Food and Agriculture Organization
of the United Nations

Green Beans Integrated Pest Management

An Ecological Guide

Training resource text on crop development, major agronomic practices, disease and insect ecology, insect pests, natural enemies and diseases of green beans

FAO Inter-Country Program for the Development and Application of Integrated Pest Management in Vegetable Growing in South and South-East Asia

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Why this guide?

About this guide

This Green Bean Ecological Guide was developed by the FAO IPM Programme in Vietnam. This guide is compiled from many documents and reports from Vietnam and abroad on beans, in general, and French beans, in particular.

The objective of this ecological guide is to provide general technical background information on bean production. The information is supplemented with field experiences from National IPM Programmes associated with the FAO Regional Vegetable IPM Programme and from other organizations active in farmer participatory IPM in Vietnam and other countries.

Who will use this guide?

The guide is intended for use of National IPM Programmes, IPM trainers, and others interested in IPM training and farmer participatory research.

Some technical issues in this ecological guide are new and complicated, requiring knowledge from many related sectors. In addition, the guide was prepared over a short span of time and may have some errors. We hope to get feedback and contributions from all readers, IPM trainers and farmers in order to improve it later.

The guide can be used as a reference. It is not an official training document for IPM in vegetable.

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I. General Introduction

1. The Fabaceae (formerly Leguminosae) family

1.2. Characteristics of the family

Most crops in the Fabaceae or Leguminosae family grown for human consumption are annual crops and some perennial varieties. The vegetable legumes have bushy types (such as French bean) and crawling types (such as green peas, long bean, broad bean, etc.). The latter are characterized with new fast growing branches and quickly climbing high. Most of the vegetable legumes in this group originated from the tropical regions in Central Asia and South America. They need high temperature for their growth and development. Low temperature inhibits their development, makes flowering difficult and results in less fruits. The optimum temperature for crops in this group is from 20-30^{o}C.

The light intensity of the typical short day length is suitable for green beans. The impact of sunlight will be strongest at the growth stages before flowering. Short day length during the vegetative growth period will cause stunted growth, reduced plant height, number and length of nodes.

The roots of fruit-vegetable legumes penetrate about 40-70 cm into the soil and expand widely to the surroundings. Leguminous crops are suitable to soil types that are soft and loamy and are rich in phosphate and potassium.

.3. Legume crops commonly grown in Vietnam

In Vietnam, many leguminous crops are currently used as vegetables such as green peas (*Pisum sativum* L.), French bean (*Phaseolus vulgaris* L.), long bean (*Vigna sinensis)* and broad bean (*Dolichos lablab*). The most popular ones are still green peas, French bean, long bean and broad bean.

Green beans are grown year round in all the vegetable cultivation areas. Different varieties in each region have different growing seasons. Green peas are grown from mid-September to mid-October or sometimes last until November. Meanwhile, ®Ëu tr¹ch is sown from September to February (in the northern midlands) or to April (in the Southern cultivation areas). Long bean which is suitable to warm and hot weather is often planted in the summer-autumn season from April to September.

1.4. Main problems: commonalities and differences

Like other vegetables, bean production has many problems. Insect pests and diseases, the major problem, occurs in all bean-growing areas and in every season. They reduce crop yield and reduce the growing area. In addition, because it is seasonal and perishable, the market for beans is one factor that affects crop production.

1.5. Sources of information

See appendices.

2. The bean crop as a farming enterprise

2.1. History

Bean varieties such as green peas, French bean and long bean have been planted for their fruits or pods for vegetables in many regions in the world since 6,000 years ago. It is possible to find wild beans everywhere. Bean varieties originated from different places or countries. Green bean originated from Central and East Asia, Northeastern Africa and the Mediterranean. French bean appeared about 8,000 years ago with its origin from Latin American, Mexico, Peru and Colombia. The origin of long bean was found in Southwest China. All these beans are at present planted in many places throughout the world such as Asia, Africa and America.

Based on the botanical characteristics, beans are classified into four groups according to shape, growth characteristics, number of nodes after flowering, height of the plant, and shape of the plant stem. These are the following:

- Determinate short plant
- Indeterminate short plant
- Indeterminate decumbent plant
- Indeterminate vine plant

2.2. Importance of the crop: food and cash value

Beans are planted for their fruits or seeds used as fresh, for frying or making soup or for processing into canned products. Fresh fruits and seeds of beans have high content of vitamins A and C, the latter contained especially in the bean sprout. Furthermore, the sprout also contains other vitamins.

In many areas in the world such as India and Pakistan, fruits and seeds of legumes are considered as a main source of protein. This kind of protein is easily digested by human beings.

2.3. Economic potential of the crop

Beans account for 5% of the total vegetable consumption of man. All kinds of beans can be planted in the garden or in small areas to meet family’s demands. Part of the fruits harvested from these areas is supplied to local markets. However, there are no statistics to support this information.

2.4. Analysis of main problems in bean cultivation

Beans are plants that favor warm and wet weather so they are suitable to many regions of Vietnam. Many crops of beans can be planted in a year and in different geological conditions. However, the most serious matters to be dealt with by farmers when planting beans are the following:

- The high percentage of insect pests and diseases on beans in comparison to other fruit crops. - Besides soil-borne diseases such as bottom rot, *Fusarium* yellow wilt and damping-off, legumes are susceptible to many diseases on leaves and fruits. Diseases such as powdery mildew, rust, angular leaf spot, bacterial blight, bacterial brown spot, and bean mosaic virus greatly affect yield.
- The yield of bean varieties is very low. - In many areas, farmers still use low yielding local varieties. However, some new varieties imported from Thailand, Japan, Taiwan and China is currently being used in several vegetable cultivation areas.
- Non-interest in legume cultivation in the past. - Most growers consider growing beans in the garden mainly for family consumption. Vegetable beans are not produced on large scale and are not seen as an important vegetable product.

2.5. Approach to solving main problems

Applying proper cultivation methods combined with IPM will reduce damage by insect pests and diseases on beans. Some major diseases of beans such as damping-off, bean mosaic virus and soil-borne diseases such as root rot can be prevented by proper cultivation practices. Growing resistant varieties effectively helps reduce damage by insect pests and diseases.

Rehabilitating seeds or using hybrid (F1) varieties will ensure quality and high yield of beans. In some cases, hybrid varieties give higher yield than pure varieties.

3. Biological facts

3.1. Botanical characteristics: taxonomy and morphology

Root: - The main root of the bean plant is called taproot. After germination, the root germ grows straight and penetrates deeply into the soil from 40-80 cm. Lateral roots that grow from the taproot establish in the root layers that become thick at 20-40 cm. The root system of the green bean normally develops vigorously at the initial stage. The system stops developing when plants reach the stages of flowering and pod formation.

Leaf: - Leaves of green beans often grow in pairs, with the leaf blades divided into lobes. Newly-formed leaves are small and greenish. At the mature stage, leaves are not flat and are toothed.

Flower: - Flowers of green bean are generally big and of butterfly shapes or of other animals. The flowers that are white, sometimes yellow or yellowish are self-pollinated. Flowers at the bottom section of the plant bloom first followed by those at the middle section and lastly those at the top. Flowers open from 8-9 in the morning. After pollination, the flowers start to wilt. The flower cup exposes young fruits on branches.

Pod and seed: - Pods of vegetable bean crops such as broad bean and French bean are big. Each fruit has 7-12 seeds and sometimes 15 seeds. Fruits gradually develop and make plump seeds. When fruits become round-shaped, it means they have reached the stage best for consumption either for cooking or canning.

Fruits can be harvested for seeds when mature. The seeds may be taken by growers either for planting or other commercial purposes.

Seeds of green beans are round with different colors such as white, yellow, brown or black. The seeds can weigh much such as 1,000 seeds of French bean weigh about 200-300 grams.

3.2. Growth stages and development

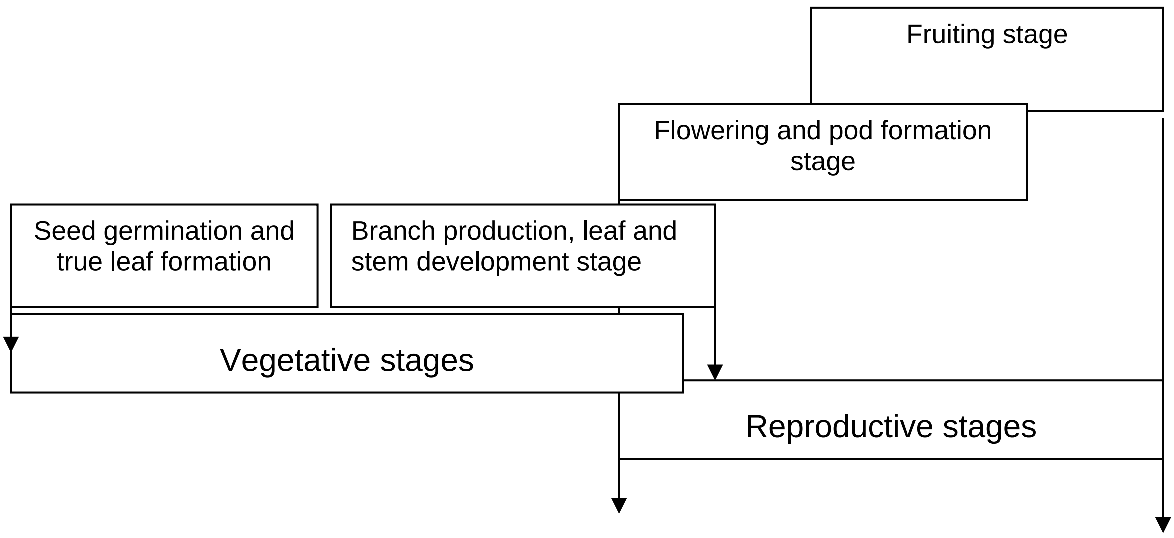
Green bean completes a life cycle, from seed to seed, in one season. Beans are usually grown for a few months, although they can be cropped for 12 months or longer when growing conditions (water, fertilization, etc.) are optimal and plants are not exhausted by diseases or insect pests.

Green bean requires 50-70 hot days to harvest. Growth and development of early maturing varieties is about 50 days, common varieties about 60 days and late maturing varieties about 70 days.

General growth stages of beans are:

1. Vegetative stages:
   - Seed germination and true leaf formation - usually from the time the seed is sown, seed germination and until the formation of the third true leaf at the fifth node.
   - Branch production, leaf and stem development stage - from the formation of the fourth true leaf until the first flower buds develop.
2. Reproductive stages:
   - Flowering and pod formation stage - from the development of the first flower buds until 50% of full-sized pods have formed.
   - Fruiting stage - from the formation of seeds in the first pod to ripening of 80% of the full-sized fruits.

The timing of the growth stages may overlap:



3.3. Relation between vegetative growth and pod development

When a bean seed germinates, it will develop continuously until its flowers can be seen. If plants do not flower, they are not considered as mature. Some crops require long day lengths and low temperatures to flower. The green bean often requires lights of short day length to flower.

A chain of advantages follows if the bean plant has a good leaf and stem development stage. The plant can compete better with weeds. It will have better photosynthesis and therefore can generate more nutrients for the plant. A good vegetative stage will result in plants with more flowers and fruits. Other plants cease development of leaves and stems when their flowers appear while legumes still develop their stems even in the reproductive growth stage. The more this stage can be developed, the better for flowers and fruits to be generated.

3.4. Abiotic factors, growth and development

Effects of temperature
Green bean does not require high temperature unlike soybean or mungbean. Temperature requirement ranges from $10^{o}C$-$30^{o}C$, but the optimum is $20^{o}C$. Temperature requirement is very strict and may greatly affect crop timing. In northern Vietnam, the best time to grow green bean is the winter-spring season (from November to March of the following year) because temperature at that time is about $20^{o}C$.

Effects of light
Green beans favor lights of short day length. The effects of short day length is strongest in the vegetative stage and before flowering stage because it helps to

shorten the time for crop growth and development, reduce plant height, number of nodes on stems and length of nodes. Sensitivity to daylight depends on varieties. Varieties that are sensitive to daylight will have longer growth duration in winter-spring season.

Effects of humidity

All kinds of green beans require high humidity. They can be grown in areas with rainfall of 400 mm/year, but the optimum is areas with humidity of 1000 mm/year. Green beans have low ability to tolerate drought but the crop will die if it is flooded for 48-72 hours.

Effects of soil and nutrients

Green beans require relatively high soil fertility. Soil with high potassium and regular balanced application of Nitrogen-Phosphorus-Potassium (N-P-K) is very important for crop growth and development. Other micronutrients, such as Boron (Bo), Molybdenum (Mo) also strengthen crop nitrogen fixing process.

Most green bean varieties are suitable for growing on sandy loam, loamy-light textured soil with good drainage. Low soil pH level is suitable for bean development. The crop will be weak and give low yield if they are grown on soil with high alkalinity.

II. Crop Management

1. Crop rotation

1.1. Importance in relation to nutrient availability in the soil

Crop rotation reduces fertility degradation and nutrient deficiency. When the same crop is planted in the same field every season, there will be a continuous consumption of the same nutrients from the soil. Adding chemical fertilizers will supply only part of the nutrients that are consumed, mostly N, P and K. Adding chemical fertilizers containing the deficient nutrients will not solve the problem. It is necessary to introduce crop rotation and supply organic matter to the soil. Rotating with green manure and nitrogen fixing crops to the rotation schedule is therefore recommended.

1.2. Importance in relation to pest and disease occurrence

Some of the more common serious pests and diseases which live in the soil attack a range of plants within the same botanical family - but not others. If the kinds of plants they attack are continuously grown in the same field, the pests and diseases can build up to serious populations. Once a soil-borne disease has entered a field it is very difficult to get rid of. If there is a break of several seasons or even several years when other crops (of a different crop family) are grown, the pest populations or disease incidence may be reduced and eventually disappear. This is the main reason for rotating crops.

Rotation is most effective against diseases that attack only one crop. However, controlling many diseases that infect several crops in the same plant family requires rotation to a crop from an entirely different family. Unfortunately, some pathogens such as those causing wilts and root rots, attack many families and rotation is unlikely to reduce the disease.

Resistant, long-lived reproductive structures as well as the immediately infectious forms are produced by some fungi. For example, the black *sclerotia* produced by the fungus *Sclerotinia* can survive for years. *Pythium* and *Phytophthora* can also produce long-lived resting spores. Such spores help these fungi to survive during a long time without a host. How long such pathogens can survive without a host plant depends on factors like environment, temperature, ground water, etc. Some indications on disease “survival rates” are mentioned later in sections on individual diseases.

A few examples of survival rates are:

Diseases	**Disease can stay alive in the soil without host plants for**
Early blight, *Alternaria solani*	at least 1 year
Mosaic virus, TMV	2 years
Southern blight, *Sclerotinia rolfsii*	7 years
Wilting, *Fusarium* and *Verticillium*	Many years (almost indeterminate)

2. Varietal selection

2.1. Demand and supply: how to choose a variety

The selection criteria for varieties vary on the consumption purposes. Most green bean varieties are used fresh, thus varietal selection is related to nutrient contents of the pod. Some other bean varieties are used for getting seeds and for eating, thus varietal selection is related to seed yield and high nutrient content.

The criteria for varietal selection for green bean are simple. However, there are some specific characteristics that breeders should consider. For example, selection criteria depends on the consumption purposes, pods used for seed keeping are usually selected from good plants, low disease infection and from the second fruiting.

2.2. Characteristics of commonly available varieties

Farmers use different bean varieties.

Varieties of long bean:
- MSG1101 variety from the East-West Seed Company - easy to plant, high yielding, medium size, green fruit with purple color on the top.

Varieties of green bean:
- MSG 1401 variety from the East-West Seed Company - favorable to rainy season, high yielding, good fruit, less fibers and green fruit with length of 15 cm.
- 'Tu Quy' No. I and II variety - imported from Taiwan, good resistance to cold weather (this variety is planted in the winter season in the North), high yielding, and good quality, green and long fruit.
- Local varieties - are bought within the country or originate from local areas. These seeds have high adaptability to local climatic conditions (especially the climatic conditions in the Northern mountainous areas of Vietnam.

3. Seed preparation

3.1. Healthy seed

Like some other crops, French bean and other beans are propagated by seed, therefore seeds play a very important role in determining fruit yield. Farmers have some criteria for selecting seeds for sowing such as seed purity and percentage of germination.

The requirements for bean seeds are: seed purity is 99%, percentage of mixture is 0.05% and no weed seeds. The seeds are light yellow, weight of 1000 seeds (P< 1000 seeds) should range from 200-300 grams, and number of seeds/fruit is 15 - 50.

The germination percentage of bean seeds is 85%. To check germination ability of bean seeds, the following simple method can be used. Lay out about 100-500 seeds on wet tissue (or cotton) on a small dish. Cover the seeds with cloth or filter-paper. Count the number of seeds that have germinated after 24 hours. Observe seed germination for three days.

3.2. Selection criteria and method (in the field, at harvest, before planting)

To get bean seeds for propagation, fields of different bean varieties should be at least 2 kms away from each other. Normally, only 3 or 4 pods/plant can be harvested for getting seeds. Often, pods in the middle section of the plant are collected.

After the first harvest, pods in the middle section of plant are kept while female flowers which open later are removed to have more nutrients for the seed pods. Seed pods are picked when the ripened pods on the plants are dry. To get the seeds, the pods are exposed to sunlight for 2 or 3 days. The pod skin is then opened to get seeds. The seeds are continuously exposed to sunlight for 5-6 times.

Hybrid varieties should not be kept for seeds for the next season.

3.3. Storage

Like other vegetable seeds, bean seeds easily lose their germination ability if they are stored under normal conditions. In order to keep seeds for the next season, two methods are applied: - close storage and cold storage.

- Close storage - dried seeds are placed in bottles, jars, pots with some lime underneath to avoid condensation. The containers should be closed carefully with lids. With this method, seeds can be stored for 3-4 years.
- Cold storage - dried seeds are placed in paper or plastic bags and then placed in a cold room with temperatures of 0-4°C. With this method, seeds can be stored for 5-10 years.

3.4. Seed treatment

Seed treatment is aimed to disinfect the seeds or protect them against pests that may pose hazards during germination and subsequent stages of plant growth. Some seed treatment methods can also stimulate seeds to germinate quickly. The seed treatment may be physical or chemical.

Physical treatment: - may consist of soaking in warm water or applying dry heat. The duration of treatment depends on the seed structure and its skin thickness. Bean seeds are soaked in water at 50ºC for 120 minutes due to thick skin. Heat treatment, however, is not normally a good practice because it tends to reduce germination. The viability of heat-treated seeds also decreases with continued storage after treatment. Therefore, alternative methods must be explored before using heat treatment.

Chemical treatment: - usually consists of a fungicide, insecticide, or a mixture of both. The most common fungicides used for seed treatment are Thiram (Tetramethylthiram disulfide) and Captan (N-trichloromethyl-thio-4-cyclohexene-1,2-dicarboximide). Both are broad spectrum in action and have low mammalian toxicity. Some systemic fungicides, such as Ridomil (metalaxyl) provide protection against fungal diseases up to maturity of the plant.

In addition to these two methods, in FFS (Farmer's Field School), we can simply treat seeds by using alcohol. Soak seeds in 70% alcohol for 2-4 minutes to eliminate fungus or bacteria on the seeds. Afterwards, clean seeds with distilled water and dry them before sowing. However, sometimes farmers sow seeds right after seed treatment.

4. Land preparation

4.1. Soil type/characteristics in relation to suitability for green bean

Green bean is very sensitive to growing conditions, especially soil humidity. Literature review states that the bean crop will die if it is kept flooded for 24 hours. The soil condition is a very important factor in determining its yield. Some soil-borne diseases, such as bacterial wilt and root rot will be more serious if the plants are flooded.

4.2. Preparation

4.2.1. Characteristics of good soil in relation with soil cultivation methods

The green bean root system develops and absorbs nutrients poorly, thus its requirement for the soil type is stricter than other crops. Sandy loam or sandy soils with pH level of 5.5-6.5 are suitable for growing bean because it absorbs heat faster than other soils in the spring season and its small particle structure helps prevent seedlings from collapsing due to rain and wind.

The green bean root system is shallow. It is only 25-30 cm deep resulting in poor tolerance to drought and flooding as well as susceptibility to pests and diseases. Therefore, the soil for planting bean crops should be prepared carefully. The best way is to keep ploughed soil for 5-7 days then sprinkle crushed lime to sterilize it and kill soil-borne disease sources. Raised beds are preferred for planting beans.

4.2.2. Method: soil cultivation and bed preparation

Soil productivity is defined as the capacity of the soil to produce a specific crop (or sequence of crops) under a specific management system that includes planting date, fertilization, irrigation schedule, tillage, and pest control. Soil productivity is very closely related to the depth of the topsoil. In many cases, thinner topsoil will have a lower ability to supply water and nutrients. Soil productivity depends largely on the kind of soil and local environmental conditions. A topsoil of 20-40 cm deep is suitable for growing vegetables and long-root crops.

Land preparation affects conservation of soil nutrients. In vegetable growing areas, land preparation is often done manually or with the help of draft animals, such as buffaloes, cows and horses. The result is substandard land preparation particularly in heavy soils that are more labor-intensive. The usual problem with manual land preparation is inadequate depth.

The steps in land preparation include:

a) Clearing/mowing. This is an optimal step necessary only in opening new areas for vegetable growing and in preparing the field after a prolonged mismanaged fallow (rest) period. Under this condition, the farm may be too weedy to be plowed. Before plowing, it may be necessary to clear the field of obstructions and tall weeds.

b) Plowing. Like other vegetable crops, the soil for green bean does not require to be too fine. If it is too fine, it will cover void space for air. Soil structure affects root distributions, adventitious roots and root quality. According to some studies, 80% of green bean roots develop and distribute in a layer of 20 mm. The topsoil on beds should be 1-3 cm or 5 cm high. When raising beds, it is necessary to make the topsoil finer than the underneath layer. This is a basic technical requirement of raising beds for vegetables.

c) Raising beds. Length of beds depends on the terrain, but should not be more than 100 m. If the bed is too long, it is not convenient for field care, watering, and fertilization. The width of the bed is normally 100-120 cm, depending on the cultivation condition in each area. In order to prevent some soil-borne diseases, especially root rot disease (see part 10.2), raising beds for green bean is very important. The disease damage is often serious in low, flooded beds. Higher beds may reduce disease incidence. In some areas, farmers often prepare beds with a height of 25-30 cm to avoid flooding during heavy rain.

The shape of raised beds may be different depending on the season. During summer season when it is rainy, it is advisable to prepare high and narrow raised beds and dig trenches between the beds for drainage. In winter season when it is dry, raised beds can be flat, large or a little bit deep in the center to keep water and fertilizer.

5. Crop establishment

Like other legume roots, green bean roots are sensitive. Hence, direct-seeding can not be done. Banana leaf pots can be used to avoid damaging roots during transplanting in the fields. The bean crop develops quickly in the fields even when conditions are not ideal. Direct seeding can increase the number of seasons. Seeds can be sown in the field/leaf pots even before the previous crop is harvested. This allows planting of the seedlings immediately after harvesting the previous crop, reducing the period when the field is unproductive.

Direct-seeding always requires three to four times more than the quantity of seeds needed when transplanting. When the cost of the seed is high, as in F1 hybrid seed, transplanting may be recommended instead of direct-seeding.

When direct-seeding is used, it is difficult to control the depth of seeding, resulting in poor emergence. If seeds are placed too deeply, it is difficult for seeds to germinate or it takes a longer time for their emergence. If seeds are placed too shallow, they will be dried and hot, have difficulty to germinate and can be easily eaten by birds and insect pests. In many cases, the topsoil is not prepared well and large soil clumps make emergence difficult. Direct seeding requires fine soil particles.

6. Nutrients

6.1. Nutrient need

Green bean needs a lot of nitrogen. The nitrogen source for green bean is often from the air. Too much nitrogen can cause excessive branches and slow pod ripening. Phosphorus (P) is a very important nutrient for seed formation, making pods ripen faster and uniformly. Many studies have shown that a combination of different kinds of fertilizers with P is very important.

In general, fertilizer need of beans changes at each growth and development stage. The crop absorbs nitrogen mostly at trellising stage and before flowering. Nitrogen uptake will be reduced when the plant forms seeds and pods are ripening.

6.2. Organic fertilizer

Soil organic materials are very important for the crop. They affect chemical and physical soil characteristics such as water holding capacity and capillarity as well as micro-organisms' activities. One of the most serious problems of farmers, however, is to maintain soil organic matter. Vegetable growing is mostly intensive farming. This means that many kinds of vegetables are grown in the field over many seasons. Crop residues can not compensate for annual loss of nutrients.

6.2.1. Application guideline: dose, timing, method

Poultry and cattle manures, such as chicken dung, cow pat, and pig manure have necessary nutrients for plants, such as N, P, and K while peats provide mostly N. Soybean meal has 7% N and fish scrap, 9% N. These figures are much higher than poultry manure (4%) and cattle manure (1.5%).

Green manures, such as legume crops and wild crops also have significant amount of nitrogen. However, other nutrients such as P and K are not available in or available in low amounts. Green manure is often composted with some amount of animal manure. Green manure provides a good ratio of C/N for soil, increases population and stimulates the activity of micro-organisms making the soil crumbly. However, farmers should not apply green manure directly on green beans.

The bean plant requires intensive cultivation with composted manure of 20-30 tons/ha. The amount of manure, however, can be reduced by adding some other organic fertilizers, such as biofertilizer or peats. Organic fertilizers are often used as basal dressing, due to its slow releasing process compared to inorganic fertilizers. Farmers often apply all organic fertilizer at one time for basal application.

6.2.2. Compost

Compost has enough nutrient contents for green bean. It has high percentage of humus that is very good for improving soil. Compost application helps to increase population and activities of micro-organisms as well as reduce infection of some soil-borne diseases. Like other pod vegetables, green beans often have serious problems with soil-borne diseases such as root rot, damping-off, or *Fuzarium* wilt. It has been found that applying fresh manure may increase root rot incidence in bean fields. (Fields without basal dressing of fresh manure do not show disease occurrence or disease incidence is low). Root knot nematodes often damage cucumber fields where undecomposed manure has been applied. This disease damages crop in the next seasons and even crops of other families.

In some countries, antagonistic fungi or bacteria are added to the compost just after the hot phase, when the compost is cooling down. When antagonists are added at that time, they can quickly build up their populations resulting to effective disease suppression.

6.3. Inorganic fertilizer

Inorganic fertilizer is also important and is commonly used in vegetable and bean production. Applying organic fertilizer only can not provide enough nutrients for the plants. Adding inorganic fertilizers during crop development will ensure high crop yield. In vegetable growing areas, however, inorganic fertilizer is used by farmers as the main nutrient source for the crop. This results in negative effects on soil physiochemical characteristics and soil structure. The consequence is more compact soil, reduced crop yield and more pests and diseases.

The bean crop needs more potassium, than nitrogen and phosphorous. The requirement for each element changes based on the crop development stages. At the start of the growing season, plants need nitrogen and phosphorous after sowing to develop roots, stem and leaves. During flowering and fruit setting stages, the plants need more potassium. Inorganic fertilizer is often applied as top dressing. Nitrogen should be applied as top dressing (near the base of the plant) at different times and at the end of harvest so that plants have enough nutrients to feed additional flower sets. These flower sets may give a stable yield of about 120-150 kg/sao.

6.4. Green bean fertilization guidelines

Fertilizer application calculation should be based on the rate of nutrient uptake, expected yield and the fertilizer. In tropical areas, bean crops will take a certain amount of soil nutrients to achieve a certain number of pods. Based on the nutrient uptake, the necessary amount of fertilizer for beans can be calculated.

For example, in order to get the yield of 12,000 pods/ha of bush bean (green or yellow pods), it needs the following amount of nutrients from the soil:

N	80 kg
P_2O_5	30 kg
K_2O	100 kg

To get a yield of 14,000 pods/ha of pole bean, it needs the following amount of nutrients from the soil:

N	120 kg
P_2O_5	35 kg
K_2O	150 kg

(Source: Vegetable Production Training Manual, AVRDC, Taiwan, 1992)

Every person, every book or guide will give another recommendation for bean fertilization.

The only way to determine the best type, amount, timing and application techniques of fertilization for your area, your field, your crop, is to
Experiment!

7. Water management

Like other vegetable crops, green bean requires frequent watering during its growth development stages. However, it can not tolerate flooding and it is necessary for vegetable growers to carry out systematic watering.

7.1. Water needs at seedling, vegetative and reproductive stages

The bean crop requires frequent watering. After transplanting, watering can be done twice per day if it is sunny. Watering often lasts 2-3 days.

Wet soil and diseases...
When the nursery soil stays wet for a long period, certain soil fungi can cause damping-off disease of the seedlings. They can even cause death of small roots emerging from the seed so the seedlings never even emerge above the soil.

When seedlings are grown in wet soil for a long time, they are weakened and become more susceptible to diseases. Hence the fungi causing damping-off can grow and spread easily. ☹

7.2. Method: irrigation and drainage

Proper irrigation is critical for maintaining high yields and quality. Soils with adequate organic matter usually have a high water holding capacity and do not need frequent irrigation. The soil type does not affect the amount of total water needed but does influence frequency of water application. Lighter soils need more frequent water applications but less water applied per application. Sandy soils may require water at more frequent intervals as water drains off quickly.

Where irrigation facilities exist, there are sometimes opportunities for manipulating pests. Where the soil is leveled, it is in some cases possible to flood the field with water or to dry the soil out to control pests and weeds. Some pest insects that survive in the soil like cutworms and nematodes and some weeds can be drowned by putting the field under water. This should be done before transplanting the crop. The field has to be under water for about four weeks and will need some time to dry up properly before a new crop is planted. This method does not control all soil-borne diseases!

The irrigation method may also have consequences for insect population and disease severity. Overhead irrigation can increase disease incidence. The spores of bean rust disease, for example, can easily germinate when the leaves are wet. The use of ditch or furrow irrigation is usually preferred to overhead irrigation. Ditches also ensure rapid drainage of excess soil moisture during the rainy season. However, if the field has soil-borne disease, try to avoid ditch or furrow irrigation.

8. Staking and pruning

8.1. Importance

All kinds of bean used as vegetables are soft, climbing plants of about 70-220 cm in height. Bean stems, leaves and vines develop quickly in the first two weeks after transplanting. Staking and pruning can improve yield and fruit size as well as reduce fruit rot incidence. It is also more convenient for crop care and harvest and gives early harvest.

8.2. Timing and method

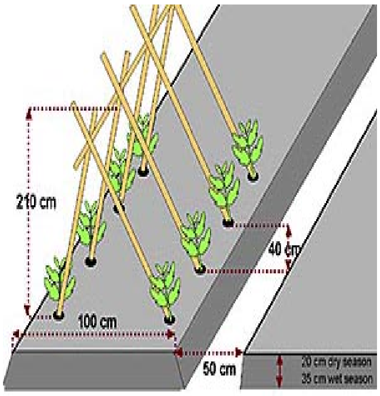
The bean plant develops stems with strong climbing ability quickly. Hence, trellises should be established early. Usually, trellising should be done when a plant is about 30 cm high (10-15 days after sowing) and vines start curling.

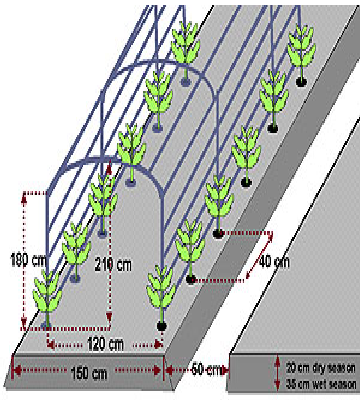
Like other climbing plants of the cucurbit or solanaceous family, there are several methods of trellising beans. In some areas, bamboo poles, wood stakes, PVC pipes or other sturdy material are used to provide support and keep the fruit and foliage off the ground. The trellis is arranged either in a lean-to or tunnel structure, but a lean-to structure is more common. The trellis should be 1.8-2 m high, constructed from stakes 1.2-1.8 m apart, almost similar to the plant row spacing.

Lean-to type: This type of trellis is used widely in all bean growing areas. The stakes are joined between two adjoining beds forming an A-shape structure (see illustration below). This type is applied where they have two rows on one bed. This can be applied also for single-row, in that case horizontal stakes are installed at the top joining all other beds (Palada et al, 2003). The stakes support the climbing vines and lateral stems. Strings are used to secure adjoining stakes. Plantings are easier to manage and more productive when 2 m-high rather than 1 m-high string trellises are used.

The advantage of this method is that locally available materials, such as bamboo can be used. Staking and trellising will increase fruit yield and size, reduce fruit rot, and make field caring and harvesting easier. This method, however, is costly and requires more labor if the material used is not durable.

Tunnel type: Plants are grown inside an arch-shape structure made of either PVC or galvanized iron pipe (1.8-2 m long and 1.2-2 m apart from each other). The centre of the arch is 2.1 m high (see illustration below). During bean development, tie main stem and lateral stems into pipe. This should be done early, 10-15 days after germination. This method requires bigger capital for initial cost of materials, but these materials are more durable, resulting in lower cost for the later seasons. This type is commonly applied for other crops such as squash, gourd, luffa, cucumber, and tomatoes. It is not commonly applied for beans due to difficulty in harvesting fresh pods.





Lean-to type　　　　　　Tunnel type

(*Source: AVRDC, International Cooperators' Guide*)

9. Weed management

9.1. Impact of weeds on crop development

Weeds in a bean field are usually unwanted because they affect crop growth, development and yield. The competition of bean and weeds are fierce in the vegetative stage and the growing process. Yields are higher when the field is weed free.

Weeds may harbor insect pests and diseases or form breeding places for insect pests, vectors and diseases. The plant *Trianthema portulacastrum* is host of chili mosaic virus that infects potato, tomato and other vegetable crops. Aphid, the vector of virus Y causing potato disease resides on *Solanum nigrum* plant.

9.2. Timing of weeding

Weed control should be done early in the growing period from week 1 to week 3 after sowing. In the first 2-3 weeks, hand weeding by hoe or other tools is very effective to control weeds and break the scum layer on the upper soil surface. In addition, hand weeding reinforces activities of microorganisms, increases nutrient absorption of the plant, limits root development so that plant nutrients are concentrated for development of leaves and branches, and increase crop yield. Only if necessary, herbicides can be applied before or after sowing to control weeds.

9.3. Methods of weed management

Breaking up the soil is a good technique for controlling weeds. Hilling-up the soil should be done before plants climb on the trellis or when the plant is 10-15 cm high. As such, the plant can produce new roots and avoid from collapsing or crawling on the ground. At this time, hilling-up meets the requirements of plants for maintaining air circulation in the field, breaking the scum on the soil surface and controlling weeds. When the plant is 30 cm high, hilling-up the soil again is done before establishing the trellis. Hilling-up can be done 2-3 times. Hilling-up should not be done after staking. During this period, weed control can be done by hand or knife.

Mulching is a very commonly used method for weed control. Mulch is any material placed on the surface of the soil. It can be organic matter such as straw or plastic sheets. Organic matter is more available and cheaper than plastic sheets. If straw is used, be sure that it is weed-free. Mulching can be done before or after sowing seeds.

Weeds can also be controlled by spraying herbicides. However, beans are very sensitive to chemicals. Therefore, if the use of chemicals is needed, be sure that the herbicide is suitable to the crop and will not cause leaf burn or tip curling. Herbicides use to control weeds in bean fields will depend on cultivation conditions in each area. It must be remembered that negative effects of herbicides are recorded in many places in the world.

10. Major diseases of green beans

10.1. Damping off, *Pythium*

See illustration Figure. 1a, 1b and 1c, page 70

Causal agent: Fungus, *Pythium*

Common name: damping-off

Signs and symptoms
Weak climbing plants result from infection of damping-off disease caused by the fungi, *Pythium,* before and after germination or in young seedlings. The infected cells in plants rot and become colorless. Infected plants wilt or die at the early stage or the next stage of plant development. Symptoms of waterlogged wounds (canker) and soft rot on the infected plants appear. The cankers gradually develop from spots that can spread from roots to stems. These wounded stains gradually develop. Although they do not cause damage, plants will be under-developed because of them. The wounded stains can spread from root to stem and sometimes to the plant growth peak. In such cases, the root system will become soft, rot and less developed. The rot stains also appear on stems above soil surface of several centimeters. The infected plants often generate sub-branches from their stems.

Source and spread
Beans are infected by several species of *Pythium* spp. Most of these species have the same disease life cycle. The fungi will live under the soil (e.g. *P. ultimum*) and

will not become active until an exogenous nutrition stimulates the germination of the seed or root. After transmitting the disease to plants, secondary transmission can develop as it is caused by the active oospores that have been released. The active osprores can swim within a limited distance in the water membrane in the soil. This activity therefore gathers the disease source from an infested point or allows the fungi to move up to the water surface and allows it to move a longer distance. The oospores formed in the infected tissues are released into soil when these tissues are further decomposed. The oospores can move longer distances in the soil due to wind, water or infected farm tools.

Pythium spp. is available everywhere in the soil as they have a wide host range. They can also stay in the fresh undecomposed organic matter in the soil and the surviving oospores. The population of *Pythium* spp. can increase in several plants and the infection level of disease caused by *Pythium* spp on bean can simultaneously develop with the increase of the disease source.

Role of environmental factors

Soil humidity and temperature greatly affect disease incidence and severity. At higher humidity, the disease becomes more serious. Wet soil provides favorable conditions for damping-off (caused by *Pythium)* to develop and spread infection from and during the period of leaf emergence to the peak of seedling stage. The two types of *Pythium* spp. described above have different responses to temperature. The disease caused by *P. ultimum* and similar species is more popular and serious at temperatures of less than 20^{o}C. On the other hand, *Pythium* blight caused by *P. myriotylum* does not harm much at temperatures of less than 20^{o}C while it is greatly harmful at temperatures of 25-35^{o}C. Diseases caused by *Pythium* can appear during the whole season whenever the environmental conditions are favorable. Even ripening fruits on plants can be infected. The disease severity mainly depends on humidity and temperature. Older plants are less infected by the disease unless the humidity is too high.

Importance of plant compensation and physiological impact

The disease infection caused by *Pythium* on beans is damping-off in seedlings and leaf wilting, fruit rot and stunted growth of mature plants. When *Pythium* spread over a large area in the soil, the disease will appear everywhere and every time. The disease caused by *Pythium* can cause serious damage to yields, from 20% to complete loss.

Natural enemies and antagonists

Many successes have been reported with the use of *Trichoderma* sp. to prevent damping-off. *Trichoderma* out-competes fungi that cause damping-off for nutrients and a place to grow around the roots (“rhizosphere dominance”). There are several species of *Trichoderma.* The species *Trichoderma harzianum* has been used successfully in tropical climates but *Trichoderma parceramosum* also gave good results in field trials in the Philippines (FAO-ICP progress report ’96-’99). *Trichoderma* sp. is now available for use by farmers in countries like Indonesia and Thailand.

There are several other antagonistic organisms that control damping-off fungi, such as *Bacillus subtilis, Burkholderia cepacia, Pseudomonas flourescens, Streptomyces griseoviridis*, and *Gliocladium catenulatum*. Different strains of these antagonistic organisms have been registered in the United States as biocontrol products to control damping-off and some other soil-borne plant diseases. In the future, these biocontrol agents might become available in Asia.

Management and control practices

- Avoid placing nurseries in areas that are always infested by diseases caused by *Pythium*, or continuously planted to legumes, cucurbits and solanaceous crops in the same field.
- Practice long-term crop rotation with rice, buckwheat or maize which is not susceptible to this disease.
- Soil sterilization is practiced in many countries, often as a preventive measure before sowing. There are many methods to sterilize small areas of soil. Biofumigation or using isothiocyanates (ITC) of brassica leaves, stems or plants is an effective method. Lime or fungicides can also be used to sterilize the soil. Soil sterilization for 4-6 weeks at temperatures of 38-50^{o}C may help reduce disease incidence. However, this method directly affects soil micro-organism systems and hence should not be applied regularly.

Using ITC for biofumigation to control damping-off disease on cucumber - experience from Australia and the Philippines

In Australia and the Philippines, brassica (green mustards, radish, Chinese cabbage) stems and leaves are incorporated into the soil 7-14 days before planting solanaceous crops to prevent soil-borne diseases such as bacterial wilt. Brassica stems and leaves have high isothiocyanates (ITC). ITC helps to prevent the development of bacterial wilt cells as well as soil-borne fungi. Five kg of chopped brassica stems and leaves/m^2 is incorporated into the soil for three consecutive seasons to give high effectiveness.

Another method is direct seeding of brassica in the fields with history of soil-borne diseases. When the brassica reaches the flowering stage, plough field and raise new beds. Keep fields unused for 7-14 days, then transplant or sow solanaceous, legumes, or cucurbit crops. This method should be done every year.

Extract from report of ACIAR- CSIRO-UP Los Baños- Benguet State University - Regional Workshop on Biofumigation for Soil-borne Disease Management in Tropical Vegetable Production - June 2005, Philippines.

- Good soil preparation. Residues from the previous crops must be completely decomposed before transplanting new crop. To do so, deep plowing of the field is required before planting. The debris of the previous crops must be deeply buried, about 10 cm in the soil. If the debris is buried at this depth, the disease-causing fungi can not live as it only can develop above or near the soil surface.
- Proper drainage can help reduce the infection.

- Reduce cultivation activities after transplanting. Cultivation activities can put the infected crop debris back into the soil and come in contact with new plants. This will create conditions for diseases to infect plants. Cultivation activities can also harm plants, especially root components, and the wounded points can create favorable conditions for *Pythium* to penetrate and cause damage.

Once there is an infection in the nursery:

- Uproot and destroy diseased seedlings to avoid build-up of the pathogen population.
- When the nursery soil is wet or waterlogged, dig a trench around the beds to help drain them. It may slow down the spread of disease to other parts of the nursery.
- Good results have been obtained with use of the antagonist, *Trichoderma* sp. For example, application of *Trichoderma harzianum* is recommended by the Department of Agriculture Extension in Thailand mainly as prevention but also possibly as a control for damping-off. In the Philippines, *T. parceramosum* and *T. pseudokoningii* are being tested (FAO Dalat report, 1998).
- If soil sterilization is not an option or is impractical, do not use the infected area for growing bean crops for at least two seasons.
- In some areas, fungicides are used to control damping-off. Results vary, however, in this guide, fungicide use is not recommended for control of bean damping-off.

Points to remember about damping-off:

1. Damping-off is a serious problem caused by *Pythium* spp.
2. Damping-off occurs in areas with a previous history of the disease.
3. Crop rotation (including nursery site), proper drainage and sanitation practices (removing crop left-overs) are ways to prevent the disease.
4. Soil sterilization practices and biofumigation using ITC of brassica leaves, stems or plants for two consecutive years is an effective method to prevent the disease.
5. Good control of damping-off can be achieved by adding compost or other decomposed organic material (15-20 tons/ha) to the soil regularly and before sowing.
6. Additional prevention control can be obtained with use of the antagonistic fungi, *Trichoderma* sp.
7. Chemical control of damping-off caused by *Pythium* is not effective.

10.2. White Mold, *Sclerotium rolfsii*

See illustration Figure 2, page 70

Causal agent: Fungus, *Sclerotium rolfsii*

Common names: White mold, Southern blight

White mold is a serious disease with origins, occurrence and spread in many regions in the world. It infects various vegetables including tomatoes, eggplant, bean, melon, carrot, chili, pepper, potato, sweet potato, water melon and other fruits and vegetables. Other crops such as cotton, peanut, soybean, and tobacco are also susceptible to this disease. The fungi can deteriorate products after harvest, particularly carrot.

S. rolfsii often occurs with other fungus in the soil such as *Phytophthora parasitica* and *Rhizoctonia solani* to cause diseases such as damping-off, root rot and stem rot.

Signs and symptoms

This disease can be recognized by early symptom such as yellow wilting and withered leaves. When infected plants are pulled out, it is easy to see that the roots are soft. The plant stem is rotted at the portion that comes in contact with the soil. A white moldy layer will appear on the stem tissues and the portion of the plant that is in contact with the soil. When the disease is further developed, the small, smooth and brown tumors called as 'mushroom nucleus' as they have the mushroom reproductive structure) form on the stem-part in contact with the soil. These ‘mushroom nuclei’ are brown and look like a group of glued cabbage seeds. The nuclei of the fungi *Sclerotinia sclerotiorum* are 'standing groups' and colored black. The brown mushroom nuclei are signs of the disease.

Source and spread

Sclerotium rolfsii is of soil-borne origin. It can survive in the nucleus form and take shelter in host residues in the soil. This fungus has a special characteristic of being limited when it is 5-7 cm higher than the soil surface and not able to live deep in the soil. In most cases, the fungi can not have a large population if it does not have the host plants after two years. However, the mushroom nucleus has a thicker layer so it can exist for a longer period of more than two years. Every crop rotation plan should therefore last at least 3 or 4 years.

Sclerotium rolfsii can be propagated through water, infected soil, farming tools, agricultural machines, and infected seedlings and exist under the mushroom nucleus form mixed among seeds. Undecomposed debris can also be a disease source.

Role of environmental factors

Warm weather and high humidity are favorable conditions for the development of this disease. In areas with cool weather, the disease often appears in fields at the 'hot period' and lasts until the weather turns cool and drier. This disease does not exist in areas with cold winter.

The use of ammonia seems to limit the disease development. However, the reason for this phenomenon can not be explained. It may have something to do with underdevelopment of the fungi or changing the susceptibility of the host plant or increasing the population of antagonistic organisms in the soil. Calcium may also have something to do with the process. The calcium fertilizer level in the nucleus increases and may restrain disease development by changing the susceptibility of the host plants. However, if the soil is fertilized with lime, following normal practices, the change of the calcium in the nuclei will not be strong enough for it to fight against *S. roflsii* in the soil.

Importance of plant compensation and physiological impact

White mold or Southern blight is a serious disease in the tropical areas. The damage caused by the disease depends on light and soil humidity. The statistics of crop loss varies. *Sclerotium rolfsii* will kill the host plant before penetrating inside and live in the dead plant cells.

Natural enemies and antagonists

The use of *Trichoderma* sp. can be a method to prevent *Sclerotium rolfsii*. Other biological antagonistic organisms can also prevent this disease.

Management and control practices

- Avoid placing nurseries in areas in the field that are always infested by *Sclerotium rolfsii.*
- Long-term crop rotation with grass, buckwheat or maize which is not susceptible to the disease.
- Soil sterilization for 4-6 weeks at temperatures of 38–50^{o}C may help reduce the disease incidence. In many countries, soil sterilization is often practiced as a preventive measure before sowing. There are many methods to sterilize small areas of soil. Biofumigation using ITC from brassica leaves, stems and plants is an effective method (see Part 10.1). Lime or fungicides can also be used to sterilize the soil.
- Good soil preparation. Residues from the previous crops must be completely decomposed before transplanting a new crop. To do so, fields should be ploughed deeply before planting. The debris of the previous crops must be buried deeply, about 10 cm in the soil. If the debris is buried at this depth, the fungi causing the disease can not live as it can only develop above or near to the soil surface.
- Proper drainage can help reduce the infestation. The preparation of the nursery in rows can help provide a proper drainage.
- Reduce cultivation activities after transplanting. Cultivation activities can plow back the crop debris into the soil or make the land with crop debris come in contact with new plants. This will create conditions for the disease to infect the plants.
- Prevention from disease pathogens carried by leaves. Diseased leaves drop to the soil surface and can be a source of infection. Since weeds harbor disease pathogens, it is therefore necessary to kill weeds at the beginning of the season to prevent the spread of disease.

✍ **Points to remember about white mold:**

- On bean crop, *Sclerotium rolfsii* causes bottom rot and rotting on the stem section that is in contact with the soil.
- The small, hard and brown masses called "Mushroom Nuclei" formed on the plant stem are signs of the disease caused by the fungi. These mushroom nuclei can exist in the soil for many years.
- Some biological protection product such as *Trichoderma* sp. can reduce *Sclerotium rolfsii*. In the future, Asia will have other biological control products available.
- Other cultivation methods and field sanitation such as removing and burning all the infected debris and crop rotation can help control white mold.

10.3. Bottom Rot, *Rhizoctonia solani*

See illustration Figure 3, page 70

Causal agent: Fungi, *Rhizoctonia solani* Kuhn

The disease mainly damages legumes, solanaceous crops (tomato, potato and pepper) and cucurbits (cucumber, watermelon, and melon).

Signs and symptoms

The typical symptoms of the disease are blackening and rotting of roots and stem portion near the soil as well as damping-off in the field. Initial symptom of the disease is a small sunken spot on the roots. The spot then quickly spreads to bind the roots. The infected sections are rotten, black, water-filled or quite dry. The bottom of the roots dwindle and leaves and stems wilt even they are still green. After 5-6 days of infection, bean crops collapse and die in mass.

Source and spread

Bottom rot is caused by fungus. Sometimes the disease is caused by a group of fungi such as *Fusarium solani* and *Thielaviopsis* together with *Rhizoctonia solani*. Bottom rot caused by *Rhizoctonia solani* makes the bottom of seedlings rot, blacken, dwindle and covered by a whitish grey mold layer.

The source of disease exists for a long time in the field and the fungus, *Rhizoctonia solani* can survive on decaying and dead debris in soil.

Role of environmental factors

Moist soil is a favorable environment for this fungus to develop. The disease becomes more serious when there is much rain, fields are flooded and the temperature is from 18^{o}C to 25^{o}C. The disease also develops aggressively when there is abrupt weather change, e.g., sudden hot or cold temperatures. The physio-chemical component of the soil is a factor related to the disease development. The disease often causes serious damage to crops planted in soils that are heavy clay, not aerated, easy to be covered with “liquid film” (pellicle) after rain or in water-logged depressions.

Importance of plant compensation

Bottom rot causes serious damage on every bean crop area in the world. In Vietnam, this disease has occurred and caused damage on all legumes planted in the winter and spring-summer seasons throughout the delta, midland and mountainous areas. The disease can affect plants in the latter part of the vegetative growth stage but mainly during the seedling period.

Natural enemies/antagonists

The efficiency of the antagonistic fungus, e.g., *Trichodema* can be tested to manage the disease. It is suggested that the best way to manage the disease is to use a combination of the antagonist fungi and compost. In America, a fusaric acid-resistant mutant of the virus *Pseudomonas solanacearum* is sold as a biological protection agent against *Rhizoctonia solani* (www29).

Several other antagonistic micro-organisms against this disease have been studied such as *Bacillus spp*. (Silveira, 1995) and *Streptomyces sp*. (El-Raheem, 1995). Most of these studies were done in laboratories so results are not yet applicable to field situations.

Management and control practices

- Several bean varieties are resistant to the disease. However, varietal resistance is unstable and since rot root can be caused by many species of fungi, resistance also varies.
- In many countries, soil sterilization is a preventive method that is used before sowing. There are many methods to sterilize small areas of soil. Biofumigation using ITC of brassica leaves, stems and plants is an effective method (see Part 10.1). Lime or fungicides can also be used to sterilize the soil.
- Sanitation or the removal of all crop debris including infected weeds helps in reducing disease incidence.
- Using compost fertilizer can reduce bottom rot incidence. Add lots of compost or other decomposed organic material (15 to 20 tons/ha). Compost contains microorganisms that feed on those already in the soil. An active population of microorganisms in the soil out competes pathogens and will often prevent disease. Organic matter in the soil improves the living conditions for helpful microorganisms including antagonists of the fungi *Rhizoctonia solani*.
- Fortified compost fertilization: In Taiwan, the use of dry Welsh powder with onion and garlic debris to improve the soil and prevent soil-borne diseases is being studied. It has been shown that if 1% of the dry Welsh powder (without root) is added into a pot of soil with a tomato plant, bacterial wilt disease is considerably reduced. However, when this experiment is implemented in the field, it does not show a good result. This is an interesting method to apply and for farmers to test in the field.

- Completely pulling out infected plants and removing the soil that was in contact (around) with the roots, taking them out of the field and burning them. Removal and burning of infected plants prevent further spread of fungus.
- Crop rotation will be good for soil with bottom rot. However, this disease has a wide range of host plants including brassica, cucurbits and legumes. This minimizes the crops that can be used for rotation. In some northern areas, farmers practice crop rotation between long bean and rice in order to prevent bottom rot disease. The disease can not exist in flooded fields.
- In some countries, keeping the fields fallow for several months is practiced to break the disease cycle and kill weeds at the same time.
- The use of lime is encouraged for the prevention of soil-borne disease. However, the effectiveness of lime has not been clearly proven. Lime has an impact on the sub-climate in the soil and can activate antagonistic organisms. It also influences nutrient availability and strengthens plant tolerance to unfavorable conditions.
- High-raised beds and proper drainage will reduce the risk of disease.

Once there is an infection in the nursery

Several bean varieties are resistant to the disease. However,

- It is very difficult to prevent and get rid of bottom rot as the disease agents can exist in the soil for many years. In some areas, the disease has made the soil no longer suitable for planting.
- It is not advisable to use furrow and over-flow irrigation when bottom rot appears in the field.
- The use of chemicals for preventing bottom rot disease is not encouraged!

Points to remember about bottom rot:

1. Bottom rot is one of the serious soil-borne diseases that can affect different kinds of plants in the same field.
2. Several common prevention methods are crop rotation, use of resistant seeds and field sanitation to prevent and reduce the infection.
3. Introducing organic matter such as compost into the soil has shown positive results. This is because the antagonistic fungus in the soil is stimulated and the French bean is provided with more nutrients.
4. Chemicals have no use in preventing bottom rot.
5. Effective biocontrol agents such as *Pseudomonas* sp. hopefully will be available in Asia in the future.

10.4. *Fusarium* Wilt, *Fusarium oxysporum*

See illustration Figures 4a and b, page 71

Causal agents: Fungus, *Fusarium oxysporum schlechten*: Fr. f. sp. *Phaseoli* J.B. Kendrick and W.C. Snyder

Signs and symptoms
At the early stage of the disease, the main root turns into dark red. This color appears when the plant is about one week or at germination. The areas quickly spread to the root neck and move to portions above the soil surface. The red mark turns into brown with long cracks. Sometimes, the main root and the lower stem become hollow. The branches that develop from the main root are usually destroyed but the tip is not damaged by the fungus.

Source and spread
The pathogen lives in the soil as inactive spores but can pass the disease to seeds. Although the symptoms of this disease mainly appear on green bean, *Fusarium* wilt can also be found in other crops, especially those in the legume family. The disease forms inactivated spores that do not show any symptoms but signals the disease. Disease infection on green bean develops through the roots, veins and on the wounds. The fungus then spreads everywhere and penetrates into the cells causing yellowing, dropping of the leaves and wilting.

Role of environmental factors
The optimum temperature for disease development is about 20^oC. Soil humidity, heavy soil texture as well as poor irrigation are favorable for disease occurrence and serious damage.

Importance - plant compensation - physiological impact
Fusarium wilt was first seen on long bean in America in 1928. Typical symptoms of the disease include stunting of the plant, yellowing and dropping of leaves and finally wilting of the whole plant. The disease causes serious damage on
French and long bean but rarely on broad bean or soy bean. Like other soil-borne diseases, when a plant is infected by *Fusarium* wilt, it can not recover or compensate. The entire root of the infected plant will become black and rot. Inside the stem, transmission veins are seriously damaged resulting in inability to transfer water and nutrients to feed on other parts of the plant. This causes wilting, dropping of leaves or even wilting of the entire plant.

Natural Enemies and Antagonists
There are several other antagonistic organisms that control fungi, such as *Bacillus subtilis*, *Burkholderia cepacia*, *Pseudomonas fluorescens*, *Streptomyces griseoviridis*, and *Gliocladium catenulatum*. Different strains of these antagonists have been registered in the United States as biocontrol products for damping-off and some other soil-borne diseases. In the future, these biocontrol agents will also become available in Asia.

Disease can also be reduced in soils rich in compost. Compost contains many different micro-organisms that either compete with pathogens for nutrients and/or produce certain substances (called antagonists) that reduce pathogen survival and growth. Thus, an active population of microorganisms in the soil or compost out competes pathogens and will often prevent disease. Researchers have found that compost of almost any source can reduce disease. The effect of compost on plant pathogens can be increased by adding antagonists such as the fungi, *Trichoderma* and *Gliocladium* species. The compost is called fortified compost.

Management and control practices

- Plant resistant bean varieties, when available. There are many bean varieties now which can resist *Fusarium* disease. Check with the local seed supplier for more information on resistant bean varieties.
- Practice of crop rotation may be useful for soils with *Fusarium* wilt. However, the wide host range of *Fusarium* wilt includes all solanaceous, cucurbits, and leguminous crops. This severely limits crops that can be used in rotations. Beans or other vegetables are often rotated with rice because *Fusarium* wilt can not survive in flooded fields.
- Use vigorous seeds or seedlings. Slow emerging seedlings are most susceptible.
- Use seed that is coated with a fungicide layer.
- Soil sterilization is practiced in many countries, often as a preventive measure before sowing. There are many methods to sterilize small areas of soil. Biofumigation using ITC of brassica leaves, stems or plants is an effective method (see part 10.1). Lime and fungicides can also be used to treat the soil.
- Good results have been obtained with the use of antagonist, *Trichoderma* sp. For example, application of *Trichoderma harzianum* is recommended by the Department of Agricultural Extension in Thailand to prevent disease.
- An interesting option is the use of *fortified* compost. This is compost that contains the antagonistic fungus *Trichoderma*. *Trichoderma* is added to the compost after the primary heating period of composting is completed. The *Trichoderma* fungus multiplies to high levels in the compost and when added to the soil is as effective as, or in many cases more effective than chemical fungicides for control of a number of soil-borne diseases such as damping-off.
- Use of lime is often recommended for control of soil-borne pathogens. The effects of lime are not clear. It may have an effect on the micro-climate in the soil, stimulating antagonistic micro-organisms. It may also have an effect on nutrient availability, “boosting” the crop through adverse conditions.
- Raising or making high beds, good land preparation and good drainage will reduce risk of disease occurrence.

Once there is an infection in the field:

- Control of *Fusarium* wilt is extremely difficult because the pathogen can remain viable in the soil for many years. In some areas, the soil can not be used for legume crops due to heavy *Fusarium* wilt infection.
- Pull out infected plants including the roots and attached soil, remove them from the field and destroy them. This may reduce further spread of the fungi and source of inoculum.

- Do not use ditch or furrow irrigation when disease is in the field.
- Chemical is not recommended for control of *Fusarium* wilt.

> ✍ **Points to remember about *Fusarium* wilt:**
> 1. *Fusarium* wilt is caused by soil-borne fungi that can damage many plants in one field.
> 2. There are some management methods for the disease such as crop rotation, use of resistant varieties, and field sanitation.
> 3. Applying more organic matter, such as compost, to the soil gives some good results. The presence of antagonist fungi in the soil is enhanced and the bean crop gets more nutrients.
> 4. The use of chemicals is not effective for the control of *Fusarium* wilt.
> 5. Biocontrol agents, such as *Gliocladium virens*, *Trichoderma* sp. may be commercially available in Asia in the future.

10.5. Bean rust, *Uromyces phaseoli*

See illustration Figures 5a and b, page 71

Causal agents: Fungi, *Uromyces appendiculatus* (Reben) Wint var. *typical* Arth

Signs and symptoms

Bean rust disease causes damage on all plant parts above the soil surface. The disease appears first on old leaves and later causes damage on stems and fruits at a less serious level. The first disease stains appear on leaves 5 or 6 days after the plant is infected. At the beginning, the stain appears like a small needle point dot or a yellowish (nearly white color) dot with edges. The stain gradually enlarges to a 2 mm diameter. When the leaf epidermis breaks, the spores (typical brown or rust in color) are easily rubbed off. The stain is surrounded by halo-like narrow yellow circles. There can be as many as 2,000 rust points on a leaf. Each point can contain many fungal spores that can spread the disease either by repeating the cycle on other surfaces of the plant or the soil.

Normally, the rust point is exposed on the lower leaf surface. On the upper leaf surface, the yellowish brown stain appears. Spore points can appear on both lower and upper leaf surfaces. At the end of the growth stage, dark red spores and sometimes black spores may be found on the fruit skin.

Source and spread

The fungi, *Uromyces phaseoli* is a single host fungus. Therefore, all its stages exist on the legume family. This fungus has a complete development period but winter and spring spores play a secondary role in the tropical regions.

The spring spore is single, with oval or undetermined shape, colorless, and has a thin capsule 20-42 x 16-28 in diameter with many small thorns. The spring spore often appears in high temperature areas. In regions with hot and wet climate, this fungus mainly exists under the form of fiber and summer spores. These summer spores are single, sphere or oval, brownish and have small thorns. They can germinate right after maturing. In suitable conditions, the germ of the spore can penetrate causing damage to the plant within 5-10 days. The summer spores spread the disease during the growth period of the plant. The spores can live about 6-7 months. In effect, the spores conserve pathogens in the field in the tropical regions. Bean rust disease does not spread through seas but it can spread to other areas through farming tools, insects, animals or farmers. Wind is one of the factors that bring this fungus to farther distances.

In cold regions, the fungi, *Uromyces phaseoli* lives through winter under the winter spores. The winter spores have oval or sphere shapes, single, dark brown, with flat and smooth pedicel, with short stem at the root and prominent peak-like nipple. The spores exist in infected debris and germinate when spring comes.

Role of environmental factors

Humidity and environmental factors have direct effects on the growth of the fungi and its damage on plants. The summer spores germinate from 10-35°C but the optimum degree is from 16-22°C. Temperatures at 15-24°C are favorable for summer spores to form and for the fungi to penetrate and cause infection. The spores do not form at temperatures between 2-6°C. Fungal germination and penetration is favorable where there is water-drop and dew-drop or high humidity (over 95%).

Importance - physiological impact

Bean rust disease was first found on French bean in 1795 in Germany. The disease causes damage in all French bean growing areas in the world where there is high humidity for a continuous 8-10 hours. When the conditions are favorable at the beginning of the season, bean rust disease can destroy the whole crop.

Leaves infected by bean rust disease become dry, scorched and drop. In the process of causing damage on leaves, the climbers of the French bean also drop and consequently the yield is reduced.

Natural Enemies/Antagonists

Unknown

Management and control practices

- <u>Use resistant seeds for seedlings</u>. Currently there are many resistant varieties of French bean and long bean against bean rust disease. Ask seed companies in the locality to obtain information about resistant varieties.
- <u>Select fields</u> in dry and aerated areas and with proper drainage. Apply methods of suitable weeding, fertilization, irrigation, raising beds and avoid flooding in furrows.
- <u>Practice crop rotation</u> often with crops in the graminaceous family. Do not plant legumes for many years in the same field.

- Clear debris from infected plants right after harvesting. Do not use stems and leaves of the infected plants to make compost. Clean up weeds, especially leguminous weeds for effective prevention and spread from infected plants to healthy plants.

Once there is an infection in the field

- Prune leaves with symptoms of the disease in order to prevent spread to other leaves.
- Avoid touching infected plants so as not to bring fungi to other areas.
- If necessary, use fungicides to prevent the disease from spreading to healthy plants. Some commonly used fungicides are Maneb, Zineb, Chlorothalonil and Sulfur. Benomyl and other systemic fungicides are also sometimes sprayed on the lower and upper surfaces of leaves. If using systemic fungicides, it is very important that the active element can cover all components of the plants and particularly entire surfaces of lower leaves.

Points to remember about bean rust:

1. Bean rust disease causes severe damage on pods as a result of leaves that drop and reduce yield of fruits.
2. Most of the control methods focus on the prevention or restraining the infection.
3. Sanitation methods such as pruning infected leaves are effective in limiting the disease spread. However, if leaves are over pruned, it will reduce the yield.
4. The use of resistant seeds will reduce damage caused by the disease.
5. When conditions are favorable, sanitation will not prevent the disease and fungicides may be necessary. However, you may want to set up disease experiments in the field and test the number and time of spraying fungicides.

10.6. Angular leaf spot (*Phaeisariopsis griseola* - Sacc.)

See illustration Figure 6, page 72

Causal agents: Fungus, *Phaeoisariopsis griseola* (Sacc.)

Signs and symptoms

The disease appears on plant parts above the soil surface. The disease stains become clear on leaves after 8-12 days after infection. Initial symptoms on leaves appear as uneven spots of brown or grey with or without circles around. After nine days of infection, leaves show necrotic stains with an angular shape that is a typical symptom of the disease. The disease has become more serious when the stains are spread and combined into a large area of yellow necrosis and the infected leaves drop. At the early stage of infection, stains on leaves have round shape rather than angular one, and can develop many rings around the same center. Stains on fruit are big, oval or round shape. Spots are red brown with darker red circles around.

Stains on pods can be mistaken with the common virus disease or light leaf spot, especially on mature plants. Stains on stems and petioles are dark brown, long and slender. Ootheca and black spores are created by the stains on the infected lower leaves, fruit, stem and leaf stem. Spore formation occurs after 24-48 hours under conditions of continuous humidity.

Source and spread
Angular leaf spot disease is caused by the fungi, *Phaeoisariopsis griseola*. This fungus belongs to the group of *Moniliales*. Groups of 8-40 conidiophores are produced that form conidia at the tip. The conidia are grayish, cylinder or spindle shape (sometimes a little bit curved) with dimensions of 3-9 x 34-83 mm and have from 0-6 partitions. The dimension and number of spores considerably change during the separation process to create new spores. Spores are formed at temperatures of 16-26^{o}C. The fungi transfer disease to many crops such as French bean, green bean and soy bean.

Role of environmental factors
High humidity (95-100%) within three hours is enough to cause the disease. If the length of time of high humidity increases up to 24 hours, the infection rates also go up. Although the infection and development of the disease happen at temperatures of 16 - 28^{o}C, the most favorable for the early stage of disease and its development is below and above 24^{o}C, and not exceeding 36^{o}C and 5^{o}C. The latency period is 5-7 days at 24^{o}C. In cold weather, (low temperatures like 16^{o}C) this period will last to 15 days.

Pathogens can successfully develop and form many substances under dry conditions. However, the disease will quickly develop when humidity is high or when there is average wind and low humidity. Symptoms in the field can be seen right after flowering or near maturation. The yield loss is caused by picking infected fruits when the harvest period is coming. Seeds can be infected and cause damage. The damage on red bean often goes with fungal development on the seed hilum. On other legume crops, fungal development can be seen at the hilum and other areas of the seed coat. The infection level of seeds varies with the kind of legume crop. The existence of the fungi *P.griseola* in seeds reduces with time.

Importance - physiological impact
Angular leaf spot disease is important on French bean in the tropical and sub-tropical regions. The disease causes damage on most of the plant parts above the soil, especially leaves and fruits of crops in fields planted continuously to French bean over many seasons. It often causes damage before and after the stage of flowering and in regions with warm and wet weather, high density of infected debris or high number of infected seeds. Angular leaf spot disease causes some or all leaves of the plant to drop off, affects stems resulting in empty seeds and loss in seed yield. If farmers use susceptible varieties and plant in areas favorable to fungi development, the loss in yield caused by this disease can go up to 80%.

Natural Enemies/Antagonists
Unknown

Management and control practices

- Use healthy seeds. Use seeds from non-infected plants or healthy seed sources. Use healthy seeds in combination with IPM methods, it may limit disease incidence.
- Use resistant varieties. Many varieties of French bean are resistant both to angular leaf spot disease and are heat-resistant (short light period, high light intensity).
- Select planting areas carefully: Do not plant French bean in areas near fields under harvest as the infected plants can transmit the disease into newly planted crops. Plant in areas where other crops such grass and maize was previously planted because these crops are not host plants of the disease.
- Apply seed treatment by putting seeds into a solution of streptomycin (50,000 ppm) before planting in order to get rid of the disease source. Seed treatment can also be done by using warm water. When necessary, fungicides are also highly effective in preventing the disease (see Part 3.4).
- Select fields in dry, aerated areas with proper drainage.
- Crop rotation should be done with other crops (not the leguminous) at least within two years in order to break the development of the fungi and make the field disease-free.
- Remove or destroy debris after harvesting. If the debris is used for compost, they should be covered by a layer of soil. The compost should not be used for other leguminous crops or those susceptible to the disease unless the compost is completely decomposed or mature. Debris from infected plants will be a new source of infection and therefore they should be burned outside field area.

Once there is an infection in the field

- Prune leaves with disease symptoms to prevent the spread to other leaves.
- Do not move into the field or take care of plants while bean plants and the field are still wet. Do not move farm tools through the infected fields.
- If it is necessary to use pesticides, use several kinds (not together) to kill fungi to keep the disease from spreading to healthy plants. Some fungicides such as Bitertanol, Chlorothalonil, Mancozeb, Zineb, and Metiram are considered to be more effective when sprayed over the surfaces of lower or upper leaves. Systemic pesticides can move to all plant parts and cover the entire surface of lower leaves.
- Establish disease forecast programmes in order to estimate disease incidence based on weather factors. These programmes can help farmers decide the period when it is suitable to use pesticides. However, the success of these programmes will vary.

Points to remember about Angular leaf spot:

1. Angular leaf spot disease caused by fungi, severely damages plants and causes great loss in fruit and seed yields.
2. Most of the control methods for the disease focus on the prevention and restraint of the infection.
3. Sanitation methods such as pruning infected leaves are good for preventing disease spread. However if pruning is abused, it will cause yield loss.
4. Use resistant seeds to reduce disease incidence.
5. Once there is an infection and the environmental conditions are favorable for the disease spread, it is very difficult to treat the disease only by sanitation methods. It may be necessary to use pesticides. However, it would be good to carry out disease experiments in the field such as on the number and timing of pesticide sprays. This experiment will show that some of the sprays are not necessary at all.

10.7. Powdery mildew, (*Erysiphe polygoni* DC)

See illustration Figure 7, page 72

Causal agent: Fungus, *Erysiphe polygoni* DC

Signs and symptoms

The initial stains are pale yellow spots. Afterwards, spores are formed as indicated by white mold on the stains. These stains gradually spread and cover the entire leaf surface. Leaves turn yellow and wilt, then turn into brown and dry up.

Whitish, talcum-like, powdery fungal growth develops on both leaf surfaces and on petioles and stems. Symptoms usually develop first on older leaves, on shaded lower leaves, and on abaxial leaf surfaces. Older, fruit-bearing plants are affected first. Infected leaves usually wither and die, and plants senesce prematurely.

Source and spread

Two powdery mildew fungi that affect beans are *Erysiphe polygoni* DC and *Sphaerotheca fuliginea*. It is difficult to determine which fungus is causing powdery mildew because a sexual stage seldom is present.

Erysiphe polygoni DC is an obligate parasite that can survive on wild legumes, cucurbits or year-round-grown crops in tropical and subtropical areas. Primary sources of inoculum include conidia dispersed over long distances, from greenhouse-grown cucurbits and from alternate hosts. Conidia remain viable for 7-8 days. Although *Erysiphe polygoni DC* has broad host ranges, non-legume hosts probably do not serve as a major source of inoculum, because of pathological specialization.

Role of environmental factors

Powdery mildew develops quickly under favorable conditions. The time between infection and appearance of symptoms is usually only 3-7 days, and a large number of spores can be produced during this period. Favorable conditions include dense plant growth and low light intensity. High relative humidity is favorable for infection and conidial survival; however, infection can occur at relative humidity below 50%. Dry conditions favor colonization, sporulation and dispersal.

The optimum temperature for disease development is 20-27ºC and infection can occur between 10ºC and 32ºC. Under field conditions, powdery mildew development is arrested at 38ºC and higher temperatures.

Importance - plant compensation
Powdery mildew has been recognized since the 1880s under field and greenhouse conditions worldwide. This disease is a major production problem. All legumes are susceptible; however, symptoms are less common on commercial beans, because many cultivars are resistant. Mildew reduces yields by decreasing the size or number of pods or the length of time crops can be harvested. Pod quality can be reduced significantly.

Natural enemies/antagonists
Unknown

Management and control practices
- Use resistant cultivars.
- Use sites with good air circulation, drainage, low humidity and with ditch irrigation.
- Rotate with some other non-leguminous crops.
- Destroy leguminous weeds to help prevent disease infection to healthy crops.
- Prune infected leaves to prevent infection of other leaves.

Once there is an infection in the field:
1. Prune leaves showing symptoms in order to prevent spread of disease to other leaves.
2. Do not move into the field or tend to plants while bean plants and field are still wet. Do not move farming tools through infected fields
3. Use fungicides to prevent disease spread to healthy crops. Systemic fungicides are useful when it is difficult to get good coverage of lower leaf surfaces and foliage below the top leaves. In the absence of systemic fungicides, thorough coverage of lower leaf surfaces is important. In some areas, solution of lime sulfur and copper fungicides is used to control powdery mildew.

✍ **Points to remember about powdery mildew:**

1. Powdery mildew is one of the important diseases causing plants to die or damage pods severely.
2. Most management practices focus on prevention or delay of infection.
3. Sanitation, such as pruning infected leaves is a good control method and it prevents spread of the fungus. However, too much pruning results in lower yields.
4. Once powdery mildew infection occurs and environmental conditions are favorable for its spread, the disease is hard to control only by sanitation methods. Fungicide application may be needed. However, the timing and number of fungicide applications can be changed by studying the disease in the field.

10.8. Bacterial blight, (*Xanthomonas axonopodis* pv.*phaseoli)*

See illustration Figure 8, page 72

Causal agent: Bacterium, *Xanthomonas axonopodis* pv. *phaseoli* (E.F. Smith) Dows and bacterium, *Xanthomonas campestris* pv. *phaseoli* (E.F. Smith) Dye

Signs and Symptoms

Bacterial pathogens may come from previously infected debris and may reside on the surface of leaves without causing disease. However, when conditions become favorable the pathogen can penetrate into leaf cells causing them to become excessively enlarged, broken, and consequently form spots. Early symptoms appear as small spots with water or darker greenish areas. Many spots combine to create necrotic spots. The centre of these spots dry and turn into brown. These spots are surrounded by thin yellow circles. These are typical symptoms to recognize the disease. For susceptible varieties, the spots will continuously spread on the leaf surface and combined with other adverse factors injure the entire leaf.

The disease can also destroy the stem and fruit of bean crops, depending on the infection in the seeds and favorable weather conditions. The small spots with water are also seen on fruits. The disease stains turn from red to brown and finally make fruits crisp.

Source and Spread

The bacteria mainly exist in seeds. When seeds infected by bacteria are planted, after germination the seedlings will have yellow spots on stems, lemma and first true leaves. If the weather conditions are not favorable, the stains will only appear when plants are mature. However, at any time during the growth stage of plant, the rot stains may be formed at the nodes on the stem, especially nodes at the lower section of the wounded plants if affected by rain or storm. The disease pathogen can live in the debris and exist for many years. Infection is observed in all French bean and other leguminous crops causing severe damage in summer and autumn. The disease is spread through seeds, wind or insects.

Role of environmental factors
Bacterial blight develops well at temperatures of 27-32ºC. Temperatures higher than 35.5ºC will restrain the development or cease the productivity of bacteria. The damage from bacteria will be greater when there is high humidity and climate is favorable. At the end of the cropping season, the disease development will be equivalent to the development of bacteria on plants.

Importance of plant compensation
Bacterial blight causes damage on all leguminous crops worldwide. The yield loss caused by each type of bacteria is difficult to statistically present as the disease symptoms on legumes are similar to one another. The bacteria causing blight can not cause plants to die but it causes serious losses in pod yields. Statistical data in 1967 from Michigan State in America, reported yield reductions of 20% due to bacterial leaf spot.

Natural Enemies/Antagonists
Unknown

Management and control practices
- Use disease–free seeds for planting. Do not use seeds from infected fields to plant in the next cropping.
- Plant resistant seeds. Many green bean varieties are both resistant to bacterial blight and impervious to heat, have short light period and high light intensity.
- Treat seeds by putting them into streptomycin solution (50,000 ppm) before planting. This will kill the disease source. Seeds can also be treated by using warm water. This method is highly effective in disease prevention.
- Selecting fields in dry, aerated areas and with proper drainage.
- Rotating legumes with crops belonging to other families at least 2-5 years.
- Tidying up debris and weeds in the field, especially leguminous weeds. This strategy will help prevent the spread of the disease from infected to healthy plants. All debris from infected plants should be burned after harvesting.

Once there is an infection in the field:
- Use bactericides to prevent the disease from spreading to healthy plants. Bronze mixture is highly effective in preventing this disease. Bronze sulfate can also be used to spray on plants when early symptoms are found in the field. Biological products like *Streptomycin* can also be sprayed to reduce the number of infected plants in the field.
- Prune infected leaves to prevent the disease from spreading to healthy leaves and plants.
- Do not enter into the field or care for plants when the plants and field are still wet. Do not move farm tools through the infected fields.

Points to remember about bacterial blight:

1. Bacterial blight is one of the important diseases of legumes. It does not cause plants to die but severely damages pods.
2. Using disease-free seeds is effective.
3. Most management practices focus on prevention or delay of infection.
4. Sanitation, such as pruning infected leaves is a good control method and prevention for the spread of bacteria. However, pruning when leaves are wet or weather is humid may lead to faster disease development and spread.
5. Once bacterial blight infection occurs and environmental conditions are favorable for its spread, the disease is hard to control just by sanitation

10.9. Bacterial halo blight (*Pseudomonas syringae* pv. *phaseolicola*)

See illustration Figure 9, page 72

Causal agent: Bacteria, *Pseudomonas phaseolicola* (Burke.) Downson and *Pseudomonas syringae* pv. *phaseolicola* (Burke.)Young, Dye and Wilkie

Signs and symptoms

The disease symptoms vary depending on the period when plants are infected, the location of infection on the plants and the environmental conditions. The diagnosis of the disease symptom is very important to assess the disease level and determine the original disease source, the extent of infection and the estimate on possible damages.

The disease symptom on seedlings after germination is very important as it reveals the original disease source. If the true leaves are yellow, it indicates that germs are infected. If the growing point is red, it also shows that germs are infected. The red germ leaves and yellow true leaves are symptoms of using seeds from infected fruits. The dripping spots scattered on leaf surfaces indicate that the seeds were infected by bacterial blight, usually from debris from dry leaves.

Severely infected seeds can be the cause of infection when plants mature. At first, the dripping spots look like needle stains on lower leaf surfaces. These spots turn into brown after several days. The surrounding areas of the spot turn into yellowish green. The yellow areas surrounding the spots and the disease stains look like bright haloes. Hence, the disease is called bacterial halo blight disease.

Source and spread

In the field, the main source of the disease comes from pods with infected seeds, seeds with infected skin or infected plants and debris from the previous crop. Infected bean seeds become a source of severe infection because it brings pathogens from one area to another. In addition, bean seeds are where bacteria over winter and cause disease to be carried over from one season to the next.

Infected seeds are seen often in susceptible varieties than in resistant varieties. Even if there are only several seeds carrying bacteria, it can easily spread if the conditions are favorable for it to develop. Even if only one out of 16,000 seeds is infected, it is enough to cause severe disease damage.

In case of bacterial halo blight, seed infection can also be spread by the talc from infected bean plants. This partially contributes to disease severity although the plants may have come from seeds certified to have originated from disease–free plants. Dusts from seeds in storage or from harvesting tools contribute to disease spread.

Infected plants also cause the spread of disease. Disease spread from plant to plant is caused by association, by splashing from rain, wind, hail, overflow or farming tools. The bacterial halo blight can over winter in the debris of infected plants and exist in stems and fruits of infected bean crops as well as remain in the field during winter.

Role of environmental factors
Low temperature and high humidity are favorable for bacterial dispersal. Optimum temperature is 18ºC to 22ºC. The disease can be easily recognized after a short time of infection, under favorable condition and at high infection level. Flower and pod sets are also infected when enviromental conditions are favorable.

Importance - plant compensation
The bacterial halo blight causes severe damage on pods worldwide. The disease causes damage in most of the areas with low temperatures and cold climate and where the disease is available. The loss caused by this disease depends on the infection incidence and environmental factors. Yield loss is recorded by as high as 43% in America.

The disease mainly causes injury on leaves and fruits and consequently severely affects fruit yield. The disease appears and damages the leaves affecting the photosynthetic process of the plants. If plants are heavily infected by the disease, the leaves drop down, wilt and die.

Natural Enemies/Antagonists
In America, the biological prevention agent - *Streptomycin* is sold under the name “Agrimycin 17 or AS-50" (Novartis company) or “Plantomycin” (Aries Agro-Vet Industries). The products prevent several pathogens including the angular leaf spot and brown spot caused by bacteria. The products are made as solution for spraying. More details on these biological products can be seen in the book "The Guidelines on Biological Plant Protection Medicine" prepared by Copping.

Management and control practices

- Use disease-free seeds. Do not use seeds from infected plants for the next crop.

- Treat seeds with chemical or physical methods to kill pathogens before seeding (see section 3.4).
- Rotate with non-leguminous crops such as graminaceous or solanaceous plants as these kill the host source of bacteria resulting in disease suppression. Crop rotation should be implemented over a long period (over two years).
- Use field sanitation practices such as weeding and clearing debris from infected plants after harvesting. This will help prevent the spread of disease. The debris of diseased plants can be made into compost for the next crops.

Once there is an infection in the field:

- <u>Limit the wet period of leaves</u> because wetness stimulates the growth process and bacterial infection. Overhead irrigation should not be done. Watering must be done in the morning so that leaves can quickly dry. Green beans should not be planted in shady areas and there is less wind as these conditions prolong the time when leaves are wet.
- <u>Prune infected leaves</u> to prevent disease spread to other leaves.
- <u>Use several bactericides</u> to restrain disease spread to healthy plants. Bronze mixture is highly effective. This mixture can be sprayed at the end of the vegetative growth period (before flowering) in order to prevent the disease or secondary spread of the disease. In addition, several bactericides such as streptomycin and several systemic pesticides are considered to be better for spraying on the surfaces of lower or upper leaves.
- <u>Do not enter into the field</u> or care for plants when the plants and field are still wet. Farming tools should not be moved through the infected fields.

Points to remember about bacterial halo blight:

1. Bacterial halo blight is one of the important diseases; it does not cause plants to die but severely damaged pods.
2. Using disease-free seeds is effective.
3. Most management practices focus on prevention or delay of infection.
4. Sanitation, such as pruning infected leaves is a good control method and it prevents spread of the disease. However, too much pruning may result in lower yield.
5. Once bacterial halo blight infection occurs and environmental conditions are favorable for its spread, the disease is hard to control just by sanitation methods. Fungicide application may be needed. However, the timing and number of fungicide applications can be changed by studying the disease in the field.

10.10. Bacterial brown spot (*Pseudomonas syringae pv. syringae)*

See illustration Figures 10a and b, page 73

Causal agent: Bacteria, *Pseudomonas syringae pv. syringae* van Hall

Signs and symptoms
The symptoms appear on leaves similar to those of bacterial leaf spots, except for the rounds spots on fruits. On leaves, there are curly parts or rot areas of different sizes. The stains do not have water and yellow circles around them. Bacteria can penetrate into stems and cause injuries on stems. Fruits are curly or curved.

Source and spread
The causal organism, *P. syringae* bacteria has a wide hosts range. The bacteria which can subdivide in legumes can cause severe damage on green bean. Bacteria can exist and develop their population on hairs of *Vicia villosa L.* and bring the early disease types to beans in the rainy season. They can live on debris of bean plants and seeds.

They can easily spread through spraying water and rain. They also can exist far from the field surface such as on the flower buds where they can penetrate into newly formed components of plant. The bacterial density in susceptible plants is much higher than that in resistant plants.

Role of environmental factors
The bacteria need optimum temperatures of 24-26ºC during the growth period. They can generate white ooze in the culture medium. In the rainy season, the bacteria spread rapidly through rain drops. Water drops sprayed in fields are also a good way for bacterial spread.

Importance - plant compensation
The bacterial brown spot was first found in America in the 1930's but it was not considered as a serious disease. It was only in 1963 when the disease caused severe damage in many planting areas of green beans in America. The disease is also found in Brazil. The causal organism of the brown spot has a diversified host source including on long bean, French bean, soybean, and many legume crops. The disease becomes more serious when it is transmitted through seeds. If plants are infected in the seedling period, the disease will affect yield greatly, and sometimes there is nothing to harvest. However, plants can have resistance to the disease.

Natural enemies/antagonists
In America, the biological agent *Streptomycin* is sold under the product name “Agrimycin 17 or AS-50" (Novartis firm) or “Plantomycin” (Aries Agro-Vet Industries. These products, formulated as spraying solutions, prevent pathogens of bacterial blight and brown spot caused by bacteria. More details on the biological products are found in the book named "The Biological Plant Protection Guidelines" prepared by Copping.

Management and control practices
- Use disease-free seeds for planting.
- Use resistant cultivars. Some bean varieties are resistant to the disease, tolerant to heat, with short light period and high light intensity.

- Use sites with good air and water drainage.
- Rotate with other non-leguminous crops.
- Destroy weeds especially leguminous weeds to prevent disease infection of healthy crops.
- Prune infected leaves to prevent spread to other leaves.

Once there is an infection in the field:

- Use copper fungicides to prevent disease from spreading to healthy plants. Applying copper fungicides before flowering stage will help to prevent secondary infection.

Points to remember about bacterial brown spot: 1. Bacterial brown spot is one of the important diseases which cause plants to die or severely damaged pods. 2. Using disease-free seeds is effective. 3. Most management practices focus on prevention or delay of infection. 4. Sanitation, such as pruning infected leaves is a good control method and it prevents spread of the bacteria. However, pruning when leaves are wet or weather is humid may lead to strong disease development and fast spread. 5. Once bacterial brown spot infection occurs and environmental conditions are favorable for its spread, the disease is hard to control just by sanitation methods.

10.11. Bean anthracnose (*Colletotrichum lindemuthianum)*

See illustration Figures 11a and b, page 73

Causal agent: Fungus, *Colletotrichum lindemuthianum*

Signs and Symptoms

C*olletotrichum lindemuthianum* can cause damage from germination to fruiting stage. The disease symptoms on seedling leaves are round, brown to black and sunken spots while on seedling stem, symptoms are long, yellowish brown, sunken and chapped. In case of severe infection, spots combine to make a long one. Consequently, seedlings die and fall down.

On leaves of mature plants, spots are round, polygon, octagon or undetermined shapes located along leaf veins. Spots measure about 3-10 mm long. The early symptom is brownish yellow and later turns dark brown with a red edge. Black fungal spores appear on many black spots on the leaves. Eventually the leaves dry up. Long, dark brown and sunken spots appear on petioles and stems. Infected plants are thin with yellow leaves that easily drop.

The disease also damages flowers and fruits, i.e., it makes flowers drop and provide no fruits. On infected fruits, skin have brownish yellow or grey, round with a 3 -10 mm diameter, deeply sunken and with red edges. Many reddish spores will form unevenly located in circles with the same centre. In several cases, the entire fruit is covered by the disease spots and the fruit will not have seeds. On seeds, the spot is small and brown or black.

Source and Spread

The fungi causing *C. lindemuthianum* mainly exists under the form of fungal fiber on seeds. In the germ and seed skin, the fungal fiber can live up to two years. Debris of infected plants in the soil is also a long-lasting disease source. The fungal fiber can live in the soil for over one year. The fungal fiber living on seeds exists with the germinating seeds. When seedlings grow out of the soil surface, the lemmas are already infected. The schizogenous spores are spread by wind, rain, and sprays. These spores germinate to penetrate into the host through injuries or directly into the epidermis. The schizogenous spores easily germinate in water drops. Each spore can form two lemma pipes (or 4 lemna pipes) through mechanical pressure from the head of the lemma pipe by perforating the cutin layer, then going through the epidermis as a result of the impact.

The fungal disease can move in water source and spread the disease to other plants or fields. Spores also can be splashed together with rain drops from infected plants to healthy ones. Furthermore, they can also spread through farm tools, clothing of farmers, pests or animals such as rabbit, rat, etc. A rabbit that runs through the green bean furrow in the morning can be the greatest infection source!

Role of environmental factors

C*olletotrichum lindemuthianum* develops and does severe damage when humidity is high and temperatures are low. When the humidity is below 80%, the disease can stop developing. The optimum temperature for disease development is 16-20ºC. The fungal spores can germinate in temperatures ranging from 4-34ºC while the optimum range is from 22-23ºC. When the temperature is below 13ºC, the disease will stop developing.

In conditions of high humidity and favorable temperatures, the incubation period is about 4-7 days. In Vietnam, the disease severely develops and does heavy damage in the rainy and wet period or in the spring-winter crop, especially in low lying and flooded fields.

Importance - plant compensation

C*olletotrichum lindemuthianum* was first found in Germany and Italy in 1875. In 1880, the disease was the main cause of severe damage on green beans in England. Currently, the disease appears and damages on all the planting regions in the world.

The damage levels of *C. lindemuthianum* on legume crops are different. Green beans and broad beans are less susceptible to the disease while long bean and some other beans are very susceptible especially at high humidity and low temperatures.

As the disease causes damage on all the developmental stages, it greatly affects the growth and development of the plant. When plants are infected, its first response is to generate new components such as branching of leaves to compensate for the wounded parts. However, the disease source is still available on the plant or in field so the newly-generated parts are continuously infected. If the weather conditions are not favorable, the disease will stop developing and the plant can compensate. However, this compensation only ensures the living mass and not the yield of plants. Yields are considerably reduced or completely lost in infected fields.

Natural Enemies/Antagonists
Unknown

Management and control practices

- Use varieties resistant to *C. lindemuthianum*. However, varietal resistance is not sustainable as it depends on the natural conditions in each region. Farmers should find the local varieties that have resistance to the disease.
- Use disease-free seeds harvested from disease-free regions for the next crops. This is an effective method to prevent the disease from spreading to many other regions.
- Treating seeds before planting is an effective preventive method. Seeds can be treated by putting them in warm water of 55-72ºC for 15 hours, then deep them in boiled water (100ºC) for 25 minutes so that the fungi will be killed. This does affect seed germination. Seeds can also be soaked in 0.2% Thiram solution for 24 hours.
- Select fields in high areas, with proper drainage and sufficient wind for aeration for planting green bean.
- Clear plant debris after harvesting especially in places where disease appeared. Burn or deeply bury debris to kill the fungal disease source. Combine with deep ploughing method to bury debris.
- Practice crop rotation with non-hosts plants such as rice, wheat or maize. Rotate crops every 2-3 years to break the disease cycle of fungi.
- Practice appropriate and balanced fertilizer application to reduce disease incidence on plants.

Once there is an infection in the field:

- When the disease newly appears in the field, use fungicides to prevent disease from spreading to healthy plants. Fungicides such as thiophanate methyl, captafol, chlorothanonil, carbendazim, etc. are considered as highly effective in preventing the disease, *C lindemuthianum,* on green beans in the period before flowering and formation of young fruits. Systemic pesticides are considered to be better than other pesticides for spraying on the surfaces of lower or upper leaves. For systemic pesticides, it is important that their active ingredients can move to all the components of plants and cover entire surfaces of lower leaves. In addition, systemic pesticides last longer and will not be washed out by rain so they are able to prevent the fungal infection on other plant components.

Points to remember about bean anthracnose:

1. C*olletotrichum lindemuthianum* causes severe damage on leaves and fruits.
2. Use disease-free seeds to plant in order to effectively prevent the disease.
3. Most of the management methods focus on the prevention or restraining the infection process.
4. Sanitation such removal or pruning infected leaves is a good control method and helps to restrain disease spread. However, too much pruning may result to lower yield.
5. Once the infection occurs and the environmental conditions are favorable for disease spread, the disease is hard to control just by practicing sanitation methods.
6. Pesticides may be needed however the timing and number of pesticide applications can be changed by studying the disease in the field.

10.12. Bean Mosaic Virus – *BMV*

See illustration Figures 12a and b, page 74

Causal agent: Three strains of virus

Signs and symptoms

The causal virus can appear on plants under three symptoms as follows: mosaic leaves, black roots or partial injuries on leaves (depending on the infestation period, green bean varieties, the causal virus and environmental conditions.) Normally, bean mosaic virus will curl leaves but rarely make plants die. On the petioles of green bean plants appear yellow lines with undertermined shapes and green areas, especially on the mosaic places. Furthermore, leaves are lumpy, deformed and show other phenomenon. Infected leaves can be smaller and longer than the healthy ones due to the uneven development of leaf cells. Leaves of plants infected at the beginning of the crop growth are yellow, curly and stiff. Petioles on the tip of plants gradually wilt when plants are in the flowering period. Plants will turn into brownish green. Leaves steadily drop and finally the entire plant wilts resulting to death. Roots of infected plants normally have dark color. Fruits of the infected plants are often smaller and have less seeds than normal plants.

Source and spread

There are three strains of virus that can be the causal agent of bean mosaic virus on green bean. These strains of virus can transfer through seeds. About 30-80% of seeds of infected plants contain virus inside. However, if green beans are infected after the flowering stage, their seeds will not be infected. Virus can exist within the seed skin for a very long period of at least 30 years.

Bean mosaic virus on green bean is mainly spread by aphids. This is a very dangerous vector for spreading disease in the green bean field. Disease incidence depends on the virus that is injected by aphids on leaves and fruits and the period before and after the transmission to other leaves or fruits.

The rate of spread in the field will be more favorable in the areas with covered roof and adjacent to areas planted to lucerne, clover and buckwheat. Aphids feed and get their virus from lucerne before moving into other fields. Temperatures from 22-25ºC and dry weather are favorable for aphids' movement.

Role of environmental factors
Environmental conditions create or prevent the virus mosaic disease. Different degrees of temperature and humidity can cause different symptoms. Symptoms of the bean mosaic virus appear clearly at temperatures from 20 to 25ºC.

Disease spread is mainly caused by aphids. Conditions that are favorable for aphid development are dry weather, drought and temperatures of 22-25ºC. Under these conditions, the disease spread also increases.

Importance - plant compensation
The disease has a high effect on fruit yield and quality if infestation happens before and during the flowering stage. It has been recorded in areas where there is intensive cultivation of green bean that yield loss due to this virus disease can go up to 100%.

When infected, plants are stunted and their compensation ability is low. Plants can not bear flowers if the disease appears during the early stage of development. If infection occurs at flowering stage, it will reduce the number of flowers and fruits. In some cases, infected plants will die if they are damaged by aphids and other insects.

Natural enemies/antagonists
To date, no natural enemies have been found for these strains of viruses. However, the virus is spread by the aphids' movement. If there is no aphid in the field, the disease will not be spread. Nowadays, a great number of natural enemies on aphids have been found. Examples of these are red lady bird beetles, ants, etc. Please refer to section 12.3 for this topic.

In several northern areas such as Hai Phong, Ha Tay, Vinh Phuc and Nghe An, the application of mineral oil products to prevent aphids and disease spread was shown highly effective.

Management and control practices
- There are several resistant green bean varieties but these are often hybrids. However, these varieties are not resistant against the bean mosaic virus as there are many strains of virus. Moreover, it seems that the strains of virus causing this disease can quickly overcome the resistance of plants.
- The use of disease–free seeds is an important preventive method. As viruses can exist in the seed coat for a very long period of time (sometimes 23 years), the seed treatment is completely complicated and requires advanced techniques because they include chemical formulations and/or dry-hot treatment over a long time in special furnaces (in order to kill virus strains existing in the seed coat).

However, the germination percentage of the seed reduces by time. It is therefore suggested not to use varieties of plants/seeds that are probably infected or suspected to be infected (including diseases other than bean mosaic virus).

- In order to reduce the effect of infected debris in the field, crop rotation every two years with a non-susceptible crop is encouraged in green bean areas where the bean mosaic virus caused severe damage before.
- Apply preventive methods for the disease vector such as the use of mineral oils weekly after germination as it also highly helps prevent the disease (see the information in the box below).

The application of mineral oils to prevent mosaic virus disease on tomato and some fruit vegetables - experiences drawn from Australia and Vietnam

In Australia, mineral oil is applied as a weekly spray on tomato after planting to kill vectors such as white fly, aphids and red lady bird beetles. These insects transmit and spread virus diseases on crops belonging to the legume, solanaceous and cucurbit families. The active elements in mineral oils seal the breathing holes on the leaf surface in order to prevent micro-organisms from penetrating into leaf cells and causing damage.

An experiment carried out in Hai Phong in the 2004 tomato spring crop showed that although mineral oil was applied after 35 days of planting, it was still highly effective in the prevention of the virus. The percentage of virus leaf curl that appeared on the tomato area sprayed with mineral oils was 35% while in the control field it was 100%. A similar experiment was implemented in Quynh Luu, Nghe An, where mineral oil was sprayed immediately after planting. The result showed that there were no infected plants in the field sprayed with mineral oils while plants in the entire control field were infected.
Information from study report from the Vietnam FAO-IPM office in cooperation with experts from the Western Sydney University, Australia and the vegetable IPM programme in Hai Phong Plant Protection Sub Department, June 2004.
Information from winter crop study report from the vegetable IPM trainers in Nghe An PPSD and Vietnam FAO-IPM office, December 2005.

- Practice suitable field sanitation to reduce infection. This can include the burning of covers from infected plants. In addition, the removal of waste material and other plants from the field can help prevent disease. Green beans should not be grown near plants for animal feed such as lucerne and clover (they harbor aphids and serve as sources of virus inoculum).
- Select suitable season for planting green beans in order to avoid dry weather that is suitable for the development of aphids. This will help minimize disease spread in the field due to the movement of aphids.
- Killing the vector (such as aphids) is also an effective preventive method. There are different methods to manage aphids such as the use of chemicals, natural enemies like spiders and lady bird beetles (see the section 12.3). At present, many studies have shown that spraying mineral oil on plants is highly effective for killing aphids and reducing the toxic effect of chemical pesticides on people and the environment.

Once there is an infection in the field:

- Uproot and burn virus infected plants. These plants may be a source for further spread of the disease when left in the field. Be sure to wash your hands and clothes carefully to avoid its spread.
- Once the virus mosaic disease appears in field, the infected plants should be uprooted and destroyed.
- Pesticides should be sprayed to control aphids, the main vector for spreading the disease in the field. Regular monitoring of aphid populations and timely management should be implemented to prevent disease spread.
- Note: there are no pesticides that prevent or cure virus diseases!

✍Points to remember about the mosaic virus disease:

1. The bean mosaic virus can reduce the yield if plants are infected before and during the flowering stage.
2. Most management methods focus on the prevention or reducing the infection and spread of the disease.
3. The disease is spread by aphids.
4. Aphid control is an important preventive method (see section 12.3)
5. Selecting and destroying all plant materials infected by bean mosaic virus including weeds can reduce the infection source.
6. No pesticide can prevent or cure virus disease.

10.13. Physiological disorders

10.13.1 Moisture Stress

The waterlogged phenomenon present worldwide on green beans is not caused by pathogens. The disorder is considered a physiological one as it relates to the loss of photosynthesis resulting in poor crop development.

Waterlogged plants have waterlogged spots near the outside edges of the underside leaf surface. These spots will increase in size and quantity until the edges and the end area of the leaf and petioles are succulent and much darker green than the color of normal leaf cells. The waterlogged cells from the leaf tip to leaf edge and to the middle veins will die. The necrotic cells will be contracted, dry and yellowish. Waterlogging will destroy 75-80% of the leaves of one or several nodes on a plant, reduce plant vigor and affect potential yields.

The waterlogged phenomenon on green bean plants is caused by favorable conditions in the environment. It appears in the field when green bean is planted in an environment where the air has high humidity, the weather is hot and the soil has high humidity. An experiment carried out in the green house gave similar results. Green bean planted in humus or hay will get waterlogged more easily than those planted in the rich or sandy soil.

11. Major insect pests of green beans

11.1. Leafminer fly (*Liriomyza* sp.)

See illustration Figures 13a, b, c and d, page 75

Description

Adult leaf miners are small flies with an average wing length of approximately 1.3-1.65 mm and body length of about 2 mm. They are yellow and black. Adult females puncture the upper surfaces of leaves with the ovipositor for feeding and egg-laying. Puncture wounds average 0.35 mm in diameter. Adults feed on fluids that exude from the wounds.

Life cycle

Mating occurs soon after adults emerge from the pupal stage. Generally, there is a pre-oviposition period of 2-5 days, depending on the ambient temperature and relative humidity. Oviposition occurs for up to three weeks, with the number of eggs deposited depending on the temperature. Adults live up to four weeks. Eggs are cream-colored and oval, laid singly in separate leaf punctures. They hatch in 2-7 days. Larvae are initially colorless but darken to yellow as they mature. They feed on the leaf mesophyll layer for 6-12 days; during this time, three instars develop. Full-grown larvae slit the leaf epidermis, fall to ground, and pupate in the soil. Pupae are dark yellow. Pupal stage range from 9-19 days. Many overlapping generations occur during a growing season.

Plant damage

Losses in legumes due to leaf miners are difficult to quantify. Most researchers believe that leaf miners are secondary pests. The mining activity of leafminer larvae and stippling (feeding and oviposition punctures) by adult females can cause photosynthetic reduction. The punctures kill localized groups of cells, causing chlorotic depressions in the leaf, which reduce photosynthetic capacity. High populations of larvae can cause curling leaves and early leaf drop.

Fungal pathogens such as *Alternaria cucumeria*, may also invade feeding punctures and mines, resulting in a loss of plant vigor or even plant death. In addition, adult leaf miners have been implicated in plant virus transmission, because of their feeding habits.

Natural enemies

Some parasitic wasps belonging to *Eulophidae*, such as: *Diglyphus webssteri*, *D. begini* are reported to be adult and pupal leafminer fly parasitoids in Peru. Some other species of *Opiinae*, *Tetratischinae* are considered as major parasitoids of leafminer fly.

Management and control practices

- Not growing cucumber or legume crops consecutively in the same field is highly effective in preventing the problem.

- Mulching with black nylon or white plastic is effective. Fields can be also covered with straw to prevent adults from laying eggs on the base of the plant.

Once leaf miners are present in the field:

- Remove damaged leaves and carry out field sanitation to reduce pest population. Damaged stems should be used for composting, or moved far from cucurbit and legume fields.
- Put traps, such as yellow sticky traps and sweet and sour traps that are effective for catching leafminer adults (see box below as an example of sweet and sour traps)
- Rotate with crops that are not hosts of leaf miners.

Sweet and sour traps to catch leafminer adults

During winter-spring season 2003-2004, ToT participants in Hanoi put sweet and sour traps (40% sugar + 40% vinegar + 10% alcohol mixed with Padan at a ratio of 1.5/1000 + water) to catch cucumber leafminer adults. Achieved results were very positive. The percentage of crops damaged by leaf miners significantly reduced in the fields with traps. This method was applied also in FFS fields and similar results were obtained.
This method is more effective if it is applied on large scale. If only one farmer uses traps in his small field, it will not be effective because all leafminer adults will come to that trap and sometimes they may do more serious damage to the field.

This method should be introduced to all farmers.
Encourage them to apply in their field.

(*Source: Mr. Pham Dinh Tho, TOT facilitator, 5th TOT, Hanoi 2003*
Study report of Vegetable IPM trainers, Ha Tay and farmers from Van Phuc commune, Phuc Tho district and FAO-IPM office, October 2004)

Points to remember about leafminer fly:

- Plants are damaged due to the pest's mining inside leaves.
- Pesticides are not effective anymore if leaf miners are inside the leaves.
- Control methods, such as putting traps to catch adults should be done at the beginning of the season.

11.2. Root borer (*Melanagromyza sojae*. Zehntner)

See illustration Figures 14a,b and c, page 76

Root borer, *M. sojae*. is a major insect pest on most green bean planting regions, especially the soybean planting areas in Vietnam and other parts of the world.

Description
The body of the adult root borer (fly) is 1.9-2.2mm long. Its wing range is 5.3-6.9mm wide and the two hind wings are black. The body of the young root borer fly is tube shaped, the head is small and the belly gradually gets big at the end. The body is milky white and the size changes with age. The young insect is 4.2mm long and 0.8mm wide. On the head of the young insect, there are two prominent flesh horns at the two sides. At the end of its belly, there is a quite round breathing tube on which there are many small breathing tubes.

The pupa has an oval-shaped curve toward the back and is brown yellow, 1.4-2.5 mm long, 0.5-1.2 mm in diameter. The head of the pupa has two flesh horns and at the distal end are long breathing tubes like those of the young insect. On the body, the node folds of the young insect phase can clearly be seen.

Life cycle
After 1-2 days of mating, the adult root borer fly finds a place to lay eggs. They often lay eggs on the lower surface of the leaves near the main vein. Eggs are laid in the hollow in the leaf tissue, beneath the epidermis. A female fly can lay 20-30 eggs in its life cycle. The egg laying period lasts 3-4 days but the female flies may die after 1-2 days of laying eggs.

After 2-3 days, larvae or maggots emerge from the eggs. The larva bore into the leaf tissues, veins and to the stem and feed inside. The larva bores a hole through the plant core in order to prepare for pupation later. The larval stage lasts from 7-15 days.

Depending on the development stage of the green bean, the pupa can stay in different areas. Most pupae live in the stem, some stay near the tip or right at the pedicel. The pupal period lasts for 10-25 days.

Plant damage and compensation
It is at the young stage when the borer causes damage by spirally boring into the stem core of plants. It causes damage from the time the plants have two single leaves until the end of the crop season. Depending on each development stage of the plant, the damage may be severe or light. If the damage happens during the stage of two single leaves to 2-3 compound leaves, it will cause plants to die. The phenomenon will cause a reduction in plant density resulting in yield loss.

When plants are mature, the damage by borers will not be as serious as they only make tips die and plants can compensate by producing new branches and produce fruits normally.

Natural Enemies
At present, several parasitoids of green bean root/stem borers have been found such as *Eucoilidae* sp., *Helicoptera* sp., and *Cryptoprymma*

Management and control practices

- Do not plant legumes and cucurbits continuously for several seasons in the same field to effectively prevent root borer infestation.
- Using resistant seeds is highly effective.
- Practicing appropriate fertilizer application for green bean plants to overcome the critical period for disease and insect damage. Fertilization should be done more carefully when green beans are planted in rotation with rice.
- Mulching with black nylon or white plastic is effective. Fields can be also covered with straw to prevent adults from laying eggs on the base of the plant.
- Cultivating green beans with cucurbits, solanaceous crops (e.g., eggplant) and legumes (e.g., pachyrrhizas) as well as green manure plants to help reduce damage by root borer maggot.
- Timing the crop season or schedule of planting green bean to reduce damage. During rainy season, insect density is normally higher than that in the dry season. The portion of plants that die is lower in the rainy season than in the dry season.
- Finding and protect parasitoids available in the field. Several parasitoids can be mass reared under laboratory conditions and released in the field after germination to control the pest.
- Using some systemic pesticides to treat seeds before planting.

Once stem borers are present in the field:

- Carry out field sanitation practices. Remove plants damaged by the borer flies in order to reduce the source of the insect. Stems where flies bored into should be composted or moved far from the fields where crops from legume and cucurbit families are grown.
- Putting traps, such as yellow sticky traps and sweet and sour traps is effective for catching adults (see section 11.1 on the sweet and sour traps)
- When insects have bored into the plant roots, the soil can be hilled-up and fertilizer applied so that the roots can generate new branches. This method helps plants quickly recover and continue to flower and have fruits although the yields may not be high.
- Rotating with crops that are not hosts of stem /root borers

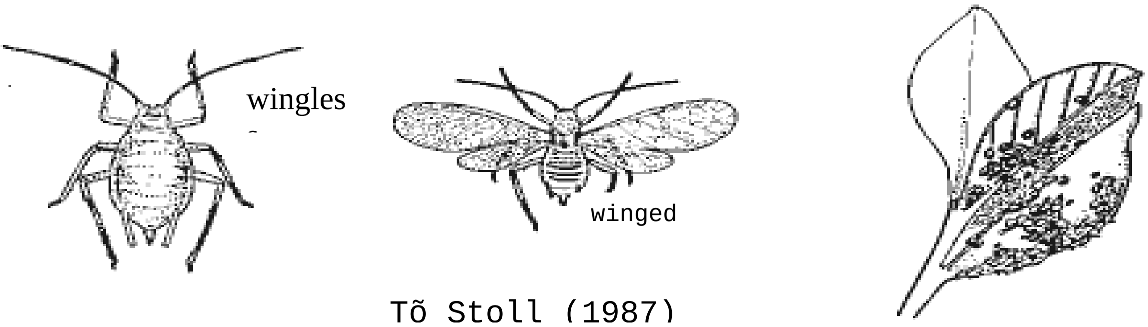
✍Points to remember about the stem/root borer fly:

- Plants are mainly damaged as the insect bores into roots/stems
- Pesticides are useless if the stem/root borers have already caused damage
- Control methods such as putting traps to catch borer adults should be implemented at the early stage of the crop season

11.3. Bean Aphids (*Aphis craccivora)*

See illustration Figures 15 a and b, page 76

Description
Aphid is a serious pest, causing damage to most bean growing areas in the world.



Tõ Stoll (1987)

The wingless aphids are up to about 2.5 mm long, grayish-green in color, with a dark head and black stripes on the body. The aphid is covered with a grayish-white colored waxy powder, which is also secreted onto the surface of host plants.

The winged aphids are slightly longer than the wingless ones and have a dark-colored head and body. The veins on the wings appear brown in color. The aphids have small siphons (looking like small antennae) at the back of their body. Siphons are a good way to recognize aphids. Colonies of these aphids are usually found on the lower surface of the leaves.

The aphids can reproduce asexually: that means that males and females do not have to mate in order to produce young. One female gives birth directly to small nymphs. That means large numbers of aphids can be produced in a very short time! Only in cool areas, eggs are produced after mating. The eggs over winter and young nymphs emerge when the temperature rises. All winged aphids are females. In the tropics, most wingless aphids are probably also females. Most reproduction in the tropics will be asexual so males are not needed.

Life cycle
In the cooler areas of its distribution, the bean aphid over winters as small, shiny black-colored eggs laid particularly around leaf scars of stems of plants that remain in the field throughout the winter. When the temperature rises, the aphids hatch and colonize the new emerging flowering stems or harvested vegetable crops that have not been ploughed in. Then, winged aphids fly away to colonize new host plants. They produce wingless aphids. These aphids produce more young aphids that form new colonies. They feed on the tender, actively growing shoots and leaves, often on the underside of leaves where they are protected from the sun and rain. When aphid

numbers outrun food supply, winged forms reappear and migrate to nearby plants to renew the growth cycle. This happens regularly during the growing season. Warm, dry weather favors a rapid build-up of aphid colonies.

Plant damage and plant compensation

The first signs of attack are small bleached areas on the leaves of infected plants. The leaves then turn yellow and become crumpled. The aphid colonies are protected inside the crumpled leaves. The effects of infestation are worst on seedlings and young plants. They can be stunted and may die at unfavorable weather conditions. Early damage to the growing point of the plant distorts the head. Even when young plants are infected only lightly, the leaves of the plants when they are mature continue to show signs of the original attack. Infestations on larger plants may reduce yield and also spoil the plants by contaminating them with wax, cast skins and honeydew. Honeydew is the excretion of aphids. It is slightly sweet and is excreted from the siphons. Honeydew can make the leaves sticky where several fungi species grow on the honeydew producing black marks on the leaf surfaces.
Aphids tend to be much localized: they usually colonize just a few plants but can be very abundant on each plant.

In addition to the direct crop damage, aphids also transmit the bean mosaic virus to beans. Good crop hygiene (uprooting and destroying the virus infected plants), rather than trying to kill the aphids, is the only way of reducing the impact of these viruses as the time taken by virus-carrying aphids to infect new crops is often less than one minute. This is too short to kill the aphids by any control practices.

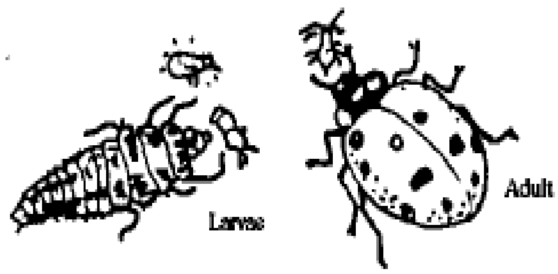
Aphids as milk cows for ants...?!

Ants are attracted to aphid colonies because the aphids produce honeydew when they are disturbed. Ants like to eat the sweet honeydew. The ants keep and sometimes even protect the aphid colonies. They “milk” the aphids to get the honeydew.
Although ants can be natural enemies of some pest insects, in this case, ants cannot be considered as natural enemies of aphids because they do not kill aphids but may in fact protect them.

Natural enemies

Weather is a major natural agent restricting the build-up of bean aphid infestation in cold, temperate regions and mountainous areas. In dry, warm seasons the aphids can often produce extremely large infestations whereas in wet, cool seasons the aphid population remains small. In a period of frequent rain, aphid populations will be very low if not absent.

Predators such as lady beetles and hover flies (Syrphids) and parasitoids like the wasp *Diaeretiella rapae* are important natural enemies of the cabbage aphid. In wet seasons, outbreaks of fungi that kill aphids may occur. This often coincides with period of high humidity and rain. Dead aphids may be seen covered with white colored fungal growth on the body. These fungi can spread quickly to reduce aphid populations.



Lady beetle : an important predator of aphids

Management and control practices

- Healthy, rapidly growing plants are the best way of preventing many pests and diseases. Aphid infestation often occurs when plant condition is slightly poor, for example just after transplanting, or when too much or too little fertilizer is added or when the soil fertility poor.
- Host plant resistance: There is little chance of producing a bean variety with a durable resistance to aphids. This is because there are many biotypes (individuals with slightly different characteristics) of aphids present in the field and new biotypes can form regularly. It is very difficult to produce a variety that has a resistance against all these biotypes.
- Cultural control: Cucurbits, cruciferous, leguminous or solanaceous plants that remain in the field after harvest are largely responsible for large numbers of eggs and/or adults staying over. Therefore, the most effective prevention and control measure is to eliminate as many of these sources of infestation as possible to prevent the aphids from spreading to the new crop. The crop left-overs can be buried into the soil, fed to farm animals, added to a compost pile or collected, slightly dried and burnt. Removing crop left-overs is also very valuable for disease prevention.
- Sowing with clover may help to reduce aphid infestation. In a study where cucumber was sown with white clover, cabbage aphid population was reduced with 90%! (Finch, 1996).

Once aphids are present in the field:

- Monitor the field regularly to check population growth. Aphid population builds up rapidly but locally. It is important to examine plants regularly, both in seedbeds and in the field. When aphids are found but the number of infected plants is low and at the same time there are natural enemies like lady beetles present, no additional control measures are necessary.
- On a small scale, aphids can be washed off from the plants with water or rubbed by hand.
- Small populations can also be removed by removing the infected leaves by hand and destroying these.
- When large populations of aphids are present in the field at an early stage (newly transplanted or young plants) and warm and dry weather, chances are that the

aphid population will increase very rapidly and cause damage to the growing points of the plants. Monitor the field carefully for the presence of natural enemies (particularly lady beetles and aphid "mummies"). When there are large numbers of natural enemies, do not apply insecticides but continue monitoring. When natural enemy populations are low compared to the aphid population, consider localized sprays. See next paragraph.

- Spraying mineral oil or oil extracts every seven days from germination until the first pod formation is a very effective control method. Mineral oil can prevent damage of other sucking pests, such as thrips, spider mites and white flies or other leaf diseases, caused by virus (see part 10.10)
- Soap solutions at concentration of 0.5 % (5 g per liter)) kill aphids instantly.
- Botanicals such as neem solutions may control aphids. Good results are obtained from various locations.
- Biopesticides: see box below for an example from Bangladesh.

☺ **Free biopesticides for aphid control**

During a ToT in Mymensingh, Bangladesh, the newly transplanted eggplant field suffered from aphid infestation. Participants from the ToT discovered aphids covered with fungus on various locations around their eggplant field. They collected as many diseased aphids as they could get, mixed them in water, and stirred briskly. This released spores from the fungus into the water and the mixture became infectious for aphids. Then the solution was slightly filtered through a cloth (to remove large parts) and sprayed on the eggplants using normal backpack sprayers (*pers. comm. Prabhat Kumar, 1999*).

- Localized sprays. There are insecticides that control aphids. However, spray applications of insecticides can kill lady beetles and many other natural enemies of aphids and other insect pests. Balance the benefits of spraying against the harm done to the beneficial. When applying insecticides is considered necessary, apply only on those plants that have aphid colonies,(spot treatment) not on all plants. This reduces the amount of pesticides needed and may save at least part of the beneficials present in the field.

✍ **Points to remember about aphids**:

1. Aphids have many natural enemies.
2. On small scale, aphids can be removed by hand rubbing, washed off with water spray, or destroyed by removing and destroying infected leaves.
3. Localized (infected plants only) spray with soap solution (0.5%) controls aphids.
4. Biopesticides, where available, may offer good control.
5. Insecticides are usually not necessary for aphid control.

11.4. Red spider mites (*Tetranychus* sp.)

See illustration Figure 16, page 77

A mite is not an insect!?
A mite has 8 legs, instead of the 6 that insects have. Also, mites don't have a "waist" like insects do and they do not have wings and antennae. Together with the spiders, mites form a separate class, *Arachnida*.

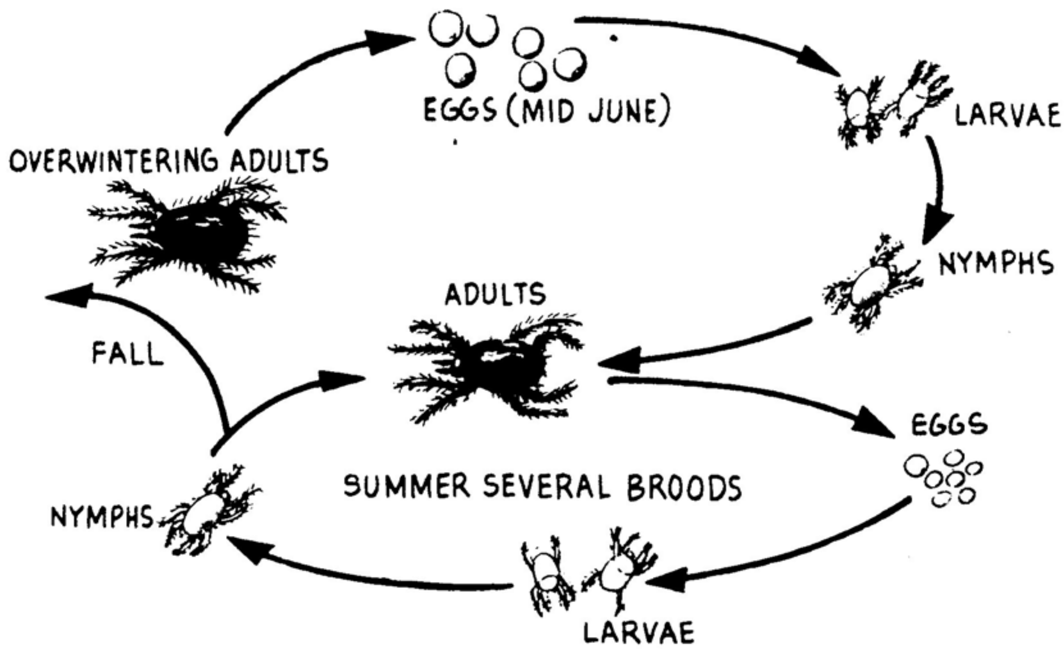
Two species of spider mites, two-spotted spider mite, *Tetranychus urticae* Koch, and carmine, *T. cinnabarinus* are important foliar pests of legumes. Other species may also feed on stems and foliage but are of minor importance.

Description
Spider mites inhabit the lower surface of leaves and cause damage by making large numbers of tiny punctures in the leaf and sucking out the sap. Attacked leaves often have a silvery, "peppered" appearance, particularly along the veins. The adults, about 0.5-1 mm long and just visible to the naked eye are protected by the fine webs which they spin on the leaf surface. The adults are orange-red to yellow-brown in color. They move slowly and cannot fly.

Life cycle
In general, all red spider mites have incomplete metamorphosis. Female red spider mites lay eggs on the lower surface of leaves and the egg surface is covered by a membrane to prevent it from being damaged by other insects. A female red spider mite can oviposit 15 eggs per day and the oviposition lasts about three weeks. The development period from egg to mature phase lasts about 10 days in continuous hot weather. This reproductive rate results in a quick increase of red spider mites in the field. Red spider mites are considered to live in the soil or on plant debris for a long time before attacking plants. Red spider mites over winter in the mature phase and start reproducing when the weather is hot and dry.

Host range
The red spider mite has a very broad range of host plants, including many vegetable crops and ornamental plants and trees. It damages most cucurbit crops, such as cucumber, water melon, bottle gourd and wax gourd, legume or solanaceous crops.

Plant damage and compensation
Red spider mites damage beans by puncturing cells of the leaves, mainly on the lower surface. They extract plant juices and chlorophyll, interrupting the normal production of photosynthate. An early sign of infestation is stippled areas on foliage. This can result in stunted growth of the plant, deformation of leaves and shoots, chlorosis, browning, etc. The leaf is often "peppered" with tiny colorless points alongside the veins, which sometimes give an almost silvery appearance to the leaf. This eventually results in reduced production. Bean pods are attacked only when mite populations are very high.



Spider mite life cycle: egg, 6-legged larvae, 8-legged nymphs, adult
(from: T.M.Perring et al, 1996)

Natural enemies

- Predatory mite, *Phytoseiulus persimilis,* an orange-red mite, about 1 mm long- This mite cannot fly but moves around much quicker than the red spider mites. In India, this predatory mite has proved to be effective against red spider mite in okra. Also in many European countries and in the USA, this predatory mite can be bought from specialized shops for release in greenhouses or in the field. Results in greenhouses are very good and hardly any chemical pesticides need to be applied for spider mite control. *Phytoseiulus* needs high humidity for effective mite control.
- The predatory mite, *Amblyseius tetranychivorus*, indigenous in India, was also found effective against red spider mite in okra. This predatory mite is commercially available in some western countries. It is released on fairly large scale for spider mite control in many vegetable crops including eggplant, strawberry, and gourds in China. Numerous research findings are available on how to mass-produce and conserve predatory mites.
- The gall-midge, *Feltiella acarisuga*.- This is again a commercially available natural enemy of red spider mite. It is very successful in European countries. The adult midge is about 2 mm long, pink-brown, with long legs. *Feltiella acarisuga* is often used in greenhouses together with the predatory mite *Phytoseiulus persimilis*, especially in periods with low humidity levels (which hinder the development of *Phytoseiulus*). The gall-midge *Feltiella acarisuga* can fly, which makes it more mobile than *Phytoseiulus persimilis*. High humidity boosts the emergence of gall-midges.

- The predatory bug, *Macrolophus caliginosus* is a known predator of red spider mites. Its main host is whitefly and to a lesser extent aphids, moth eggs, leaf-miner larvae and thrips. Bug populations develop most rapidly on whitefly. Adult bugs can also survive for some time on plant saps. *Macrolophus* is another commercially available natural enemy, again successful when released in greenhouse environments. Whether this bug occurs naturally in the tropics and how effective it is in red spider mite control needs to be further investigated.
- Larvae of the green lacewing, *Chrysopa* sp. are predators of red spider mite.
- Ladybeetle adults and larvae feed on red spider mites.

How effective one predator is, how many prey it eats per day, usually depends on many factors including host plant and temperature. The feeding capacity of a predator can easily be tested in the field with a caged plant or in an insect zoo (glass or plastic jar).

> ❒ **Life cycles: red spider mites and predatory mite reproduction examples**
> In a study from China, 50 red spider mites inoculated on eggplant cultivated in plastic bags multiplied to 13,000-14,000 individuals after 40 days, and the predatory mite, *Amblyseius longispinosus* placed into the bag could subsequently propagate to 500-1,000 individuals after 20-25 days. Not bad…!
> (Zhang-YanXuan, 1996).

Management and control practices

- In general, vigorous growing plants are less susceptible to pest and disease attack. Creating proper environment, e.g. applying lots of compost to improve the soil condition, applying modest rates of nitrogen, help prevent red spider mite infestation.
- Predatory mites can often be found spontaneously in the field. Like many other predators, these predatory mites are very sensitive to pesticides, especially broad-spectrum pesticides. Avoid the use of such pesticides as much as possible.

Once spider mites are present in the field:

- Crop rotation is a very important method in controlling the pest.
- Keep plant moisture as high as possible. It helps to prevent red spider mites from increasing their population. Keeping plant moisture high can be done by reducing planting density, mulching, watering on leaves and watering plants regularly.
- Small populations can be tolerated because they allow build-up of natural predatory mite populations.
- Release of predatory mites. If predatory mites are available and permitted for field use, this would be the best control option.
- Application of botanicals, such as neem can be effective. Most of these have a broad-spectrum activity against many pests and natural enemies. For this reason, they may best be applied locally, only on infected plants, not on all plants. Most botanicals are not very effective against red spider mite eggs. Application will have to be done at least weekly.

- Spraying mineral oil or oil extract every seven days from germination until pods develop helps to limit red spider mite damage (see part 11.3).
- Numerous acaricides, chemical pesticides that work specifically against mites, exist. Unfortunately, most acaricides also kill predatory mites and some kill other natural enemies as well. Prolonged use may reduce the predator population of red spider mite and may even result in more crop damage. See box above. In addition, red spider mites can develop resistance to many chemicals quickly because of their high reproduction rate. Many chemicals are already ineffective due to resistance. If acaricides are used at all, try using them very localized on infected plant/plant part only (spot application).

Immunization, a natural vaccination program….?!?
Research on cotton plants at the University of California, USA, showed that when young plants were slightly infested by red spider mites, the plants at a later stage were less attractive to red spider mites. This method of "vaccination" is already practiced with tomatoes. Tomato plants are infected with a weak virus strain that does not lower plant production, resulting in resistance against more aggressive strains of virus.

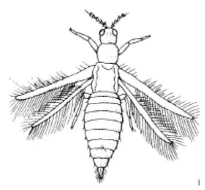
Although more research is needed to investigate the potential for pest control, it could be considered to tolerate low levels of insects or mites in the crop and not to try for 100% control.

☑**Points to remember about red spider mite:**
1. Red spider mite damages mostly in the dry season.
2. Red spider mite does not damage young leaves, but mostly older and underneath leaves.
3. Red spider mite has become an important pest in areas where pesticides have been used intensively.
4. Many species of indigenous natural enemies such as predatory mites may occur in vegetable fields untreated with pesticides. Several predators are commercially available in some countries.
5. Biopesticides or mineral oil extracts are good for controlling red spider mites.

11.5. Thrips (*Thrips* sp.)

See illustration Figures 17a and b, page 77

Various species, most common are *Thrips tabaci* and *Thrips palmi.*


Thrips adult

Description
The adult thrips is a very small insect, about 1 mm long, brownish-yellow in color with two pairs of long, narrow wings

(the fore-wings are longer than the hind wings), both pairs of which are fringed around their edges with hair-like structures. The nymphs are pale yellow, almost transparent when newly-hatched, and similar to the adults but smaller and wingless.

There is a “pre-pupal” stage which is white in color with short wing-sheaths and antennae which are held straight in front of the head. The “real” pupa is about 1 mm long and brownish in color.

Thrips are gregarious insects and large numbers are often found together on single leaves.

The insects can be found during the day at the base of the plant, on the underside of the leaves, at the sections with healthy tissue that border areas of brown or damaged tissue. Pupae are found in the soil.

Thrips move frequently to new locations to make more feeding incisions. hey fly weakly, but they may be carried great distances on wind and air currents.

Life cycle

Eggs are laid in notches of up to 100 eggs within the tissue of the leaves and stems of young plants. They are white, and take 4-10 days to hatch.

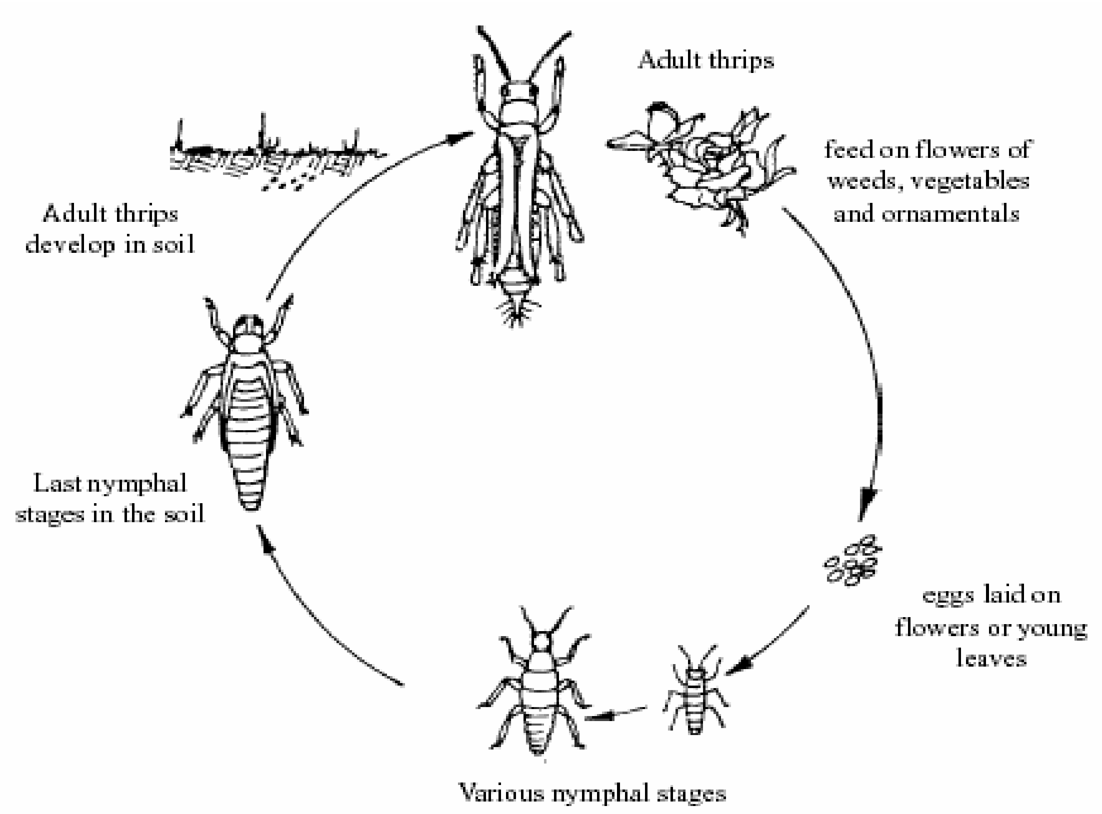
Thrips develop through two nymphal instars, a prepupal form and one or two more or less immobile pupa-like stages. These developmental stages are of similar general appearance to the adults but without wings.

Nymphs molt twice in about five days, they are white or yellow. The nymphs usually can be found among debris or in the surface layers of the soil before changing to pre-pupae. After about two days, pre-pupae change into pupae. These resting stages do not feed but are capable of slow movement in response to suitable stimuli e.g. they tend to avoid light. Pupation occurs in the soil, usually at the base of the plant.

The life-cycle spans about three weeks. There are generally several generations per year. Warm, dry weather favors thrips development.

Host range

Thrips are polyphagous and have been recorded on more than 300 species of plants, including legumes, cucurbits, solanaceous crops, crucifers and even ornamentals.



Life cycle of thrips (from: Kerruish et al, 1994)

Plant damage and compensation

Both nymphs and adults rasp the surface tissue of the leaves causing wounds from which flows the sap on which the thrips feeds. Damage is most obvious on the underside of the lower leaves, where areas appear brownish and dried up. Similar damage is seen along the mid-vein on the upper leaf surface.

The leaves of attacked plants are silvery with blotches and may shrivel. Heavy attacks lead to stunted leaf-growth, wilted shoots, reduced fruit size and in extreme cases, death of the plants. Fruits can be damaged by small necrotic spots.

Natural enemies

- Predatory mite, *Amblyseius cucumeris.* This predatory mite eats various thrips species; both hatching eggs and larvae. Predatory mites also eat red spider mites, several other mites, honeydew and pollen. Very good results are obtained in various countries with release of this predatory mite for control of red spider mites and thrips. In Indonesia for example, *Amblyseius cucumeris* was introduced from the Netherlands, where it is commercially available, for testing its effect on *Thrips parvispinus* on hot pepper.
- Natural enemies of *Thrips palmi* had not been recorded from Southeast Asia until they were discovered in Thailand during 1987-88. Among eight species discovered, the larval parasitoid *Ceranisus menes,* a wasp; larval predatory bugs, *Bilia* sp., and *Orius* sp., were evaluated as effective natural enemies of *T. palmi* in

Thailand. Neither classical biological control of *T. palmi* nor inundative release of its natural enemies is considered necessary for South East Asia because *T. palmi* is native to this region and should have effective natural enemies in this region. Studies in Thailand and Japan support the view that the increase of *Thrips palmi* is due to the exclusion of natural enemies after insecticide application.

Parasitism of thrips on eggplant in Thailand
In a field survey, 40–60% parasitism of thrips by *Ceranisus menes* was found in eggplant gardens, which were not treated with insecticides. In commercial production fields sprayed with insecticides, no parasitism was found. The survey also showed that the thrips population was always higher in the sprayed than in the unsprayed plots (Hirose, in Talekar, 1991).

This, at first sight controversial phenomenon can be explained as follows: insecticide application may kill part of the thrips population but will seldom eradicate all thrips. Parasitoids are more sensitive to pesticides and usually need more time to build up an effective population. By the time a small new population of parasitoids is built up, the thrips are already abundant and damage to the crop may occur.

AND, to make it all worse: in fields where thrips were not a problem before, they can become a major pest after insecticide applications. Again, this is because the natural enemies of thrips are killed and thrips can expand into damage causing levels. Insecticides used for the control of pests other than thrips in fact contribute to its resurgence….☹

- Lacewings, *Chrysopa* sp. are predators of thrips. The green lacewing, *Chrysopa carnea*, is the most common species. Because larvae of lacewings are generalist predators, (larvae feed on thrips, whitefly, aphids, jassids, and small caterpillars) they can be used in a wide variety of agricultural crops. In various countries, lacewings are commercially available.
- There seem to be fungi that attack thrips. Fungal infestation however, requires high humidity and thrips are important mainly in the dry season. The potential for pathogens for the control of thrips seems therefore not very high.

Some scientists say that the increased incidence of *Thrips palmi* in Southeast Asia could be the result of increased insecticide applications in some areas of this region for the past 10 years.

Management and control practices

- Resistant varieties: Differences in varietal reaction to thrips infestation have been recorded in a number of vegetables, but not in beans. Breeding for resistance of beans to other insect pests such as leafminer and pod borer, which in most areas is the most serious insect pest of beans, should be strengthened. Crop varieties resistant to these pests will reduce the need for the use of insecticides. Non-chemical control of other pests will similarly help prevent thrips outbreaks.

- Mulching has potential in reducing thrips damage. White-plastic or silvery plastic mulch can reduce thrips infestation considerably. See box below. However, these mulching materials are expensive. Straw mulch can also be used. Colored paper or colored plastic sheets attract thrips.

Reflecting mulches to prevent aphid and thrips infestation?!?
In countries like U.S.A. (California), some farmers place aluminum film on the soil around and among plants. The reflection of sunlight deters aphids and thrips and they will not land in the crop but fly elsewhere. For the best prevention, 50% of the soil should be covered with the reflecting mulch.

The repellency could be associated with disturbance of orientation before landing on the crop. In case of thrips, another possibility is the reduced access to suitable pupation sites in the soil under the crop (Vos, 1994).

- Flooding the field seems to have potential in reducing thrips populations, presumably drowning thrips pupae in the soil. This may be feasible in areas where vegetables are rotated with rice. Another option is to flood the field during the dry season for irrigation. When the field is flooded for longer period of time, pupae in the soil may be killed. More research is needed.
- Spraying mineral oil or oil extracts every seven days from 3-true leaves stage until beginning of flowering stage will limit thrips damage. Mineral oil can prevent damage of other sucking pests, such as aphids, spider mites and white flies (see part 11.3).
- Intercropping: There are no consistent effects reported on thrips populations. Not advisable.
- To reduce thrips infestations at seedling stage, which reduces plant vigor later on, seedlings could be raised inside a fine-mesh net cover, fine enough to exclude thrips. However, this type of screen is extremely expensive. It is only justified when problems with thrips (or thrips transmitted diseases) are severe.
- Excessive use of fertilizer which increases vegetative growth beyond the normal needs of the plant should be discouraged. Excessive growth does not increase yield but it does provide shelter for thrips.
- Avoid unnecessary applications of pesticides to prevent secondary outbreaks of thrips.

Once thrips are present in the field:

- When numbers are low, and symptoms of plant injury are not severe, control measures need not be taken. Continue monitoring population growth and check for parasitoid presence.
- In some regions, green traps are put to catch adult thrips. People use hard covers or thin boards 20 x 20 or larger then use blue paint to cover them. Use beef fat (the fat to lubricate motorbikes or engines) to lubricate plastic bags, then cover the

blue boards with these bags. Put these traps in the field with a distance of 2 m x 3 m between them. Weekly check these traps and replace with new ones. This method has high potential to prevent thrips.

☑**Points to remember about thrips:**
1. Thrips have probably become an important pest as a result of increased use of pesticides which killed the natural enemies of thrips.
2. Thrips have several natural enemies, e.g. predatory mite species, predatory bugs, and lacewings.
3. Cultural practices that help prevent/delay crop infestation include flooding the field and use of silvery plastic mulch.
4. Avoid unnecessary pesticide applications to prevent secondary thrips outbreaks.

11.6. Bean pod borer (*Maruca (testulalis) vitata* - Geyer)

See illustration Figure 18, page 77

Description
Male adult pod borer is 11.2 mm long and wing span of 24 mm. Females are 11.5 mm long and wing span of 24.5 mm. The head of the larva is about 1.75 mm wide. The front wings of the adult have three veins: a big vein with a rectangle shape located at 1/3 of the wing edge, the vein with oval shape located at the middle and the vein with round shape located at 1/3 from the wing end. The abdomen has nine nodes and is longer in males than females. At the distal end of the abdomen are three black hair groups.

The larvae are tube shaped, with slender heads. Their color changes from greenish to brown depending on the food available. The larva has five instars, measures 11–12 mm long, 2.1–2.4 mm wide.

The egg has an oval shape of 0.67 - 0.84 mm length and 0.41 - 0.55 mm in diameter. The newly-laid egg is greenish white in color and later turns into yellow.

Life cycle
At day time, they take shelter under the plants' shadow. They only move when they are disturbed and the movement distance is about 1m. The adults are active at dark or night time finding their food. After 1-2 days of eating, the adults start mating. The mating period is at night from (2100 hr to 5 in the morning). Mating lasts about three minutes at 20-25°C and humidity of over 80%. During mating, one male often mates with one female but sometimes one male can mate with two females. There is a higher percentage of one male mating with one female.

After mating, adults lay 2-16 eggs singly on branches, flowers or calyx or peduncle. A female lays 37.6 eggs within a life cycle. Depending on the food availability, the adult stage will last about 4-8 days.

The eggs hatch after 3-6.5 days. The newly-hatched larvae are creamy white in color. They will move to petals to find food and bore into them. The larva in this period will go through four instars that last about 8-16 days. The pre-pupal stage lasts 1-2 days depending on temperature and humidity.

Pupation takes place in the soil and lasts 6.4-11 days. The life cycle of the pod borer which last for 18-35 days is greatly affected by temperature and humidity. The life cycle of the pod borer will only be completed in temperatures of 22°C and 28°C. If the temperature is over 34°C, the larvae will die. Temperatures of 15.6 to 17.8°C and from 28 to 34°C will affect the development of pupae.

Host range

The pod borer is a major insect in the green bean growing regions in Vietnam. Larvae cause damage on most crops of the legume family such as long bean, French bean, soybean and green bean. When there are no crops in the field, pod borers often live in the wild legumes like *Vigna triloba*.

Natural Enemies

There are many predators and parasitoids of the pod borer.

Plant damage and compensation

After the green bean plant flowers, the larva penetrates into the flower through their edges. The larva chews on flower parts, thus affects pollination or make flowers drop. The larva can spin a thread to connect flowers together, and then enter to damage. It can roll leaves to make a nest-like and then feed on the mesophyll layer of the leaves and leaf veins. Older insects can eat branches and stems.

When plants have young pods, pod borers start to bore into the fruits. At day time, they stay in the fruits to damage. At night time, they go out and move to other fruits to continue damaging seeds and pods. This affects the yield and quality of pods.

Management and control practices

- Rotation with other crops is a highly effective method to control pod borers. The damage from pod borers in a field that has been continuously grown to green beans will be higher than a green bean field rotated with maize.
- Delayed planting of green beans will help reduce the damage from pod borers.
- Bio-pesticides such as *Bacillus thuringiensis*, neem oil have been shown to be highly effective against the pest.
- Protect natural enemies of the pod borer in the green bean field.

Once pod borers are present in the field

- Collection of eggs and larvae by hand at the early stage of the crop will be effective in reducing damage. However, this method can only apply to fields with small-scale bean production.
- Pruning and destroying flowers and fruits affected can reduce the spread of pod borer.

- Pesticides may not be effective in preventing pod borer in green beans. Many pesticides, especially the systemic kind are used against pod borers. However, the effects of systemic pesticides on other organisms in the soil and on fruit quality are not known. Care must be taken when advising farmers to use pesticides.

When many pods are found to be damaged by the pod borer, attention should be paid to the following points:

- Application of pesticides will reduce the populations of natural enemies in field!
- If pesticides are necessary, timely application may be helpful: spray pesticide on plants when eggs are hatched in order to kill newly hatched larvae. Eggs are not susceptible to most pesticides.
- Spraying pesticides when the insect is already in the pods is useless as they would already have caused damage and may not be affected because they are covered by the fruit.
- If pesticides are necessary, they should be sprayed when plants are having young fruits as the harvesting period is short and it is necessary to consider the pre-harvest interval. When the green bean plant has fully flowered, it is not necessary to use pesticide as in this growth stage moths do not oviposit.

Points to remember about pod borers:

1. Pod borer is a serious pest especially in flowering and fruiting stage.
2. Most pesticides are not effective in controlling pod borers once they have bored into fruits. Pod borers can become a serious epidemic as the high application of pesticides kill their natural enemies.
3. Pod borers have several natural enemies such as parasitoids, predatory spiders, bugs, and lacewings.
4. Cultivation methods such as field flooding and mulching by silver plastic helps prevent/restrain the damage on plants.

12. Harvesting

The time of harvesting of various legumes will vary depending on their use or purposes. For example, French bean, long bean, broad bean are harvested early when fruits are plump if they are to be used as vegetable. At this period, seeds are small and fruits have high nutrient content and less cellulose. Fruits should be picked by hand to avoid damaging flowers and young pods and so that harvest can be done many times.

Several bean varieties such as French bean and green bean can be harvested when fruits are mature for seeds, for food, or canning. When fruits are mature, they can be harvested manually or by machines in developed countries. However, harvesting by machine can cause up to 7-10% yield loss. The manual method where entire plants are dried and smashed to take seeds have a less losses but requires more labor.

Appendices

References

Ahmed K.M. vµ Rey C.R., 1993. Guidelines on how to classify fungus on crops in the legume family, published by International Crops Research Institute for the Semi-Arid Tropics.185 pages.

Asian Vegetable Research and Development Center (AVRDC), 1990. Vegetable Production Training Manual. 447 pages.

Department of Entomology, 2002. Specialising Entomology Document. Agricultural publisher: pages 163 -172.

Copping L.G., 1998. The Biopesticide Manual. British Crop Protection Council. 333 pages.

List of pesticides allowed to apply on vegetables, 2004 as issued by Ministry of Agriculture and Rural Development.

Drijfhout, E. and Morales, F.J., 2005. Bean Mosaic virus in Compendium of Bean Diseases. ASP Press: 62 - 63.

Grubben, G.J.H., 1993. Long Beans in Plant Resources of South-East Asian Vegetable. Vol. 8: Prosea: 274 - 278

Hagedorn, D.J., 2000. Waterlogged phenomenon on green bean. Compendium of Pea Diseases and Pest. ASP Press: 53-54

Kooi, G., 1993. C©y ®Ëu rång, trong Plant Resources of South-East Asian Vol. 8: Vegetable. Nhµ xuÊt b¶n Prosea: 134-136.

Mai, T. Ph-¬ng Anh, Tran, V. Lai and Tran, K.Thi, 1996. Vegetable and vegetable growing (Agricultural MSc curriculum). Agricultural Publishing House. page:217-234.

Ngo The Dan, Tran Dinh Long, Tran Van Lai, Do Thi Dung and Pham Thi Dao, 1999. Diseases and Insects on Soya bean. Agricutural Publisher, pages 280-336

Saettler, A.W., 2005. Diseases Caused by Virus in Compendium of Bean Diseases. ASP Press: pages 46-50.

Salukhe D.K. vµ Kadam, S.S., 198.. C©y ®Ëu tr¹ch, trong Handbook of Vegetable Science and Technology. Nhµ xuÊt b¶n Marcel Dekkerr: 457-532.

Schwartz, F.H., 2005. Diseases Caused by Virus in Compendium of Bean Diseases. ASP Press: pages 22-46.

Shanmugavelu, K.G., 1978. Green bean in Production Technology of Vegetable Crops. published by Oxford and IBH: pages 421-494.

Sharma H.C., 1998. Bionomics, Host Plant Resistance, and Management of the Legume Pod Borer, Maruca vitata: A Review, published by Crop protection vol. 17: 373-386.

Shepard, B.M., Carner, G.R., Barrion, A.T., Ooi, P.A.C. and van de Berg, H., Insects and their Natural Enemies on Vegetables and Soyabean in Southeast Asia. (Books to be presented to farmers).

Sherf, A.F. and Macnab, A.A., 1986. Bean Diseases in Vegetable Diseases and Their Control. John Wiley and Sons: 33 - 92.

Sinclair, J.B., 1983. C¸c chiÕn l-îc phßng trõ bÖnh h¹i trªn c©y ®Ëu t-¬ng ë vïng nhiÖt ®íi vµ cËn nhiÖt ®íi, trong Soybean in Tropical and Subtropical Cropping Systems. Nhµ xuÊt b¶n AVRDC: 251 - 255.

Sumner, D.R., 2005. Root Rot Disease in Compendium of Bean Diseases. ASP Press. 20-21.

Talekar, N.S. and Chen, B.S., 1983. Major Studies on Stemborer on Green Bean and Soyabean in Tropical and Subtropical Cropping Systems, published by AVRDC: pages 257-271.

Thompson, H.C. and Kelly, W.C., 1957. Green Bean in Vegetable Crops, published by McGRAW - HILL Book Company. pages 431 - 470.

Tomlin, C.D.S., 2003. The Pesticide Manual. British Crop Protection Council. 1343 pages.

Tschanz, A.T., Wang, T.C. vµ Tsai, B.Y., 1983. Advantages in the Rust Disease Study on Soybean in Tropical and Subtropical Cropping Systems, published by AVRDC: pages 238 - 245.

Vu Trieu Man and Le Luong Te, 2001. Document of Disease on Agricultural Crops. Agricultural publisher, pages 17 - 121.

Vimala, P., Yeong, N.H., vµ Salbiah, H., 1996. Nutrient content in plant and ability of absorbing nutrient substances on long bean and ®Ëu tr¹ch in Malaysia, in the soil nutrient management in the intensive cultivation of high vegetables in Asia, published by AVRDC and Food and Fertilizer Technology Center, pages 71 - 77.

Major Diseases of Legumes

Figure 1. Damping off caused by *Pythium* sp.
(See Section 10.7, page 18)

(a)-germ bottom (b) root rot (c) wilting seedling
Source: R. Hall and H.F. Schwartz, 2005)

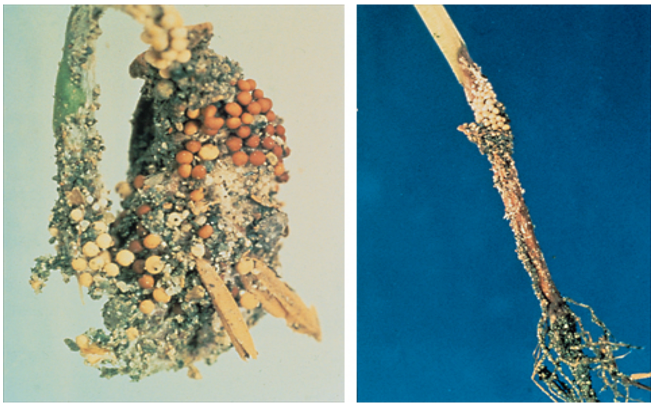


Figure 2. White mold
(See Section 10.2, page 21)

Stains on plant root and brown fungal nucleus
(Source: H.F. Schwartz and M.A. Corrales, 2005)

Figure 3. Bottom rot
(See Section 10.3, page 24)

Stains on bottom rot cause by fungi, *Rhizoctonia solani* (Source: H.F. Schwartz and M.A. Corrales, 2005)

Figure 4a *Fusarium* wilt
(See Section 10.4, page 26*)*
Leaves near to plant base are yellowing and wilting
(Source: H.F. Schwartz, 2005)

Figure 4b *Fusarium* wilt
*(*See Section 10.4, page 26)
Vascular veins on the stem turns *brown*
(Source: H.F. Schwartz, 2005)

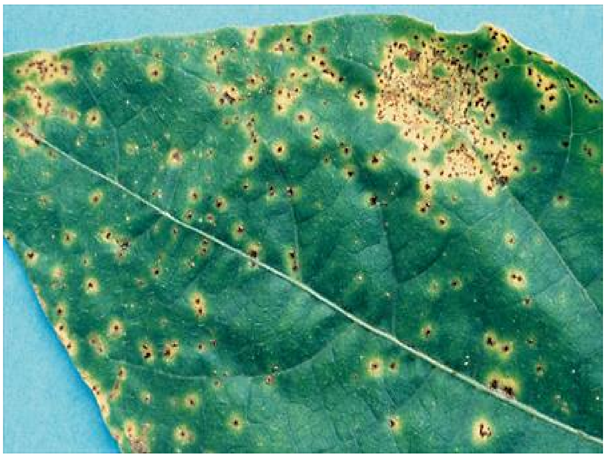


Figure 5a. Bean rust on green bean, symptom on leaves
(See Section 10.5, page 29)
(Source: R. Hall, 2005)

Figure 5b. Bean rust on green bean, symptom on fruits
(See Section 10.5, page 29)
(Source: R. Hall, 2005)

Figure 6. Angular leaf spot,
symptom on leaves
(See Section 10.6, page 31)
(Source: H.F. Schwartz, 2005)

Figure 7. Powdey Mildew, signs
and symptoms on leaves
(See Section 10.7, page 34)
(Source: H.F. Schwartz and S.K. Mohan 2005)

Figure 8. Bacterial blight,
symptoms on leaves
(See Section 10.8, page 36)
(Source: A.W. Saettler, 2005)

Figure 9. Bacterial halo blight,
stains on leaves
(See Section 10.9, page 38)
(Source: H.F. Schwartz, 2005)

a b

Figure 10a and b. Bacterial brown spot,
symptoms on pods (a) and leaves(b)
(See section 10.10, page 37)
(Source: H.F. Schwartz, 2005)

a ***b***

Figure 11. Bacterial brown spot,
Symptoms on leaves (a) and pods (b)
(See Section 10.11, page 42)
(Source: H.F. Schwartz, 2005)

a

b

Figure 12a and b. Bean mosaic virus
(See Section 10.12, page 45)
(Source: H.F. Schwartz, 2005)

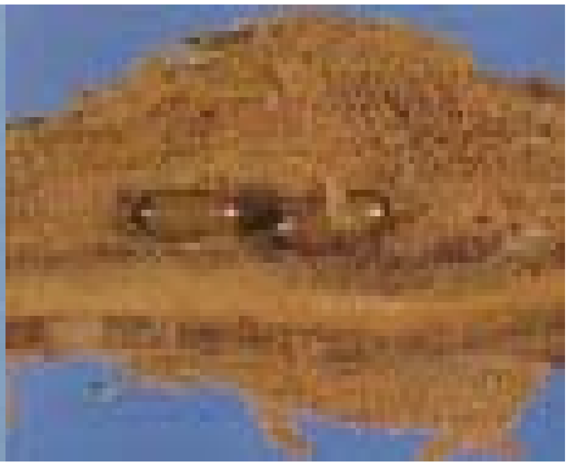
Major Insect Pests of Legumes

Figure 13a. Leaf miner fly
(See Section 11.1, page 49)
(Source: Shepard, et al., 1999)

Figure 13b. Larva of leaf miner
(See Section 11.1, page 496)
(Source: Shepard et al., 1999)

Figure 13c: Pupa of leafminer
(See Section 11.1, page 49)
(Source: Shepard et al., 1999)

Figure 13d. Leafminer damage on potato leaves
(See Section 11.1, page 49)
(Source: Shepard et al., 1999)

a b

c

Figures 14 a, b and c. Adult (a), pupa (b) and damage (b) on bean seedlings by root borer

(See Section 11.2, page 51)


Figure 15 a and b. Black bean aphid colonies on young seedlings and flowers

(See Section 11.3, page 52)

(Photographs Figure 15a by V.P. Justo, 2007; Figure 15b , Shepard et al.1999)

Figure 16. Red spider mites
(See Section 11.4, page 56)
Photographs by V.P. Justo, 2007

a b

Figure 17 a and b: Adult thrips eat along the main leaf vein (a) and damage on underside of the leaf (b)
(See Section 11.5, page 56)
(Source: AVRDC, 2000)

Figure 18. Larva of bean pod borer, *Maruca (testulalis) vitata*
(See Section 11.6, page 64)
(Photograph by V.P. Justo, UPLB, 2007)