staff in simple extraction methods, so that water containing nematodes can be sent for analysis, instead of soil samples. This will give more accurate data and it may be cheaper, as the lab does not have to undertake the extraction process.
- Blocks identified with high rkn levels could be planted (full field) with dwarf Mexican marigold at a rate of 8 – 10 kilos/ha of seed. If water is a limiting factor on the farms, it could be organised for these high-risk fields to be removed prior to expected rainy periods, so that rainfall can help establish the marigold 'trap crop'.
- It is important to recognise that weeds, particularly 'MacDonald's Eye or Gallant Soldier (Galinsoga parviflora) are hosts for root knot nematode. To optimise the benefit of marigold, the marigold-planting should be weed-free for at least six weeks, which is the period required to maintain maximum benefit of nematode trapping from the marigold.
- There is no additional benefit from the marigold after six weeks growth. This six week period is a 'growth period' – from germination onwards (not from planting).
- Root knot nematode can be killed by desiccation of soil from discing operations after the removal of the infested crop. A proportion of the rkn egg masses, which remained in the soil after the removal of the crop, will be killed by desiccation.
- The remaining egg masses, that survive the desiccation process, will hatch if the ground is irrigated. Since rkn is an obligate parasite (cannot live in the absence of the host) – it is possible to further reduce the field rkn levels by ensuring a weed-free period of two weeks after the eggs hatch. Any eggs, which hatched as a result of irrigation (or rain) after the desiccation process, will produce nematodes that search for a host.

If they do not find a host within about two weeks – they die.
Scouts would benefit from being able to distinguish the difference between root knot nematode and healthy Rhizobium nodules on legume roots. Rhizobium nodules are external swellings of the root (sometimes pinkish). Root knot nematode egg masses are internal swellings of the root.

Root knot nematode

Rhizobium nodules

Control with pesticides:

Overall or localised treatments should be conducted during preliminary cultivation and localized treatments can also be carried out about 10 days after sowing.

Migratory endoparasitic nematode

Scientific name:

Pratylenchus spp. including *P. brachyurus*

Other host plants:

Poaceae, Solanaceae (tomato), *Cucurbitaceae, Arachis hypogeae* (peanut), *Zea mays* (corn), etc.

Symptoms and damage:

Attacked plants show halted growth, reduced vigour, leaf necrosis and chlorosis, defoliation, brown, reddish or blackish root rot, and a reduction in yield.

Conditions conducive to infestation:

Pratylendus spp. are internal parasites with migration potential. All larval stages can attack roots and move between roots. Most of these species reproduce by parthenogenesis, which is faster at high temperatures (27-32°C), with an optimum at 26°C. The development rate and cycle depend on the host plant and environmental conditions, and especially on the soil temperature, which is optimal for eggs at 35°C. A single generation may range from 14 weeks at 15°C to 4 weeks at 30°C. A temperature of 20°C is required for both root and parasite development. Rain does not seem to have an impact on these species, but increased development has been noted during the rainy season, and nematode damage increases as the humidity decreases. These pests can survive for several months (up to 22 months in Côte d'Ivoire) in the absence of host plants. They can also withstand exposure to high soil temperatures. In the greenhouse, these nematode species can survive for 35 days in very dry soil at 43°C, and their survival is favoured by the presence of root debris. The presence of some fungi such as *Rhizoctonia solani, Pythium, Phytophthora, Ralstonia solanacearum, Fusarium, Penicillium* and the symphite *Hanseniella ivorensis* promotes their colonisation and development. Their dissemination is also promoted by excessive irrigation.

Susceptible growth stages of crop:

From emergence to flowering.

Preventive control:

Crop residue, especially from attacked plants, should be carefully removed from the fields immediately after harvest, and the soil should be kept moist because the nematodes can readily withstand dry soil conditions. Crop rotations are not very efficient for preventive control of this pest because of the broad range of host plant species. However, non-host species can be planted alongside the bean crop (Ivory Coast). In Nigeria, it was also noted that nematode populations are higher in monocropped fields in which NPK fertilizers have been applied. These inputs should thus be reduced. Soil amendments (well decomposed organic matter) seem to reduce nematode populations. Maintaining the soil pH at around 5-6 is also an inexpensive control method recommended for use on smallholdings, thus avoiding expensive nematicide treatments.

Non-chemical control:

Soil infestation levels can be reduced by flooding irrigable fields to asphyxiate larval and adult nematodes, by introducing bare or tilled fallows in the dry season, or by implementing suitable crop rotations. Fungal parasites such as *Catenaria vermicola, Pasteuria penetrans* and *thornei* could turn out to be efficient biological control agents. Planting resistant varieties (pineapple, potato, etc.) appears to be the most cost-effective and efficient way to control these nematodes in the field.

Control with pesticides:

Overall or localised treatments should be conducted during preliminary cultivation and localized treatments can also be carried out about 10 days after sowing.

Monitoring methods:

Typical signs of attack by these nematodes are reduced plant growth, and even chlorosis and defoliation. Patches of infected plants can be noted in the field. Root lesions are a sign of the presence of nematodes, and these infected plants should be carefully uprooted to examine the lesions. For a more accurate determination, a detailed morphological examination of nematodes extracted from infected roots or other plant parts can also be undertaken.

Appendix 10: Identification of main pests and diseases

Pictures credits: Gilles Delhove, David B. Langston, University of Georgia, Bugwood.org

Fungi

Colletotrichum lindemuthianum (Gloeosporium) (Anthrachnose)

Damage on pods

Fusarium solani f. sp. *Phaseoli* (fusarium collar rot)

Death of young plant

Macrophomina phaseolina (stem rot)

Lesion on stem

Pythium spp. (black leg)

Affected pods

Rhizoctonia solani (rhizoctonia black scurf)

Reddish sunken cankers of the collar and dry rot of rootlets

Sclerotinia rolsfii (Corticum rolsfii) (sclerotinia rot)	
	
Wilting of plants	Mycelium and spherical white, then beige, sclerotia
Isariopsis griseola (Phaeoisariopsis griseola) (angular leaf spots)	*Uromyces appendiculatus* (rust)
	
Spots on leaves	Spots on leaves

Bacteria

Pseudomonas syringae pv. *phaseolicola* (halo blight)

Symptoms on young leaves

Hemiptera: Aphididae (Aphids)	*Diptera: Agromyzidae*
Aphis craccivora	*Liriomyza* spp. (leafminer)

Aphis craccivora on leaf

Mines on a leaf

Thysanoptera (Thrips)	*Homoptera: Aleyrodidae*
Different species	*Bemesia tabaci* (Whitefly)

Damage on a leaf

Adults of *Bemesia tabaci* on the underside of a leaf

Lepidoptera: *Noctuidae*

Helicoverpa (Heliothis) armigera

Holes in pods

Pupa of *H. armigera*

Larva of *Helicoverpa armigera*

Nematodes

Meloidogyne spp. (root-knot nematodes)

Galls on the roots

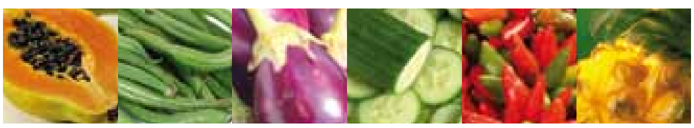
Stunted plants

CROP PRODUCTION PROTOCOLS

Avocado (*Persea americana*)
French bean (*Phaseolus vulgaris*)
Okra (*Abelmoschus esculentus*)
Passion fruit (*Passiflora edulis*)
Pineapple Cayenne (*Ananas comosus*)
Pineapple MD2 (*Ananas comosus*)
Mango (*Mangifera indica*)
Papaya (*Carica papaya*)
Pea (*Pisum sativum*)
Cherry tomato (*Lycopersicon esculentum*)

GUIDES TO GOOD PLANT PROTECTION PRACTICES

Amaranth (*Amaranthus* spp.)
Baby carrot (*Daucus carota*)
Baby and sweet corn (*Zea mayis*)
Baby Leek (*Allium porrum*)
Baby pak choy (*Brassica campestris* var. *chinensis*), baby cauliflower (*Brassica oleracea* var. *botrytis*), baby broccoli and sprouting broccoli (*Brassica oleracea* var. *italica*) *and head cabbages* (*Brassica oleracea var. capitata* and *var. sabauda*)
Banana (*Musa* spp. – plantain (*matoke*), apple banana, red banana, baby banana and other ethnics bananas)
Cassava (*Manihot esculenta*)
Chillies (*Capsicum frutescens, Capsicum annuum, Capsicum chinense*) and sweet peppers (*Capsicum annuum*)
Citrus (*Citrus* sp.)
Coconut (*Cocus nucifera*)
Cucumber (*Cucumis sativus*), zucchini and pattypan (*Cucurbita pepo*) and other cucurbitaceae with edible peel of the genus *Momordica, Benincasa, Luffa, Lagenaria, Trichosanthes, Sechium* and *Coccinia*
Dasheen (*Colocasia esculenta*) and macabo (*Xanthosoma sagittifolium*)
Eggplants (*Solanum melongena*, *Solanum aethiopicum*, *Solanum macrocarpon)*
Garlic, onions, shallots (*Allium sativum, Allium cepa, Allium ascalonicum*)
Ginger (*Zingiber officinale*)
Guava (*Psidium catteyanum*)
Lettuce *(Lactuca sativa*), spinach (*Spinacia oleracea* and *Basella alba*), leafy brassica (*Brassica* spp.)
Lychee (*Litchi chinensis*)
Melon (*Cucumis melo*)
Organic Avocado (*Persea americana*)
Organic Mango (*Mangifera indica*)
Organic Papaya (*Carica papaya*)
Organic Pineapple (*Ananas comosus*)
Potato (*Solanum tuberosum*)
Sweet potato (*Ipomea batatas*)
Tamarillo (*Solanum betaceum*)
Water melon (*Citrullus lanatus*) and butternut (*Cucurbita moschata*)
Yam (*Dioscorea* spp.)



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