Food and Agriculture Organization
of the United Nations

Cucumber Integrated Pest Management

An Ecological Guide

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

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

August 2007

Why this guide?

About this guide

This Cucumber Ecological Guide is developed by the FAO Inter-Country Programme (ICP) for IPM in Vegetables in South and Southeast Asia. This guide is summarized from many documents and reports on cucumber in Vietnam and other countries.
The objective of this ecological guide is to provide general technical background information on cucumber production, supplemented with field experiences from the National IPM Programmes, FAO's Vegetable IPM Programme, and from related organizations active in farmer participatory IPM in Vietnam and other countries.

Who will use this guide?

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 contributions from many related sectors. In addition, the time for preparing this guide was limited and the material may have some mistakes. We hope to get feedback and contributions from all readers, IPM trainers and farmers in order to improve the material.

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

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I General Introduction

1. The Cucurbitaceae Family

Crops belonging to the Cucurbitaceae family are commonly called cucurbits. Cucurbits are a big group of vegetables that include cucumber, bitter gourd, squash, bottle gourd, ridge gourd and snake gourd. Cucumber is commonly used for salads and pickles while squash and most of the gourds are for cooking. Watermelon and muskmelon are taken as dessert while wax gourd is prepared as jam and biscuits.

In the world there are 120 genera and 1000 species distributed in tropical and subtropical areas. Cucurbits are tropical in origin and grown mostly in Africa, tropical America, and Asia, mainly Southeast Asia. Some genera are found in South and East Asia while some are also distributed in temperate areas. In Vietnam, there are 23 genera and 53 species of cucurbits.

Cucurbits are perennial crops and multiply by seeds although few are clones.

1.1. Characteristics of Cucurbitaceae family

Cucurbits have common botanical characteristics as follows:

Roots: The root system is extensive and largely superficial. The taproot is long and adventitious roots develop up to 60cm. The root system of drought tolerant varieties can grow 170-180 cm deep.

Stem: Stems are 3-8 angled branches. Vines extend up to 9-10 m. The nodes produce roots when they reach the soil under saturated humidity.

Leaves: Leaves are simple and most have 3-5 lobes with different shapes. Some are deeply lobed, e.g., watermelon.

Flowers: Flowers are solitary or in clusters, most being gynoecious. Some are *hermaphroditus, dioecious, andromonoecious.*

Fruits: Fruits are solid and succulent.

Seeds: Cucurbits have many seeds of different shapes and colors, e.g., watermelon except chayote with only one seed per fruit.

1.2. Cucurbitaceae crops commonly grown in Vietnam

Cucurbit crops grown in Vietnam are classified as follows:

1. *Cucumis*: cucumber, muskmelon
2. *Citrullus*: watermelon
3. *Cucurbita*: pumpkin, squash
4. *Lagenaria*: bottle gourd
5. *Momordica*: bitter gourd
6. *Luffa*: loofah
7. *Trichosanthes*: snake gourd
8. *Benincasa:* wax gourd

9. *Coccinnia:* ivy gourd
10. *Sechium*: chayote

1.3. Main problems of cucurbits

As other crops in the Cucurbitaceae family, cucumber has many field problems such as insect pests and diseases, deteriorated varieties and reduced fruit quality.

Pollination: Cucumber is cross-pollinated by insects. The ratio of male and female flowers and number of bees or other pollen-feeding insects are important factors affecting the yield. The constant reduction in populations of pollen-feeding insects due to pesticide misuse becomes a problem for pollination.

1.4. Source of information

See list of references

2. The cucumber crop as a farming enterprise

2.1. History

Most cucurbit species have an African origin. However, cucumber is believed to have originated from the foothills of the Himalayas where the closely related wild species *C. hardwickii* Royle still exists. In India, the cucumber was already being cultivated 3000 years ago, and it was known in ancient Egypt, Greece and the Roman Empire.

In the 6th century, it was cultivated in China and was probably the source of the first cucurbit to reach Malaysia. Now it is cultivated worldwide.

2.2. Importance of crop: food and cash value

Cucumber is grown for its immature fruits that are used as salad vegetable and for pickles. The slicing cucumber are peeled, sliced and served with vinegar or dressing or as an ingredient of salads. Cucumber and other cucurbit fruits are generally fat-free and low in sodium. However, processed cucumbers (pickles) can have high sodium contents.

Cucumber is the highest export-processed product with increasing productivity annually.

2.3. Economic potential of the crop

Compared with other vegetables, cucumber occupies fourth place in importance in the world, following tomato, cole crops and onion. In 1987, world acreage of cucumber was estimated at about 850,000 ha with a total production of 12.5 million tons. About half of this production was from Asia, with China leading at 240,000 ha and 3.7 million tons in. The total production for Southeast Asia was: Indonesia - 40,000 ha and 291,000 t (1988); the Philippines - 1000 ha and 6000 t (1987); Thailand - 12 000 ha and 143 000 t (1988).

Pickling cucumber (gherkins) is not popular in Southeast Asia. Western countries.prefer to import small-size gherkins due to high labor costs for harvesting from Indonesia and Vietnam. According to statistics from the Vietnam Fruit and Vegetable Cooperation in Vietnam, pickling cucumber from northern export-food factories exported to European markets was 1117, 2184 and 2309 tons in 1992, 1993 and 1995, respectively. In the coming years, markets for this product will not only be stable, but also will be developed in terms of types and volume. Good production and new techniques for varieties, cultivation and processing technology will help bring about higher efficiency and better quality of products.

2.4. Analysis of main problems in cucumber cultivation

There are many difficulties associated with cucumber cultivation such as insect pests and diseases, varieties and markets.

- Pests and diseases: Pests and diseases on cucumber are not as many as in solanaceous or cruciferous crops. Usually, problems with pests and diseases are linked to crop timing and yield.

- Varieties: Cucumber varieties deteriorate rapidly because they are pollinated by insects. Varieties affect the requirements of processing factories regarding fruit size and quality. This limits the expansion of consumption markets as well as expansion of cucumber cultivation areas.

2.5. Approach to solving main problems

Applying proper cultivation methods combined with IPM will reduce damage by insect pests and diseases on cucumber. Major diseases of cucumber, such as angular leaf spot, powdery mildew, downy mildew, and soil-borne diseases, such as bacterial wilt, can be prevented by cultivation and other cultural practices. Growing resistant varieties can effectively reduce insect pests and diseases.

Seed rehabilitation or using F1 varieties to grow will ensure quality and yield of cucumber. In some cases, F1 varieties give higher yield than pure varieties.

3. Biological facts

3.1. Botanical characteristics: taxonomy, morphology

Cucumber is an annual crop and a climbing herb. In favorable conditions, its growth development duration can last 12-13 months.

Root: The cucumber root system develops weakly. Root length can be 10-25 cm in sandy loam soil. The root system makes up 1.5% of the total biomass. Secondary roots distribute on the surface covering an area of about 60-90 cm wide. Varieties that are long maturing have stronger root systems and parts above the ground. F1 varieties, however, have longer roots than parent varieties at any stage of crop growth and development. Therefore, the development of the root systems at the early stages is closely related to yield.

Leaves: Leaves are alternate, simple, in outline triangular-ovate. Leaf-blades are 3-7 lobed and deeply cordate at base, acute at apex. Lobes are triangular, acute at apex and dentate.

Stem: The stems of the cucumber produce vines; are 4-5 angled and sparingly branched. The length of the main stem may be 2-3 m.

Flower: Flowers are axillary and unisexual and occasionally hermaphrodite. However, due to the process of evolution and human interventions, new flower types occur among cucumber such as:

- *gynoecious*
- *hermaphroditus*

- *gynoandromonoecious*
- *gynomonoecious*
- *andromonoecious*

Among these types, the gynoecious and hermaphroditus flowers play a significant role in breeding and in producing F_1 seeds.

The yellow flowers have 4-5 calyxes. Male flowers are single or borne in clusters, smaller than female flowers that have 4-5 calyxes. Female flowers are solitary on short thick pedicels of 3-5 mm long. Flowers have 3-4 ovules.

Fruit: Fruits change color from pale green when young to white, yellow or brown when ripened depending on the color of fruit spines. Fruits with white spines are green and never turn yellow. They are whitish-green when ripened. Fruits with black or brown spines are yellow or brown in color when ripened.

Seed: Seeds are light yellow and the weight of 1000 seeds is about 20-30 g. There are about 150 - 500 seeds per fruit.

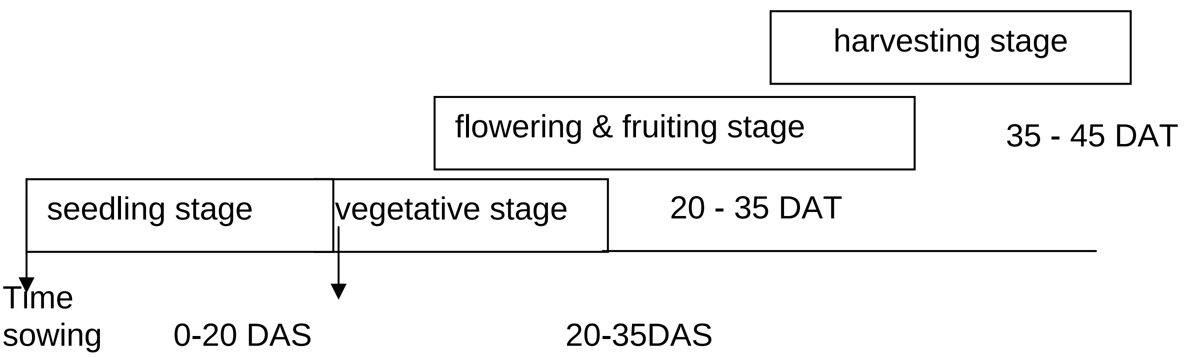
3.2. Growth stages and development

Cucumber completes a life cycle, from seed to seed, in one season. Cucumbers 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.

Cucumber requires 50-70 hot days to give a harvest. Early maturing varieties have growth development duration of 50 days, common varieties - 60 days and late maturing varieties - 70 days. The general growth stages for cucumber are:

- Seed.
- Seedling stage - usually the period from emerging seed to transplanting to the main field.
- Vegetative stage - from transplanting until the first flower buds develop.
- Flowering stage - plant with flower buds and open flowers.
- Fruiting stage - plant with small to full-sized fruits.
- Harvesting stage - period when plant yields mature fruits.

These growth stages are overlapping in time:



DAS = Days after sowingDAT = Days after transplanting

3.3. Relation between vegetative growth and pod development

Vegetative growth is closely related to flowering, fruit formation and development stages. If cucumber crops are grown in poor soil, especially when there is lack of nitrogen, they will develop slowly and fruits will be small and bitter. Fruit formation is also closely related to soil nutrients. Cucumber grown on loamy-light textured or sandy loam soil, gives higher quality fruits than on other kinds of soil.

▪ 3.4. Abiotic factors and growth development

Effects of temperature

Cucumber requires a warm climate. Seeds can germinate at 12-13ºC, however; the optimum temperature for cucumber growth development is 25-30ºC. Higher temperatures will stop the crop development and under long duration temperatures of 35-40ºC, the plant will die. At temperatures below 15ºC, the plant will loose balance between assimilation and catabolism.

Temperature directly affects time of flowering. At optimum temperature, the plant produces female flowers 26 days after germination. The lower temperature, the slower the plant produces flowers. Degree-days from germination until the first harvest of local varieties is 900ºC and until the end of season are 1650ºC.

Effects of light

Cucumber favors lights of short day length. The suitable daylength for the plant to grow and develop is 10-12 hours/day. An abundance of light tends to increase photosynthesis, productivity, increase yield, fruit quality, and reduce time for the fruit to mature. The suitable light intensity for cucumber is within 15,000 – 17,000 lux.

Effects of humidity

The cucumber fruit is 95% water, thus the plant has a high requirement of humidity. On the other hand, due to large foliage and high drainage coefficient, cucumber needs the highest amount of water among cucurbit crops. The optimum soil humidity for cucumber is 85-95% and air humidity at 90-95%. It has low ability to tolerate drought. Water deficiency results to weak development of the plant and the accumulation of cucurbitacins which causes bitter taste of fruits. Cucumber flowering and fruit development stages need the highest amount of water.

Effects of soil and nutrients

Cucumber has stricter requirements of soil than other cucurbits due to its weak root system. The suitable soil is sandy loam, loamy-light textured soil, with pH level of 5.5 - 6.5.

A study of cucumber productivity using mineral fertilizers showed that cucumber needs more potassium, followed by nitrogen and phosphorus. Cucumber can not be given too much fertilizer, but quickly responds to nutrient deficiency.

II. Crop Management

1. Crop rotation

1.1. Importance in relation to nutrient availability in 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. Rotation with green manure crops such as legumes increases nitrogen supply to the crops.

1.2. Importance in relation to pest and disease incidence

Some of the common serious pests and diseases which live in the soil attack a range of plants within the same botanical family - but no others. If the kinds of plant they attack are continually grown in the same area, the pests and diseases can build up to infectious level. Once a soil-borne disease has entered a field it is very difficult to get rid off. If there is a break of several seasons or even several years in which other crops (of different family) are grown, their population will be reduced and will eventually be suppressed. 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 of the same plant family requires rotation with an entirely different family. Unfortunately, some pathogens, such as those causing wilts and root rots, attack many families and rotation is unlikely to reduce disease.

In addition, some fungi produce resistant, long-lived reproductive structures as well as the immediately infectious forms. 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 for a long time without a host. Survival of pathogens without a host plant depends on factors like the environment, temperature, ground water, etc. Some indications on “survival rates” per disease are mentioned in the sections on individual diseases. The following are few examples:

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

1.3. Rotation guidelines: crops and cycles

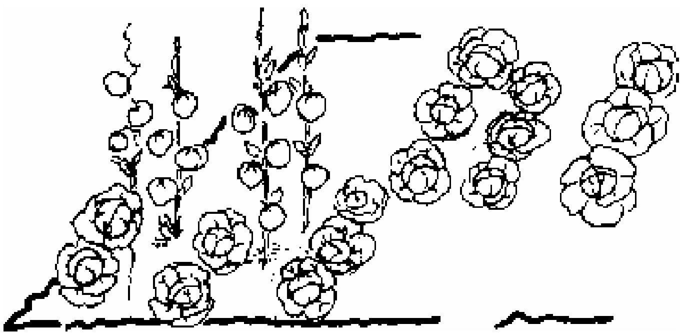
Cucumber is a vegetable crop belonging to the Cucurbitaceae family and is attacked by pests of other cucurbits such as watermelon, wax gourd, pumpkin, bottle gourd, luffa, bitter gourds and squash. These problems are limited when cucumber is rotated with non-cucurbit crops such as water plants including rice and jute. Some common crop rotation formula practiced in Northern Vietnam is the following:

Formula	Growing area	Crop rotation formula
1	Vegetable intensive farming	White radish – Kohlrabi – Cucumber (wax gourd) – Green mustard Sep-Dec Oct-Dec. Dec-Jun Jul–Aug
2	Vegetable intensive farming	Tomato - Kohlrabi - Cucumber (wax gourd) – White radish Aug-Dec Dec-Feb. Dec-Jun Jul–Aug
3	Vegetable intensive farming	Tomato/Cucumber – Corn – Summer leafy vegetable Aug.-Dec. Jan-May Jun–Aug.
4	Vegetable intensive farming	French bean - Tomato/Cucumber – Green mustard/white radish Oct-Feb Feb-May Jul–Oct
5	Semi-vegetable intensive farming	Cucumber – Early rice autumn season – French bean/Short-duration brassicas Feb–May Jun – Oct Oct–Jan

(*Source: Mai ThÞ Ph-¬ng Anh, Curriculum for Veg. MSc, 1996*)

2. Intercropping

2.1. Advantages and disadvantages in relation to pest and disease incidence, marketing, soil utilization and conservation



Intercropping is the simultaneous cultivation of two or more crops in one field. It can also be called *mixed cropping* or *polyculture*. When plants of different families are planted together it is more difficult for insect pests and diseases to spread from one plant to the next. Insects have more difficulty in finding host plants when they are camouflaged between other plants. Fungal spores may land on non-host plants where they are lost. Natural enemies of insect pests get a chance to hide in the other crops. When the intercrop is taller than the cucumber plants they can form a “barrier” thus reducing spread of insect pests and diseases.

Certain intercropped plants excrete chemicals or odors which repel insect pests of other plants. Examples are onion and garlic. The strong smell repels some insects, and they fly away and will not attack other plants growing between the onion or garlic plants.

Intercropped solanaceous crops with onion or garlic reduced levels of whiteflies and aphids on tomatoes (Tumwine, 1999).

Other plants may have nematicidal activity, killing nematodes in the soil. An example is sesame: root extracts caused mortality of nematodes in laboratory tests (Karshe, 1993). Another “famous” nematode-killer is the flower *Tagetes* sp. which can effectively control nematodes on tomato (Tumwine, 1999). According to AVRDC (1994), intercropping tomato with cowpea could be used in IPM in the tropics to control bacterial wilt.

Intercrops could also reduce the risk of crop failure by providing an alternative crop and additional income to a farmer. However, when the intercrop is taller than main crop (e.g. sunflower or sorghum) it may cause yield reduction due to competition for light, space and nutrients (Tumwine, 1999). See box below.

Other disadvantages include more difficult harvesting operations due to different ripening times of the crops, and the planning of crop rotation schedule is more complicated. Intercropping is usually a bit more labor intensive.

Effects of intercropping on tomato late blight disease: a study from Uganda

Experiments were conducted in Uganda to identify crops which could be grown with tomato and which reduced late blight disease (*Phytophthora infestans*). Tall and short crops were intercropped with tomato and sanitation (removal of infected leaves, shoots and flowers) were practiced. Some conclusions from these studies were:

- Late blight incidence in intercropped plots was lower than in control plot (also due to sanitation practices).
- Soybean and sesame are compatible for intercropping with tomatoes at 60cm between row spacing.
- Tall plants such as sorghum and sunflower have a suppressive effect on tomato growth and productivity when intercropped, presumably because of shading.
- Sanitation alone had a negative effect on tomato growth and production.
- Row spacing between intercrops is crucial to minimize side effects such as shading and competition for nutrients.

(Tumwine, 1999)

2.2. Suitable crops

Intercropping should ensure some requirements, such as not affecting or reducing the yield of the main crop, harvesting time should not be too different from the main crop, and it must bring about higher benefits than the mono-cropping system.

Some crops can be intercropped due to their different growth development times and different morphological characteristics. For example, in Vietnam, farmers often intercrop spring onion, green mustard, kohlrabi, radish, Chinese cabbage between rows of cucurbits.

2.3. Method: timing and spacing

Some intercropping practices that have been applied in Vietnam include:

- Cucumber grown together with radish, green mustard, and Chinese cabbage. Radish should be sown at the time of transplanting cucumber. It is essential to take good care of the cucumber to avoid poor development resulting in low yields. Varieties of green mustard and Chinese cabbage used for intercropping should be of short duration (40-45 days), grown between two rows of cucumber. (*Source: IPM trainers in Hanoi, April/2000*).

3. Variety selection

3.1. Demand and supply: how to choose a variety?

The selection criteria for a variety to grow will vary depending on the purpose for its consumption (as fresh fruits or for processing). Varieties for fruit processing are divided into the following groups: small fruit group; medium fruit group and big fruit group.

3.2. Characteristics of commonly available varieties

Small fruit group: - very small cucumber fruits (baby cucumber) have length of below 11 cm and diameter of 2.5-3.5 cm. Products for processing are 2-3 day old fruits. This group has short growth duration (65-80 days) with an average weight of 150-220 fruits/kg. Most varieties in this group are gynoecious, such as the F_1 Marinda, F_1 Dunja, F_1 Levina (Dutch) and American varieties. Only Marinda variety has a bunch of 3-5 fruits on each leaf axil and although yield is not high (3-8 tons/ha) its market value is still high. Therefore, growing this variety is still preferred. In addition to fresh consumption, this fruit group is used for processing. One major production difficulty for this group is that the varieties are susceptible to disease, mainly downy mildew causing moderate to severe damage.

Medium fruit group: - includes most local varieties and F1 hybrid varieties. Fruits are 13-20 cm long and 3.5-4.5 cm in diameter. The growth duration of varieties in the medium fruit group is 75-85 days and yield is about 22-25 tons/ha. Some varieties in this group can be sliced to put in glass bottles.

Big fruit group: - includes F_1 hybrid varieties from Taiwan, America and Japan. Taiwan varieties are 25-30 cm long, 4.5-5 cm in diameter, cylinder-shaped fruit, light green in color and have white spines. Japanese varieties are longer, about 30-45 cm long, about 4-5 cm in diameter, fruits are smooth or wrinkled with white spines and are dark green in color. Varieties in this group have relatively high yield at an average of 30-45 tons/ha and sometimes 50 tons/ha if cultivation is good.

3.3. Commonly grown cucumber varieties in Vietnam

There are many hybrid and imported cucumber varieties which are grown now in Vietnam but the more commonly grown ones are those in the small and big fruit groups.

Small fruit group

- Hybrid variety PC 1 by Food Crops Research Institute. This variety has a growth duration of 35-40 days, develops well with high yield of about 35-40 tons/ha. The fruits are small, about 9 x 3.2 cm and weigh 100-110 g/fruit with thick pulp (1.2 cm). This variety is suitable for export. Fruits can be stored for a long time, lengthening the time for local consumption. Immature fruits can be harvested for processing as baby cucumber. Fruits rarely turn yellow after harvest. Fresh fruits are crispy and have good smell. Plants are tolerant to major diseases such as powdery mildew, downy mildew, bacterial wilt and virus diseases. Variety PC 1 can be grown in both Spring-Summer season and Autumn-Winter season and can give high yield.

Big fruit group

- Hybrid Sao Xanh 1 by Food Crops Research Institute. This variety has a growth duration of 85-90 days and harvesting time lasts for 40-45 days. Plants of this variety develop well and characterized with thick stem and dark green leaves. Fruits are big, about 23 cm long and about 3.5-4.0 cm in diameter. Average fruit weight is 200 g/fruit, with thick pulp (1.3 cm). Fruits rarely turn yellow after harvest. Fresh fruits are crispy and have good smell and good quality. Consumers like the variety very much. It has high yield at an average of 35-40 tons/ha. Plants are relatively tolerant to major diseases such as powdery mildew, downy mildew, bacterial wilt and virus diseases. The variety can be grown in both Spring-Summer season and Autumn-Winter season.

- F_1 Mü xanh: provided by East-West seed company. Plant develops well with a lot of branches. It is suitable to grow during rainy season. It can resists downy mildew. Harvesting starts about 35-37 days after planting. Average yield is 3-4 kg/plant. Fruits are straight, green in color, 15-17 cm long, with white spines, good quality, sweet, crispy and can be stored 10 days after harvest.

- F_1 Mü trang from East-West Seed Company. Plants of this variety develop well with a lot of branches. It is suitable to grow in different seasons and shows resistance to diseases. It produces a lot of fruits with a yield of about 3-4 kg/plant. Fruits can be harvested at 15 different times. The plant gives the first harvest about 35-37 days after sowing. Fruits are straight, pale green in color, 15-17 cm long, with white spines and can be stored ten days after harvest without turning yellow.

- F_1 124 from East-West Seed Company. The variety gives high yield of about 48 tons/ha.

- F_1 702 from East-West Seed Company. It can be planted both in the rainy and dry season. Fruits are straight, about 20 cm long and green in color. The average yield is 5.4-9.5 tons/1000 m^2.

4. Seed preparation

4.1. Healthy seed

Like some other crops, cucumber is propagated by seed; therefore seeds play a very important role in determining fruit yield. Farmers usually have some criteria for selecting seeds such as seed purity and germination percentage.

For cucurbit seeds, the requirement for seed purity is 99% with a percentage of mixture at 0.05% and no weed seeds. Seeds should be light yellow, with weight of 1000 seeds (P< 1000 seeds) ranging from 20–30 and with the number of seeds/fruit at 150 - 500.

The germination percentage of cucumber seeds is 70%. One simple method that can be used to check germination ability of cucumber seeds is to put about 100-500 seeds on wet tissue (or cotton) lying on a small dish. The seeds are then covered by cloth or filter paper. The number of germinated seeds is counted after 24 hours and seed germination is observed for three days.

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

To get cucumber seeds for propagation, fields of different cucumber varieties should be at least 2 km away from each other. Normally, only 3 or 4 fruits/plant can be harvested for getting seeds. Often fruits in the middle section of plant are collected. After the first harvest, fruits in the middle section of the plant are kept and female flowers which open later are removed in order to have more nutrients for seed fruits.

Seed fruits are picked at 25-30 day old, and then they are kept for 4-5 days for physiological maturation. To get the seeds, the fruits are opened vertically and a small spoon can be used to collect the seeds, put in a plastic basin for 24 hours, then washed and exposed to sunlight 3-4 times.

Seeds from F_1 varieties should not be kept for the next season.

4.3. Storage

Like other vegetable seeds, cucumber seeds easily lose their germination ability if they are stored under normal conditions. In order to keep seeds for the next season, two methods either the close storage or cold storage methods may be applied.

- Close storage: Dried seeds are placed in bottles, jars, pots with some lime underneath to avoid condensation. Containers should be closed carefully with lids. Seeds can be stored for 3-4 years using this method.

- Cold storage: Dried seeds are placed in paper or plastic bags then put in cold room with temperatures of-4°C. Seeds can be stored for 15-20 years using this method.

4.4. 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. In addition, some treatment methods can stimulate seeds to germinate quickly. The seed treatment may be physical or chemical.

Physical treatment - may consist of soaking seeds in warm water or applying dry heat. The duration of the treatment depends on the seed structure and the thickness of its skin. Cucumber 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 (Tetramethylthiuram-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.

5. Land preparation

5.1. Soil type/characteristics in relation to suitability for cucumber

Compared to other cucurbits, cucumber plant has a stricter requirement of soil type as its root system develops and absorbs nutrients poorly. Researches show that sandy loam or sandy soils are suitable for growing cucumber because it absorbs heat faster than other soils in Spring season and its small particle structure helps prevent seedlings from collapse due to rain and wind.

The cucumber root system is shallow (only 25-30 cm deep from ground) resulting in poor ability to tolerate drought, flooding and making the crop susceptible to pests and diseases. Therefore, the soil for cucumber planting should be prepared carefully. The best way is to keep ploughed soil for 5-7 days, then sprinkle crushed lime to sterilize and kill soil-borne diseases. Raised beds are prepared before planting.

Cucumber requires loamy light-textured soil, such as loamy soil or sandy loam soil with pH level of 5.5-6.5.

5.2. Preparation

5.2.1.. Characteristics of good soil in relation to soil cultivation methods

Soil productivity is defined as the capacity of the soil to produce a specific crop (or sequence of crops) under a specific management system which includes planting date, fertilization, irrigation schedule, tillage, and pest control.

Soil productivity is very closely related to the depth of topsoil. In many cases, the thinner the topsoil is, the lower is its ability to supply water and nutrients. In addition, soil productivity depends largely upon the kind of soils and local environmental conditions. A topsoil 20-40 cm deep is suitable for growing vegetables and long-root crops.

5.2.2. Method of soil cultivation and bed preparation

Land preparation affects soil nutrient conservation. 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 which are more labor-intensive. The usual problem with manual land preparation is inadequate depth. The steps in land preparation are the following:

a) Clearing/mowing: This is an optimal step necessary only in opening new areas for growing vegetables 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, then, it may be necessary to clear the field of obstructions and tall weeds.

b) Plowing: Like other vegetable crops, the soil for growing cucumber should not be too fine. If it is too fine, it will cover void space for air. Soil structure affects root distribution, adventitious roots and root quality. Studies have shown that 80% of cucumber roots develop and are distributed in a layer of 20mm. Topsoil on beds should be 1-3 cm or 5 cm high. In the process of raising beds, however, try to make topsoil finer than the underneath layer. This is a basic technical requirement of raising beds for vegetables.

c) Raising beds: The 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 120 cm, depending on each cucumber variety. Bed height should not be more than 25-30 cm.

The shape of raised beds will vary depending on the season. Because of the rains in Summer season, it is advisable to prepare high and narrow raised beds for growing the crop and to dig trenches between the beds for drainage. In the dry Winter season raised beds can be flat, large or a little bit deep in the center to keep water and fertilizer.

6. Crop establishment

6.1. Direct planting

Vegetables can be classified into three categories, depending on the planting practice: crops that are transplanted, crops that are usually direct-seeded, and crops that should be direct-seeded. Cucumbers are transplanted or usually direct-seeded.

Direct-seeding prevents crops from being injured and helps them to develop quickly. Some tuber crops, such as carrot and radish easily develop forked root due to root damage at seedling stage. Therefore, they should be direct-seeded. Like other cucurbits, cucumber roots are easily affected. However, when direct-seeding can not be done it is advisable to grow seedlings in banana leaf pots to avoid roots from being damaged during transplanting.

The cucumber crop develops quickly in the field even when conditions are not ideal. Direct seeding can increase the number of seasons. Seeds can be sown in the field 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 amount of seed than transplanting. When the cost of the seed is high, as in hybrid seed, transplanting may be recommended instead of direct-seeding.

In direct-seeding, 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. In many cases, when the topsoil is not prepared well, large soil clumps also make it difficult for seeds to emerge. Therefore direct seeding requires fine soil particles. However, if seeds are placed too shallow, they become dry and hot, difficult to germinate and easy to be eaten by birds and insect pests.

Time of sowing

The growth duration of cucumber is very short. It takes only 35-45 days from sowing until flowering stage, and 45-55 days until harvest. Time of sowing is determined by the season. Cucumber requires warm climate and its seed can germinate at temperatures of 12-13ºC. Thus, sowing time should be determined based on climate and temperature.

In cold areas, seeds should not be sown in Winter season when temperature is under 10ºC. Under that condition, it will be difficult for seeds to germinate or they may even die. If seeds can germinate, it will take a long time and the plants will develop poorly. In cold areas, seeds are often sown in the greenhouse three weeks before there is no more frost or two weeks after there is frost in the field.

In tropical areas, sowing time should be considered carefully so as not to affect flowering and pod formation. Flowering and pollination will stop if temperature is over 35ºC. If temperature is 35ºC for several days, plants may die.

Example of time of sowing in the North of Vietnam:

In Winter-Spring season, farmers sow cucumber seeds during days when the temperature is 10°C. For the first five days after sowing, none of seeds germinate at all. In the following days, some seeds germinate although at a low percentage. When the temperature increases to about 15°C, seeds start to germinate although not uniformly and it takes a long time. Some farmers sow seeds later when days are warmer and the percentage of germination is higher with shorter germination time. If temperature is high and there is much rain during flowering stage, flowers can not be pollinated resulting in low percentage of fruit formation and reduced yield. Therefore, the best time for sowing should be determined carefully especially in the Winter-Spring season, otherwise yields will be affected.

(*Source: Document of T¹ Thu Cóc, NguyÔn ThÞ Ph-¬ng Anh*)

In some areas, the sowing time in Spring season is about 20–30 March or 15 April–15 May. In the Summer season, it is about 1–15 July or 1–20 August.

In northern Vietnam, cucumber sowing time follows:

- Winter season: sowing seeds at the end of September or beginning of October; harvest from 15 November to 15 December.
- Spring season: sowing seeds from 10 February to 15 March.
- Summer season: sowing seeds at the end of April or beginning of May; harvest from 15 June to 30 July.

Method

Cucumbers are seeded directly into holes in the field. Holes are prepared after raising beds. Holes are spaced 40-50 cm apart in rows spaced 60 cm apart. Transplanting density is about 33,000 holes/ha.

Seeds are placed directly in holes at 2-3 seeds per hole. Plants are thinned later to keep only 1-2 plants/hole. For F_1 seeds, plant only one seed per hole. Cucumber seeds have thick skin, thus they should be soaked in warm water before sowing in Winter season.

Sow seeds on the beds at a depth of 1-1.5 cm and cover with humus or rice husk before watering.

> ✓ **Precision sowing: inspiration from Jessore, Bangladesh**:
>
> A farmer from Jessore uses a wooden frame with small pins which he places on the soil of the nursery beds as a guide for sowing eggplant seeds. The pins make small holes in the soil at equal intervals to indicate the points for sowing seeds. He then sows 2 to 3 seeds in each hole. With this method of precision sowing, this farmer is able to get a good nursery using only a small amount of seed.
>
> Good idea, especially for expensive hybrid seed! ☺
>
> (pers. comm. Farmer Yousuf, Jessore, Bangladesh, 1998)

6.2. Using seedling

In many cases, due to the long growth duration of the previous crop or unfavorable conditions for direct-seeding, transplanting can be done by making banana leaf pots for seedlings.

In addition to addressing crop timing, the use of banana leaf pots prevents root damage or minimizes mechanical wounds on roots of seedlings during transplanting that affects plant growth and development.

Pots can be made out of banana leaves, polyethelene bags, jars or other materials. The pots are usually filled with clean soil and some compost. Various soil mixes can be used, for example sub-soil with compost. One or two seeds are sown in each pot. The pots are watered regularly and protected from full sun or rain, if necessary.

> **Potting seedlings versus flat field beds, experiences from Asia:**
>
> In a tomato study in Hai Phong province, Vietnam, seedlings for the IPM treatments were raised in banana leaf pots filled with clean soil and compost, whereas farmers traditionally raised them in flat field seed beds.
>
> Farmers found that there was less damping off in seedlings, and less seed was needed, when plants were raised in clean conditions in pots rather than in traditional seedbeds.
>
> ☺ (*source: Dr. J. Vos, 2000*)

Cucumber transplants are usually about 4–6 weeks old and have 4 or 5 true leaves when set into the field. Transplants usually have straight, thick stems and disease-free leaves.

Pots or polyethelene bags are usually removed at transplanting. Each hole should have 1 or 2 transplants. The soil should be raised up high to ensure a sturdy plant that will not fall over when it reaches it full size. The plant is irrigated after transplanting.

7. Pollination and fruit setting

Most cucumbers, whether monoecious or gynoecious, require insects to transfer pollen between flowers of the same or different plant. Fruit abortion can reach 100% in flowers bagged to exclude insect visitors (Stanghellini et al., 1997), but self-pollination rates of

30-36% have been documented in the absence of insects (Jenkins, 1942; Gingras et. al., 1999) and a small rate of parthenocarpy is known to exist (Gustafson, 1939; Gingras et. al., 1999). Nevertheless, insect pollination is the norm.

All of the major varieties are interfertile. Each stigma should receive several hundred grains of pollen for best fruit set and quality (Seaton et al., 1936). Pollen grains do not necessarily need to be spread evenly on all three lobes of the stigma to form a good fruit, but it does take multiple bee visits to optimize fruit-set. The minimum number of required bee visits per flower is probably variety-dependent and has been recorded as 8 -12 (Connor, 1969; Stephen, 1970; Lord, 1985), 18 (Stanghellini et al., 1997) and six (Gingras et al., 1999).

About 30% of the flowers in gynoecious plantings should be male in order to optimize pollination and economic return (Connor and Martin, 1971). This means that gynoecious varieties require a supplemental source of male flowers. This is done is by pre-mixing commercial seed with around 10% monoecious seed.

Cucumber produced from early flowers on young plants often have fewer seeds and inferior shape compared to fruit produced without competition on more mature vines (Connor and Martin, 1970). In unpublished studies, these authors found that older vines produce larger female flowers with more ovules. Thus, fruit quality may be improved if pollination could be delayed until vines are more mature. Connor and Martin tested this idea with selected monoecious, gynoecious and gynoecious hybrid varieties. Delaying pollination (with cages to exclude or include bees) for up to 11 days after the first appearance of female flowers increased the number of fruit per plant and the dollar value per acre. The increase was likely due to stronger vine and root growth in more mature plants.

It is difficult to realize the benefits of delayed pollination under field conditions. The only way to delay pollination in monoecious varieties is to delay importation of honey bee hives, but one cannot practically keep wild bees from visiting the plants. With gynoecious varieties, one can interplant male-bearing monoecious pollenizer varieties a few days after planting the gynoecious variety. As such, male flowers become available to bees only after gynoecious plants have reached a suitable level of maturity. Connor and Martin (1969a, b) recommended alternating a 12m-wide strip of gynoecious variety with a narrow strip of monoecious pollenizer varieties a few days after the gynoecious variety. The strip of monoecious pollenizer should probably be no wider than 1m (Free, 1993). Delayed pollination in gynoecious varieties is further complicated by the fact that even gynoecious plants produce a few male flowers.

Cucumbers are grown in Europe that set fruit parthenocarpically without pollination. Pollination is undesirable in this context because it results in misshapen, devalued fruit. Growers exclude pollinators with modified glasshouses and government-enforced restrictions on beekeeping (Free, 1993)

8. Fertilization

8.1. Nutrient requirements

Cucumber is very sensitive to high fertilization, but quickly responds to nutrient deficiency. Studies on fertilizer use on cucumber show that potassium is used most, followed by nitrogen and phosphorus. An indication of the amount of organic and inorganic fertilizers for use of cucumber is given in the table below. These guidelines are very general and the range in doses for the fertilizers is broad. The accurate amount of fertilizer to be added depends on the amount of nutrients already available in the soil, soil type, soil structure, environment, etc. Fertilizers needed for cucumber in sandy or sandy loam soils are higher than in loamy light-textured soil or loam soil.

The use of organic above inorganic (chemical) fertilizers is recommended for cucumber.

The effects of Nitrogen, Phosphorus, Potassium, Calcium, and Boron in growth and development of cucumber

Nitrogen (N) promotes vegetative growth, however, applying too much N before fruit setting results in dark green plants with thickened stem. New leaves sometimes ball up rather than expand. The ratio of carbohydrates (available from photosynthesis) and nitrogen (supplied through fertilizers) or C/N ratio is critical.

If nitrogen and sunlight for photosynthesis are both adequate, then plants will grow and yield well. If N is high, light is low and plants are crowded, fruit set will be poor because vegetative growth consumes all available carbohydrates produced in the process of photosynthesis. Such plants are sometimes described as 'viney'. The best solution is to provide as much light as possible and enough nitrogen to keep the plant grow steady. Too little N is, also bad because plant becomes stunted.

Note: *Too much nitrogen can cause excessive shoot growth but no flowers!*

Phosphorus (P) stimulates growth of root, branches, flowers, pods and seeds. High level of phosphorus (P) throughout the root zone is essential for rapid root development and for good utilization of water and other nutrients by the plants. Phosphorus has an effect on the number of flowers that develop. Poor root growth and poor fruit development are associated with low P.

Potassium (K) affects fruit size and fruit quality. Higher levels of K tend to increase fruit size. Increased levels of potassium also help in decreasing the incidence of irregular shaped fruits.

Be aware that both P and K are released slowly and that particularly P is needed for root development. Therefore, basal application of P and K is crucial for healthy crop development. Topdressing P and K is often not efficient.

Calcium is very important for manipulating soil pH, enhancing nutrient uptake, making stems solid in order to avoid them from breaking. Deficiency symptoms can be seen in new leaves that do not unfold and instead tend to stick to each other; apical roots that fail to develop; and yellowing of the margins of younger leaves. On the other hand, leaves become yellow and fruits are small when the plant is grown in the calcium-rich soil.

Micronutrients such as: boron (B), manganese (Mn), magnesium (Mg), sulfur (S), copper (Cu), iron (Fe) and zinc (Zn) are also needed for cucumber growth and development. The cucumber crop is very susceptible to Mg deficiency and also has reactions when it lacks B, Fe, Mn and Cu.

You can set up a small trial to test different types and doses of fertilizers to check the ideal combination for your crop and field situation.

8.2. Organic fertilizer

Organic fertilizers are usually low in nitrogen, the one nutrient that must be added in large amounts. When organic matter is added to the soil with low levels of nitrogen, the microorganisms that degrade this organic matter use the available soil nitrogen.

Organic fertilizer, especially manure helps increase cucumber yield significantly. Other organic materials such as green manure, cover crops, organic mulch, and composted organic residues are all nutrient sources for plants. Decomposed organic materials also provide beneficial microorganisms that suppress soil-borne diseases.

Application guidelines: dose, timing and method

Nutrients available in organic fertilizer often are released slowly, making them available to the plant over the entire growing season. The nutrients are less likely to be lost from the soil. In addition, many organic fertilizers also act as soil amendments, improving the physical condition of the soil and indirectly improving plant growth.

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

Green manures, such as legumes crops and wild crops also have significant amount of nitrogen. However, they do not or have but in very low amounts other nutrients such as P and K. Green manures are often composted with an amount of animal manure to apply for plants. Green manures provide good ratio of C/N for the soil, increase population and stimulates the activity of microorganisms making soil crumbly.

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

Compost

Compost inhibits soil-borne disease development and damage. Some major soil-borne diseases of cucumber are bacterial wilt, damping-off, *Fusarium* wilt and root knot nematodes. The application of fresh manure has been observed to increase bacterial wilt incidence in cucumber fields while in fields without basal dressing of fresh manure, the disease does not occur or disease incidence is low. Root knot nematodes often damage cucumber fields where undecomposed manure is applied. This disease damages crops in the following seasons and even crops of other families.

In some countries, antagonistic fungi or bacteria are added to the compost just after the hot phase or when the compost is cooling down. When antagonists are added at that time, they can quickly build up their populations and this will result in compost with good disease-suppressing quality.

8.3. Inorganic fertilizer

Inorganic fertilizer is also important and is used a lot in vegetable and cucumber production. Applying organic fertilizer alone can not provide enough nutrients for 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 resulting in negative effects on soil physiochemical characteristics and structure. The consequence is more stiff soil, reduced crop yield and more pests and diseases.

The cucumber crop needs more potassium, then nitrogen and phosphorous. The requirement for each element changes based on crop development stages. At the beginning of the season, plants need nitrogen and phosphorous after sowing for the development of roots, stem and leaves. During flowering and fruit set stages, plants need more potassium. Inorganic fertilizer is often applied as top dressing. Nitrogen should be applied as top dressing at different times.

8.4. Cucumber fertilization guidelines

The amount of fertilizer application should be based on the rate of nutrient uptake and expected yield and soil fertility. In tropical and sub-tropical areas, cucumber yields of 20 tons/ha can be achieved from the soil with the following amounts of nutrient:

N:	39 kg	MgO:	10 kg
P_2O_5:	27 kg	CaO:	35 kg
K_2O:	70 kg		

Usually the soil contains a limited amount of N, P and K to supply the plant. To quantify the available fertilizer in the soil we need to do soil analysis. Based on the results of the soil test and the nutrient requirements of the cucumber plant, we can establish an appropriate regime for fertilizer application. However, nutrient absorption by the plant depends on many factors such as fertilizer type, application method, watering and other cultivation methods.

If the soil has normal nutrient amount, the recommended fertilizer application for cucumber to achieve yield of 30-40 tons/ha is: N = 100 kg; P_2O_5 = 100 kg; and K_2O = 200 kg.

In the Philippines, the recommendation for total application of fertilizer for cucumber is:
N = 120 kg; P_2O_5 = 120 kg; K_2O = 120 kg.

In Vietnam, the general recommendation for <u>total application of fertilizer</u> for cucumber is:

Compost	25 - 30 tons/ha
N	100 - 120 kg/ha
P_2O_5	80 - 100 kg/ha
K_2O	100 - 120 kg/ha

See an example of a fertilizer recommendation for cucumber from Vietnam in table below.

Table: Example of Fertilizer Recommendation for Cucumber in Vietnam

Timing	Fertilizer	Quantity	Method
2-4 days before transplanting	Compost	25-30 tons/ha	Mixed into soil or incorporate with soil
At transplanting time or 2-4 days before	P_2O_5 Nitrogen Potassium	100-120 kg 30 kg 50-60 kg	Mixed into soil
7-10 DAT	Nitrogen Potassium	15-20 kg 10-12 kg	Side-dressing
20-25 DAT	Nitrogen Potassium	25-30kg 20-24 kg	Side-dressing
First fruit setting (40-45 DAT)	Nitrogen	30-40 kg	Side-dressing

(*Source: High-tech cucumber production, Research Institute for Fruits and Vegetables, MARD, April 2003*)

DAT = Days after transplanting

Part of the recommended nutrients can come from organic sources, such as compost or green manure.

Every person, every book or guide will have another recommendation for cucumber 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!

9. Water management

9.1. Water requirements at seedling, vegetative and reproductive stages

The cucumber crop requires frequent watering. After transplanting, if it is sunny, watering can be done twice per day. 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. Damping off causes death of the small roots emerging from the seed. Thus, some seedlings never even emerge above the soil

When seedlings are grown in wet soil for a long time, they become weak and more susceptible to diseases such as damping off. The fungi causing damping off grow and spread easily in wet soil. ☹

9.2. Method of irrigation and drainage

Proper irrigation is critical for maintaining high yields and quality. Soils with adequate organic matter usually have high water holding capacity and do not need frequent irrigation. Soil type does not affect the amount of total water needed, but does influence the 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 level, it is in some cases possible to flood the field with water or to dry the soil out to control pests and weeds. Some pests that live in the soil such as cutworms, nematodes and some weeds can be drowned by putting the field under water. Obviously, it 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 populations and pathogens. Overhead irrigation can increase disease infection. The spores of early and late blight 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.

10. Staking and pruning

10.1. Importance

Cucumber 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. The process also makes it more convenient for crop care and harvesting. Plants staked and pruned give early harvest.

10.2. Timing and method

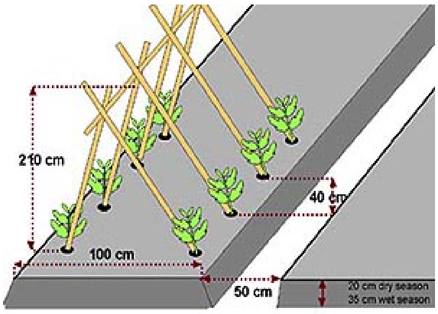
Trellising should be done when the plant is about 30 cm high. Cucumber stem grows very fast and vines elongate rapidly. Thus vines should be tied regularly, better every 2-3 days.

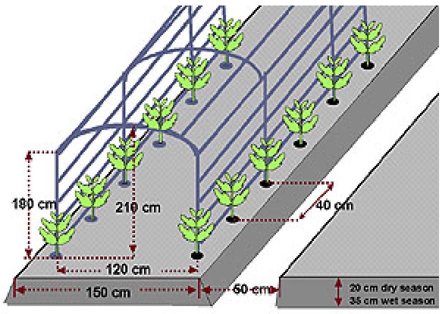
There are several methods of trellising cucumber. In some areas, bamboo poles, wood stakes, PVC pipes or other sturdy material are used to provide support and keep the fruit and foliage off the ground. The trellis is arranged either in a lean-to or tunnel structure. The trellis should be 1.8-2 m high, constructed from stakes which is almost similar to the plant row spacing.

Lean-to type: 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 rows, 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. Plants are easier to manage and more productive when 2-m-high rather than 1-m-high string trellises are 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.

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 cucumber development, tie main stem and lateral stems onto the pipe. This should be done every 2 - 3 days.





Lean-to type　　　　　　Tunnel type

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

10.3. Pruning

Cucumber develops many side branches that are not productive. To improve yield, remove lateral branches until the runner reaches the top of the trellis. Leave 4-6 laterals and cut the tip of the main runner to induce early cropping. Removal of lateral branches in the first 10 nodes has a positive effect on total yield. Without pruning, most of the female flowers occur between the 10th and 40th nodes, or at a height of 0.5-2 m.

11. Weed management

11.1. Weed and impact of weed on crop management

Weeds in a cucumber field are usually unwanted because they affect crop growth, development and yield. The competition of cucumber and weeds are fierce in the vegetative development stage and the growing process. Yield is good in a weed-free environment.

Weeds may harbor insect pests and diseases or become breeding places for insect pests, vectors and diseases. The weed, *Trianthema portulacastrum i*s host of chili mosaic virus, which affects potato and tomato. Aphid, the vector of potato virus Y disease, infests a weed, *Solanum nigrum*.

11.2. Timing

Weed control should be done early in the growing period from week 2 to week 4 after cucumber is transplanted. In the first 2-3 weeks after transplanting, 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 in order to concentrate nutrients for the development of leaves and branches consequently increasing crop yield.

Only when other forms of weeding practices can not be done, herbicides can be applied before or after transplanting to control weeds.

11.3. Method

Hand weeding is a technique to control weeds. It should be done before the flowering stage at an average of 2-3 times/cropping season. When weeding is done and when the plants are 10-15 cm high, it is important to hill-up the soil so that new roots can be produced and prevent the plant from collapsing. This process aids in maintaining air circulation in the field, breaking the scum on the soil surface and controlling weeds.

Breaking up the soil is a good technical method to control weeds. Hilling-up the soil should be done before flowering stage 2-3 times in the season. Hilling up is done to break up the soil to make it crumbly and in the process give good soil air circulation. Hand weeding or 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 planting, or after sowing seeds.

Weeds can also be controlled by spraying herbicides. The cucumber crop, however, is very susceptible to herbicides. Therefore, be sure that the herbicide you are using is suitable to the crop and will not cause leaf burn or tip curling.

The application of herbicides to control weeds in cucumber fields will depend on the cultivation conditions in each area bearing in mind the negative effects of herbicides already known in many places in the world.

12. Major diseases of cucumber

Summary: Major diseases of cucumber are downy mildew, bacterial wilt, mosaic virus, and damping-off. In the field, a number of other diseases can occur and cause yield loss, which occasionally can be severe. However, it is very seldom that diseases will cause total yield loss.

Some general disease management practices are given here. Specific practices are listed under individual disease sections.

- Use of disease-resistant varieties. Cucumber varieties may vary in susceptibility to diseases. Check with seed companies and local extension offices for information. Setting up variety trials to test how particular varieties perform locally is recommended.
- Increasing soil organic matter. This can increase soil microorganism activity, which lowers population densities of pathogenic soil-borne fungi.
- Use of clean planting material. This includes use of clean seed (see section 4.4) or "certified" seed that has been inspected for pathogens at all stages of production. Clean planting material includes healthy, disease-free transplants, also when bought from else where.
- Grow a healthy crop: A vigorous but balanced plant growth is the key! Fertilizer and water management are important factors. Some examples are:
  - ⇒ Proper fertilizer use. Using too much fertilizer may result in salt damage to roots, opening the way for secondary infections. Balanced irrigation and fertilizer application is also important. The succulent growth of plants given too much water and nitrogen encourages certain pathogens. On the other hand, stressed plants, especially those low in potassium and calcium, are more vulnerable to diseases.
  - ⇒ Proper water management. The most important practice is providing drainage to keep soil around roots from becoming waterlogged to prevent rotting. It is also important that foliage stay dry. Infectious material or inoculum of water-borne pathogens spread from infected to healthy leaves by water droplets or air borne parthogens. Inoculum needs water to germinate and enter the leaf (see section 9 for water management).
- Practice good sanitation. Removal and proper disposal of infected plants or plant parts help prevent the spread of pathogens to healthy plants. Crop left-overs can be used to make compost. If temperatures during composting rise high enough and are uniformly achieved in the pile by mixing, most pathogens are destroyed. Sanitation also includes weed control and, in some cases, insect control because many pathogens persist in weed hosts or are spread by insects.
- Practice crop rotation. Rotate crops to disease-free fields to avoid build-up of pathogens in the field. Rotation to an entirely different plant family is most effective against diseases that attack only one crop. However, some pathogens, such as those causing wilts and root rots, attack many families and in this case rotation is unlikely to reduce disease.
- Use of biological control agents. Good results have been obtained with use *Trichoderma* sp. for control of soil-borne diseases, including damping-off.

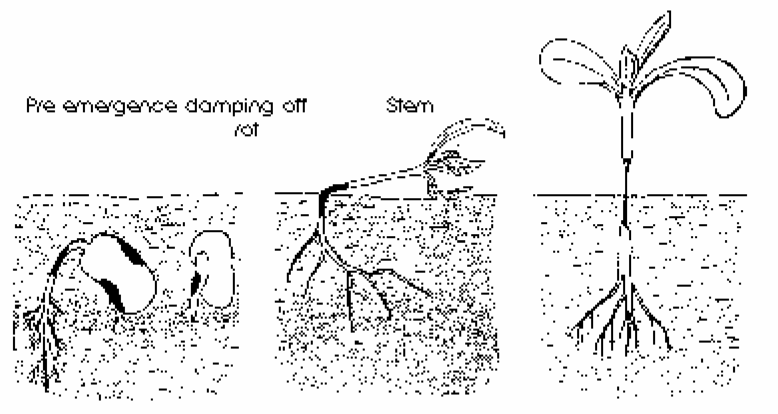
12.1. Damping off - *Fusarium*, *Rhizoctonia*, *Pythium*, *Phytophthora* sp.

(See Plate 3 Figure 1 Page 81)

Causal agent: Fungi - *Fusarium, Rhizoctonia, Pythium* and *Phytophthora sp*.

Photographs by Tom Isakeit

There are many soil-dwelling fungi, including *Fusarium, Rhizoctonia, Pythium and Phytophthora* sp*.* These soil-dwelling fungi infect vegetables, especially legumes, crucifers and solanaceous crops. Species of *Pythium* are more common than the others. If the infection occurs either before (pre-emergence) or just after emergence (post-emergence), and development of a spot (lesion) at the soil line results in collapse and shriveling of the plant, the disease is called 'damping-off'.



(from Kerruish, 1994)

Signs and symptoms

The root rots caused by these pathogens typically have similar symptoms. In seedlings, a watery rot develops in the taproot and hypocotyl at or near the soil line. Damping-off or a slower decline may occur when seedling death is preceded by cotyledon and leaf chlorosis. Mature plants show symptoms of root and crown rot. Initially, feeder roots are depleted. Soon after, brown lesions, 0.3-2.0 cm long, develop on lateral roots. Roots may have one or several lesions. Subsequent infections occur on the taproot or in the hypocotyl area. As the severity and size of the lesions increase, the plants may show varying degrees of stress. The crown leaves often become chlorotic. Necrosis soon follows, as the symptoms gradually move outward, toward the runner tips.

Sudden wilt is another symptom, healthy-appearing plants suddenly collapse during the heat of the day. Although some plants recover turgidity at night, wilting recurs the next day, and the plants die in 2-4 days. The onset and severity of sudden wilt vary from field to field, but the suddeness of collapse is directly proportional to the degree and speed of root infection.

Source and spread

The fungi are natural soil inhabitants but when circumstances are favorable and when susceptible host plants are present, the population can increase to damaging levels. It is difficult to predict when that will occur. Population increase depends on temperature and humidity and also on the population of micro-organisms in the soil. Sometimes, there are micro-organisms called antagonists that serve as natural enemies of the pathogens. They can keep the population of the pathogen under control. This can occur especially when the soil contains a lot of organic material such as compost.

Infection occurs through wounds or natural openings but *Pythium* can also actively penetrate the tender tissue near root tips.

In case of *Pythium* infection, dying seedlings contain the spore-carrying structures of the fungus. The spores can drop to the soil, and attack seed or young seedling roots, or be carried by wind or spread to another location by surface water or irrigation water. *Pythium* can be transported in soil attached to seedling roots during transplanting. *Pythium* can form thick-walled spores called *oospores* that can survive during adverse conditions and persist for several years in the soil

Role of environmental factors

Damping-off occurs in areas with poor drainage or areas with a previous history of the disease. Damping-off is often associated with high humidity and high temperature. The temperature range in which these fungi can live is quite broad, from about 12 to 35^{o}C with an optimum (the temperature at which damping-off develops fastest) of 32^{o}C. That is why you can find damping-off disease both in highlands with a temperate climate and in (sub) tropical lowlands.

Several species of *Pythium* and at least one species of *Phytophthora* are involved in cucurbit root rot. Among the *Pythium* species, at least one, *P. ultimum*, is a low-temperature pathogen while *P. aphanidermatum* and *P. myriotylum* require higher temperatures (32-37^{o}C) for pathogenicity. *P. ultimum* also differs from the other *Pythium* spp. in that its sporangia germinate directly, while *P. aphanidermatum*, *P. myriotylum* and *P. irregular* produce spores.

Importance - plant compensation

Damping-off and root rot of cucurbits have been reported in production areas in the United States, Israel, Iran, Canada, and China. These diseases have been observed in melon, summer squash, cucumber, watermelon, pumpkin, and winter squash. Cucurbit damping-off and seedling root rot have been ascribed to several *Pythium* spp., including *P. ultimum*, *P. aphanidermatum*, *P. irregulare* and *P. myriotylum*. *Phytophthora drechsleri. P. ultimum, P. aphanidermatum,* and *P. myriotylum* have also been shown to cause root rot of mature plants, resulting in decline or rapid wilting. *Phytophthora* *drechsleri* has been reported to cause severe root rot and rapid plant collapse in Iran and China and in California.

Natural enemies/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 fluorescens, 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.

Damping-off 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 antibiotics that reduce pathogen survival and growth. An active population of micro-organisms in the soil or compost out competes pathogens and will often prevent disease. Researchers have found that compost of almost any source can already reduce damping-off disease. The effect of compost on plant pathogens can be increased by adding antagonists such as the fungi,*Trichoderma* and *Gliocladium* species. Such compost is called fortified compost.

Management and control practices

Prevention activities:

- Chances of disease incidence will be reduced if fields are <u>deeply plowed</u> at least 30 days before planting to allow time for old crop and weed residues to decompose.
- <u>Remove and destroy crop left-overs</u> as these may contain spores of damping-off fungi and other pathogens.
- Control of root rot can be achieved by planting on raised beds to allow for maximum water drainage after each irrigation. Irrigation should not cause beds to be wetted inward beyond the plant canopy. If symptoms of root rot are evident, short irrigation of alternative furrows is adequate to maintain plant vigor.
- Do not apply high doses of <u>nitrogen</u>. This may result in weaker seedlings which are more susceptible to damping-off. Usually, when organic material has been incorporated in the soil before sowing, there is no need to apply additional fertilizer.
- <u>Crop rotation</u>: If you are raising cucurbit crops every season, use fresh soil that has not been used for cucumber or other cucurbit crops for at least two years. Plant another crop (not a cucurbits or solanaceous crop) in the 'old' cucumber nursery.
- Use <u>vigorous seed or seedlings</u>. Slow emerging seedlings are most susceptible to diseases.
- Only if necessary, use seed that is <u>coated with a fungicide layer</u>.

- 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 brassica leaves, stems or plants that release isothiocyanates (ITC), is an effective method of suppressing soil-borne pathogens. Lime or fungicides, if necessary, can also be used to sterilize the soil.
- 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 to prevent damping off.
- An interesting option is the use of *fortified* compost. This compost contains the antagonistic fungus, *Trichoderma*. *Trichoderma* is added to the compost after the primary heating period of composting is complete. The *Trichoderma* fungus increases to high levels in the compost and when added to the soil, they are 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.

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, broccoli, and cauliflower) stems and leaves are incorporated into the soil 14-21 days before planting cucumber to prevent soil-borne diseases. Brassica stems and leaves have isothiocyanates (ITC) that helps to prevent the development of bacterial wilt cells as well as soil-borne fungi. Five kg brassica stems and leaves/m^2 cut into small pieces, incorporated into the soil and irrigated two weeks before transplanting crops will get higher suppression from soil-borne diseases. Soil incorporation of brassicas for three consecutive seasons will provide more effective suppression of soil-borne diseases such as bacterial wilt.

Another method is sowing brassica seeds directly in the fields with history of soil-borne diseases. Before flowering, plough the field incorporating the brassica into the soil and raise new beds. Keep fields unused for 14 days, and then grow solanaceous, legumes, or cucurbits crops. This method should be done continuously if acceptable.

Source: Workshop proceedings, Regional Workshop on Biofumigation for Soil-borne Disease Management in Tropical Vegetable Production, University of the Philippines Los Baños-ACIAR-CSIRO-Benguet State University, June 2005, La Trinidad, Benguet, Philippines.

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 the beds. It may slow down the spread of diseases 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 possibly as a control of

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 cucumber or cucurbits for at least two seasons.
- In some areas, fungicides are being used to control damping-off and results vary. In this guide fungicide use is NOT recommended for control of cucumber damping-off.

Points to remember about damping-off:

1. Damping-off is a serious nursery problem, caused by several soil-borne pathogens.
2. Damping-off occurs in areas with poor drainage or 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 disease problems.
4. 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 or transplanting.
5. Damping-off can be controlled by doing biofumigation.
6. Additional prevention and control can be obtained with use of the antagonistic fungi, *Trichoderma* sp.

12.2. Bacterial wilt – *Erwinia tracheiphilia*

(See Plate 3, Figures 3-4, Page 81)

Causal agent: Bacteria - *Erwinia tracheiphila* (E.F.Sm.) Holland

Photograph from University of Minnesota

Bacterial wilt is a serious threat to commercial melon and cucumber production in some parts of the world, including parts of North America. The disease is not as damaging to squash, pumpkin, and watermelon.

Signs and symptoms

The expression of bacterial wilt varies with different crop species. Cucumber and melon are severely affected by the disease. The disease is characterized by sudden wilting of the plant without leaf yellowing. Individual runners or whole plants wilt and die rapidly. Wilt symptoms appear first on individual leaves, but soon they affect lateral shoots and finally the entire plants. Sometimes initial leaf symptoms are associated with cucumber beetle chewing injury. Leaf tissue surrounding such an injury becomes dull green and wilts rapidly. A single inoculated leaf may wilt and die about 5 to 6 days after inoculation. Wilt of lateral shoots and plants can occur as early as two weeks after inoculation. The development of early symptoms occurs on young vigorous plants. Apparently, the larger the plant at inoculation, the longer the period of time between initial wilting and plant collapse. When older cucumber plants are inoculated, sometimes only one shoot wilts initially, although at fruiting, entire plants may collapse.

Source and spread

Cucumber beetle is a disease vector. The bacterial wilt organism apparently overwinters in cucumber beetles. Wilt appears on a low percentage of plants when beetles, present before cucurbit crops are established, are allowed to feed on test plants. Infections that occur on cucurbit plants before symptoms occur in the plant are attributed to bacteria from beetle feces rather than from beetle mouthparts. Bacteria are most prevalent in the mid-intestine and appear to multiply in the beetle.

Another source of primary inoculum could be an overwintering host infected with the bacterial wilt organism. If beetles feed on such plants, beetle mouthparts could become contaminated with the bacteria, and the bacteria is spread to other susceptible cucurbits when beetles feed. Although suggested, there is no evidence to indicate an overwintering host is an important source of inoculum for primary disease cycles.

Secondary cycles begin when beetles feed on newly infected plants with symptoms. Beetles apparently prefer to feed on plants with bacterial wilt symptoms than on healthy plants. When beetles feed on plant tissues containing the wilt bacteria, their mouthparts become contaminated; such beetles can inoculate several plants when they feed on successive plants, and they can remain infective for at least three weeks. Inoculation is accomplished by the striped cucumber beetle, *Acalymma vittata* Fabricius and the 12-spotted cucumber beetle. However, for *Diabrotica undecimpunctata howardi* Barber, wounds such as beetle-chewed areas are necessary for entrance of bacteria into the plants.

Another hypothesis is bacteria *E. tracheiphila* survives in many seasons in the field through weeds that serve as host crop. It can survive on plant residues for a short time only.

Role of environmental factors

Weather appears to have little effect on incidence of diseased plants, but may affect rate of wilting. Distinct wilting is associated with succulent plants that are growing rapidly. Some growers think bacterial wilt is most severe during wet weather and just after heavy rain, especially if the sun is bright. These weather conditions favor bacterial growth and movement within plants.

Environmental conditions at inoculation time appear to have little effect on disease severity. However, environmental conditions from inoculation through harvest may have a more significant effect.

Bacterial wilt is more severe with adequate to excessive levels of balanced nutrients than with deficient levels. It is promoted by low nitrogen and potassium levels in unbalanced nutrient situations.

Importance of plant compensation

Bacterial wilt is a serious threat to commercial melon and cucumber production in some parts of the world, including parts of North America. The disease is not as damaging to squash, pumpkin and watermelon.

Once present in the field, it is very difficult to control. Usually, plants will die quickly and no compensation occurs.

Natural enemies/antagonists

- The antagonist, *Trichoderma* species may be tried, preferably in combination with compost.
- Several other antagonistic micro-organisms have been studied against bacterial wilt, 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

Prevention activities:

- Control of bacterial wilt is extremely difficult because the pathogen can remain viable in the soil for many years. In some areas, soils cannot be used for cucurbit crops due to heavy bacterial wilt infection.
- Use resistant varieties.
- Use biofumigation method (see part 12.1).
- Select high field with good drainage for growing cucumber.
- Treat seeds by biological, physical or chemical methods (see section 4.4)
- Prevent occurrence of striped cucumber beetles or twelve-spotted cucumber beetles from damaging crops. Their development stages (egg, larvae and pupae) take place under ground, thus the most effective method is soil sterilization before transplanting.
- Pull out infected plants including roots and attached soil, remove them from the field and destroy them. This may reduce further spread of the bacteria.
- Crop rotation may be useful for soils with bacterial wilt. However, the wide host range of bacterial wilt includes all cucurbits which severely limit crops that can be used in rotations.

Once there is an infection in the field

- Kill the cucumber beetle vectors (see part 13.2).
- Rouging wilted plants and using trap crops have been suggested to slow the progress of the disease.
- A fallow period of several months, including weed control, was reported to be effective in some countries.
- 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 micro-climate in the soil, stimulating antagonistic micro-organisms. It may also have an effect on nutrient availability, “boosting” the crop through adverse conditions.
- Grafting: When soil is infested with bacterial or fungal wilt organisms, there is an option to graft cucumber seedlings on resistant rootstocks (usually cucurbit varieties). This means that initially both the rootstock and the cucumber seedlings are grown. When both seedlings are in the vegetative stage the stems of both the seedling and the rootstock are cut and the stem of the seedling is placed on the rootstock stem and tied together. The two will merge and continue to grow. In the process, the rootstock (resistant) is not affected by wilt diseases and the seedling will produce normal fruits.
- All available chemicals CAN NOT control bacterial wilt!

✍Points to remember about bacterial wilt:

1. Bacterial wilt is a serious soil-borne disease that can cause total loss of plants in large parts of a field.
2. Some general management practices such as crop rotation, use of resistant varieties, and sanitation of the field help to prevent and suppress bacterial wilt infection.
3. Interesting results have been obtained with adding organic matter such as compost into the soil. This is possibly due to stimulation of antagonistic fungi in the soil and better nutrition for the cucumber plants.
4. Chemical control of bacterial wilt is not effective.

12.3. Yellow wilt *Fusarium – Fusarium oxysporum*

Causal agents: Fungus - *Fusarium oxysporum* f.sp. *cucumerinum*

Photographs by Tom Isakeit

(See Plate 3, Figure 2, Page 81)

Fusarium wilt in cucurbits crops is caused by several different strains of the fungus *Fusarium oxysporum.* These are*: F. oxysporum f. sp. cucumerinum* (cucumber), *F. oxysporum f. sp. niveum* (watermelon). All of the *Fusarium* wilt pathogens are generally specific to their hosts. Many other crops or weeds can be colonized too. Cucurbits such as watermelon can be infected with the disease.

Signs and symptoms

Plants may be infected at any age by the fungi that cause *Fusarium* wilt and *Verticillium* wilt.

Symptoms of this disease are yellowing of the lower leaves. Yellowing of the leaves progresses upward from the base of the plant. Wilting or yellowing may occur on only one side of a leaf or a branch, or on one side of the plant. Often, the area between leaf veins turns yellow first, resulting in V-shaped areas. Yellow leaves wilt noticeably before they die. Separate shoots, and later entire plants, finally wilt permanently and die. In fields, the affected leaves may dry up before wilting is detected. Woody stem tissue often becomes brown in affected stems. This discoloration can be detected by cutting affected stems diagonally. The brown discoloration may extend into the roots and lower part of the stem.

Young plants appear normal, but become stunted as they develop. Often no symptoms are seen until the plant is bearing heavily or a dry period occurs. Wilting may occur at midday, when sunlight is bright and temperature is high. Infected plants may survive the season but are stunted and both yield and fruits may be small depending on severity of attack.

Source and spread

Fusarium wilt is caused by soil-borne fungi that can persist in the soil for many years. The fungi produce a very strong type of spores that can survive indefinitely in most fields. Survival is aided by weeds which are susceptible to the fungus. The fungus can be introduced and spread with soil that is attached to transplants. Within each cropping season, most disease originates from inoculum surviving from previous cropping seasons. Wilt disease can also be spread by seed. Long-distance dissemination probably occurs on seed.

When fungus spores germinate close to roots of a susceptible cucumber plant, the fungus penetrated the fine root hairs of the root system. Penetration is enhanced by root wounds. The fungus grows inside the root and eventually reaches the vessels. It may move slightly inside the plant vessels but is largely confined. In susceptible varieties the fungus moves through the vessels from the roots both to and through the stem. The vessels are blocked by the fungus and water cannot (or very limited) be transported from the roots to the leaves and above ground plant parts. These wilt as a result.

Role of environmental factors

Environmental conditions that affect disease development include temperature, moisture and soil pH. The optimum air and soil temperature for disease development is about 28^oC. No disease develops if the soil temperature is too cool (15^oC and below) or too warm (35^oC and above), though differences between the fungi species may be found. Generally, high temperatures favor *Fusarium* wilt. That is why in tropical lowland areas, usually *Fusarium* wilt is found.

When the soil temperature favors disease development, root infection can occur. Root infection can be extensive and the fungus grows up into the lower portion of the stem. If the air temperature is too cool for disease development, the plants grow well without external symptoms of the disease. Once the temperature rises, the wilting process may develop quickly.

Importance of plant compensation and physiological impact

The wilt fungi usually enter the plant through young roots and then grow into and up the water transporting vessels of the roots and stem. As the vessels are plugged and collapse, the water supply to the leaves is blocked. With a limited water supply, leaves begin to wilt on sunny days and recover at night. Wilting may first appear in the top of the plant or in the lower leaves. The process may continue until the entire plant is wilted, stunted, or dead. Plants may recover somewhat but are usually weak, and produce fruit of low quality.

When disease development is stopped or inhibited due to unfavorable environmental conditions (e.g. when temperature is below 17^oC or when the soil is very dry) the plant may form additional shoots to compensate for some of the wilted shoots. However, the conditions unfavorable for the disease are usually also unfavorable for vigorous plant development. Once infected, the plant usually cannot recover completely.

Natural enemies and antagonists

When it comes to biocontrol, different fungi usually have different antagonists (natural enemies). Most antagonistic fungi are very specific in host selection. However, the antagonist, *Trichoderma* sp has given good results in the control of many soil-borne pathogens, including *Fusarium*. *Trichoderma* is available commercially or from extension agencies in many countries in Asia.

Fusarium can be controlled by a non-pathogenic strain of *Fusarium oxysporum*. See box below.

Control of Fusarium by Fusarium…..! Family feud at micro level!

There are many strains of *Fusarium oxysporum* fungi that cause wilting of plants. A specific strain of *Fusarium oxysporum* is actually highly effective at controlling *Fusarium* wilt of tomato and other crops. They work as antagonists against their own “family members”! These isolates consistently provide 50-80% reduction of disease incidence in repeated greenhouse tests. They work against the pathogenic strain by “blocking the entry” so the pathogen cannot enter the plant.

Commercial products such as “Biofox C” and “Fusaclean” are now available in the USA containing the non-pathogenic *Fusarium oxysporum*. The product is used as seed treatment (dust formulation) or incorporated into the soil (granule formulation).

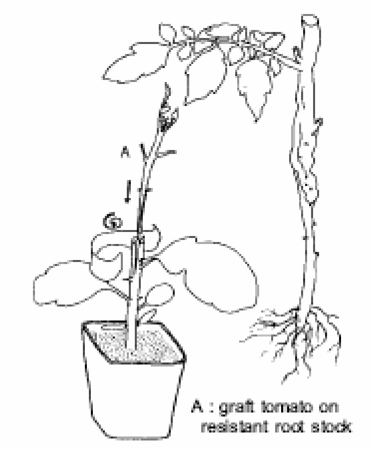
For details on commercial biocontrol products check "The BioPesticide Manual" (Copping, 1998) or several internet sites such as www25, www29 (see reference list).

There are several other antagonistic organisms that control *Fusarium* and/or *Verticillium*, such *as Bacillus subtilis, Burkholderia cepacia, and Streptomyces griseoviridis.* Different strains of these antagonistic organisms have been registered as biocontrol products to control fungal wilt and some other (soil-borne) plant diseases in the United States (www25, www29).

Management and control practices

Prevention activities:

- Using resistant varieties is the best prevention of wilt disease. There are many resistant varieties of cucumber available.
- Grafting: Where soils are infested with fungal wilt organisms, there is an option to graft cucumber seedlings on resistant rootstock (can be wild eggplant varieties). This means that initially both the rootstock and the eggplant seedlings are grown. When they reach a certain vegetative stage, the stems of both the seedling and the rootstock are cut and the stem of the seedling is placed on the rootstock stem and tied together. The two will merge and continue to grow. In the process, the rootstock (resistant) is not affected by wilt diseases and the seedling will produce normal fruits.



Grafting
(from Messiaen, C.M., 1992)

- Locally produced seeds should be used only from plants free of any signs of wilt disease. Locally produced seeds should be subjected to hot-water treatment or coated with a fungicide or an antagonistic fungus (when available).
- Healthy planting material: Seedlings that are suspected of having wilt disease (or any other diseases) should not be transplanted into the main field.
- Use biofumigation method (see part 12.1)
- Maintain a high level of plant vigor with appropriate fertilization (not too much nitrogen should be applied) and irrigation.
- Plant in well-drained soil.
- Keep rotational crops weed-free (many weeds are hosts of *Fusarium*).
- Where available, preventive application of *Trichoderma* sp. may be tested. This may be only economic in fields with a history of soil-borne diseases.

Once there is an infection in the field

- Infected plants should be removed carefully and burned or composted outside the field. The soil, from which the plants were pulled, however, is still infected.

Removal of infected plants will at least reduce the increase of the fungal population. After the final harvest, remove and destroy all infested plant material including the roots.

- Wilt disease is increased by cultivation of the land, such as weeding. This is possibly because of root disturbance and increased root damage which form entry points for the fungus.
- Application of biocontrol products such as *Trichoderma* sp. or others, where available, may be a good option for control of soil-borne pathogens. See section on antagonists above.
- Soil pH of about 7 seems to be optimal to suppress this disease. Liming can increase the pH of the soil.
- Long-term rotation: Wilt disease is controlled (or reduced) by long term rotations with non-related crops that are not susceptible to wilt. A long crop rotation period of about 4 to 6 years is necessary to reduce population of *Fusarium* because they are widespread and persist for several years in the soil. Avoid planting any cucurbits (watermelon, melon) in the rotation, and if *Verticillium* wilt is also a problem. Avoid planting highly susceptible crops such as strawberries and raspberries. Rotate with cereals and grasses wherever possible. A 3 or 4 year rotation is usually sufficient to reduce disease incidence although special fungus spores (so called *microsclerotia*) persist in the soil for 10 years or more. Reducing root lesion by nematodes helps control wilt because the wilt fungi often infect nematode-damaged root systems.
- If soils are severely infested, production of cucurbits may not be possible. Soil solarization and use of plastic mulch are other options described for control. However, soil disinfection is very difficult because the soil can be infested to at least 90 cm depth!

Points to remember about fungal wilt:

1. *Fusarium* wilt is caused by soil-borne fungi that can persist in the soil for many years.
2. Use of resistant varieties, where available, is probably the best prevention.
3. Use biofumigation method.
4. Several antagonistic organisms are available as biocontrol agents for control of fungal wilt but not all of these may be available in Asia. *Trichoderma* sp. may be tried as a preventive measure.

12.4. Downy mildew – *Pseudoperonospora cubensis*

Causal agent: Fungus - *Pseudoperonospora cubensis* (Berk. & Curt.) Rostow

Photograph by GJHolmes

Signs and symptoms

Downy mildew symptoms in cucurbits are almost exclusively confined to the leaves, although there are rare reports of sporulation on melon fruits and on floral parts. The appearance of leaf lesions varies considerably, both between and within species of cucurbit crops.

On most cucurbits, symptoms of downy mildew are first evident as small, slightly chlorotic to bright yellow areas on the upper leaf surface. The color is less vivid on the corresponding lower leaf surface. Lesions appear first on the older crown leaves and appear progressively on the younger, more distal leaves as these leaves expand. As the lesions expand, they may remain chlorotic or yellow or become necrotic and brown. Lesion margins are irregular on most cucurbits, but on cucumber they are angular and bound by leaf veins. When conditions favor sporulation, the production of sporangia on the lower leaf surface gives the undersides of lesions a downy appearance, which may vary from colorless to light gray to deep purple, depending on the intensity of sporulation. On cultivars with even minor levels of resistance, infected leaf areas die after one cycle of sporulation, but on highly susceptible cultivars these infected area may remain chlorotic or yellow while supporting multiple sporulation cycles. As lesions expand, they often coalesce, resulting in the necrosis of progressively larger leaf areas, so that in a few days the entire leaf is dead. Death of the leaves exposes the fruit to sunscald, which results in reduction in both quality and quantity of marketable yield.

Source and spread

The fungus is an obligate parasite. Its season-to-season survival is dependent on the presence of cucurbit hosts either in the areas with climates which permit their growth throughout the year or on cucurbit crops in greenhouses or other protected cultures. In some areas of the world where cucurbits are grown extensively in greenhouses during the cold season of the year, such culture may serve as an important source of primary inoculum for crops in the field. However, in the United States and many other countries, there is little production of cucurbit crops under protected conditions during the cold months. Therefore, the source of primary inoculum in these areas is considered to be windblown sporangia from infected cucurbits in places where these plants survive the cold season.

Airborne sporangia from either nearby or very distant infected cucurbits serve as primary inoculum. Sporangia also serve as secondary inoculum. Spread of secondary inoculum within a field is usually by air currents, but it may also be dispersed by rain splash or by contact with workers or tools. The incubation period is 4-12 days. The length of incubation depends on temperature and photoperiod.

Production of oospores is extremely rare and their germination has not been reported, thus, their possible importance in the disease cycle is unknown. They could serve as survival structures during periods when living hosts are not present, but this has not been demonstrated.

Role of environmental factors

Temperature and humidity are important factors for disease infection and development. A period of at least six hours of 100% relative humidity at the leaf surface and temperatures from 5-30 ^{o}C are required for the production of sporangia. Optimum production is obtained at 15-20^{o}C. When the surrounding air dries, sporangia are dispersed primarily by air currents. Both relative humidity and temperature affect their survival. Retention of germination ability for up to 16 days has been reported for detached sporangia on glass slides at temperatures of 17-21^{o}C and relative humidities from 38 to 71%. Sporangia require free moisture for germination, which can occur in as little as one hour at 20^{o}C. Depending on the temperature, released zoospores retain motility in water for ten minutes to 18 hours, with higher temperatures inducing more rapid encystment. Zoospores must encyst on stomates for infection to occur. The germination of cysts is optimum at 25^{o}C. With very high inoculum levels, such successful penetrations occur when free moisture is present for as little as two hours. Once the germ tube has penetrated the substomatal chamber, the presence of free moisture is not required for the infection process to proceed. Haustorium formation requires about four hours. With an 18-hour photoperiod, successful infection can result in sporangial production in four days at night temperatures of 15^{o}C and day temperatures of 25^{o}C.

Most mature sporangia are released into the air between 6AM and 12 noon, with a maximum concentration detectable about 8 AM. Infectivity of sporangia decreases when relative humidity and temperature are high after dispersal. The sporangia survive better at temperatures of 5-16.5ºC than at 24-30ºC. Once wet, the sporangia must remain wet until they germinate; otherwise, they die.

Importance of plant compensation

Downy mildew is one of the most important foliar diseases of cucurbits. It has been reported worldwide in production areas where humidity and temperature favor its establishment. The disease occurs in temperate and tropical areas with either high or low rainfall as long as sufficient leaf wetness periods are provided, usually by dew.

The disease damages leaves directly while fruits are seldom affected directly as poor flavor and be somewhat dwarfed, giving low yield. Without adequate control measures, it can result in major losses to cucumber and other cucurbits in open fields as well as in greenhouses and other types of protected culture.

Natural enemies and antagonists

The fungus *Ampelomyces quisqualis* was found to have high resistant ability and can be used to control *Pseudoperonospora cubensis*. *Ampelomyces quisqualis*, however, causes some effects on the crop.

Management and control practices

Prevention activities:

- Some varietal resistance/tolerance against downy mildew has been reported. Resistance in cucumber is expressed as a restriction of fungal growth and prevention of sporangia formation. However, the resistance may not be complete or may be overcome easily by the fungus. To date, developing late blight-resistant varieties is still a struggle. When varieties with some degree of tolerance are available, it would be advisable to set up a trial plot comparing these varieties against the locally used varieties. Check disease incidence, fruit quality and yield.
- Using healthy planting material is another important prevention activity. When transplants have suspected leafspots or brown leaves, destroy them. Otherwise, you may risk introducing the disease into the field!
- Cultural practices that reduce downy mildew incidence and severity include maximizing the distance from potential sources of inoculum, using plant spacing that reduces canopy density and avoiding overhead irrigation that can lengthen the duration of leaf wetness periods. When possible in greenhouse or other protected cultures, management practices should be used to reduce the relative humidity as well as the presence of free moisture on the leaves.
- Use of bed culture, wide spacing between plants, and planting sites with good drainage, air movement, and exposure to sunlight should help check disease development by promoting good aeration and rapid drying of plant surfaces.
- Elimination of sources of infection (sanitation) is the most important but also most difficult prevention activity as it should involve many farmers in an area. Spores can spread over long distances with the wind! Sanitation may include destroying cucumber cull piles, removing all cucumber plant left-overs from the field and planting cucumber as far as possible from cucumber or other cucurbits fields. Do not place infected plant left-overs on the compost pile unless covered with a thick layer of other materials. Spores may still spread from the compost pile when left open on top. Also when removing infected plant parts, make sure to put them in a polyethylene bag because moving infected material also helps spread the fungus!

Once there is an infection in the field

- The principal control measures include fungicide application, use of resistant cultivars, and cultural practices. Maximum control is usually obtained only with a combination of these measures. Both protectant and systemic fungicides effective in controlling downy mildew on cucurbit crops are available. However, the efficacy of protectant fungicides is reduced when host plants are highly susceptible, inoculum levels are high, and meteorological conditions are very favorable for epiphytotic development. Also strains of the pathogen have developed tolerance for one systemic compound.

- <u>Disease-forecasting programs</u> have been developed to predict the rate of disease development based on weather patterns. Such programs could enable farmers to better time their fungicide applications but the success of forecasting programs varies.

Points to remember about downy mildew:

1. Downy mildew is one of the most important foliar diseases of cucurbits.
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 downy mildew infection occurs and environmental conditions are favorable for its spread, the disease is hard to control just by sanitation. Fungicide application may be needed. However, the timing and number of fungicide application can be changed by studying the disease in the field.

12.5 Powdery mildew - *Erysiphe cichoracearum* DC

(See Plate 4, Figure 5, Page 82)

Causal agent: Fungus - *Erysiphe cichoracearum* and *Sphaerotheca fuliginea*

Photographs from National Research Council Canada and the Bugwood Network

Signs and symptoms

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. Fruit infection occurs rarely in watermelon and cucumber.

Source and spread

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

Erysiphe cichoracearum is an obligate parasite which can survive on wild 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 cichoracearum* has broad host ranges, non-cucurbit 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 symptom appearance is usually only 3-7 days. A large number of spores can be produced during this time. Favorable conditions include dense plant growth and low-intensity light. High relative humidity is favorable for infection and conidial survival; however, infection can occur at relative humidities below 50%. Dry conditions favor colonization, sporulation and dispersal.

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

Importance of plant compensation

Powdery mildew has been recognized since the 1880s under field and greenhouse conditions in most areas of the world. This disease is a major production problem. All cucurbits are susceptible; however, symptoms are less common on commercial cucumbers because many cultivars are resistant. Mildew reduces yields by decreasing the size or number of fruit or the length of time crops can be harvested. Fruit quality can be reduced significantly.

Natural enemies and antagonists

Unknown

Management and control practices

Prevention activities:

- Use resistant cultivars.
- Use of sites with good air drainage and low humidity and where ditch irrigation is used.
- Destruction of weeds belonging to the cucurbit family is helpful to prevent disease infection to healthy crops.
- Pruning diseased leaves to prevent disease spread to other leaves

Once there is an infection in the field

- Use fungicides to prevent disease spread to healthy crops. Fungicides such as benomyl, capable of some systemic movement, are considered beneficial when it is difficult to get good coverage of lower leaf surfaces and foliage below the top leaves. In the absence of systemic movement, thorough coverage of lower leaf surfaces is important. In some areas, solution of lime sulfur and copper fungicides are used to control powdery mildew.

Points to remember about powdery mildew:

1. Powdery mildew is one of the most important diseases of cucurbits.
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 just by sanitation. Fungicide application may be needed. However, the timing and number of fungicide application can be changed by studying the disease in the field.

12.6. Target Leaf Spot - *Corynespora cassiicola*

(See Plate 4, Figure 6, Page 82)

Causal agent: Fungus - *Corynespora cassiicola*

Photographs from AVRDC

Signs and symptoms

The disease is known to be most damaging to cucumber and cantaloupe but may occur on other cucurbits. Lesions on leaves begin as small water soaked spots, delimited by small veins, but soon enlarge to form large circular, sometimes zonate spot that range from tan to dark brown in color. As the spots increase in size or number, the whole leaf turns yellow and dies.

The disease often does not damage fruits directly but through wounds or insect-vectors, etc. For young fruits, disease fungus may enter inside fruits through sun burnt wounds or wilting fruits.

Source and spread

Mycelium and spores can survive on plant debris for six months. Chlamydospores and sclerotia occur on plant debris but their role is unknown. The period from inoculation to appearance of symptoms is about six or seven days, depending on the susceptibility of the plant part.

The spores can be spread by wind and by splashing rain.

Disease fungus survives on plant debris, weeds and other crops. It has different host crops.

Role of environmental factors

Long rain and high temperatures of 25-37ºC are favorable conditions for disease development. Fluctuating day and night temperatures, combined with long days seem to favor disease development.

Disease develops well under wet conditions due to long rain and poor field drainage.

Disease causes severe damage in greenhouse cultivation.

Natural enemies and antagonists
Unknown

Management and control practices

Prevention activities:

- Using healthy seeds and disease-free plant materials is a major method to prevent target leaf spot. Use seeds from disease-free plants only. Growers should apply all methods to treat seeds well. Seeds that are stored for three years may be free of fungus. Sometimes fungus-infected seeds can be treated well in the dry areas where target leaf spot does not occur. Many seed treating methods are reportedly effective, including dipping in hot water or salt solution. Other methods can be applied also, such as letting seeds germinate in the laboratory and evaluating its disease infection level.
- Location: Select field with good drainage to be sure that there is no water running from fields with cucurbit residues.
- Crop rotation: Cucumber should be rotated with plants other than cucurbits in a schedule of at least one, preferably two, years. This will help eliminate hosts for bacteria. In sub-tropical areas, bacteria may not exist in the soil, so it is not necessary to do crop rotation.
- Resistant and tolerant varieties against target leaf spot may be available. However, resistance may not be sustainable in all growing areas. It would be advisable to test some varieties to check the resistance against angular leaf spot under local conditions.
- Crop remains should be removed and destroyed immediately after harvest. Make a compost pile and cover it with a layer of soil. Do not use this compost on cucumber or any susceptible cucurbit crops unless it is completely decomposed. Infected crop left-overs are a very important source of new infection!

Once there is an infection in the field

- Fungicides can reduce disease infection. Some copper fungicides or organic fungicides, such as Mancozeb were used to control this disease. The use of fungicides depends on the time of disease occurence and its spread speed.

Pruning infected leaves and destroying them outside the fields, sometimes helps to reduce disease infection. Fungicides often should be applied before the disease is observed because fungicides create a protection layer on the leaves, preventing spores from germinating. New leaves are produced regularly and rain may wash off fungicides thus, fungicides should be applied often, but the frequency depends on the disease level, crop growth development stage and weather conditions. Sometimes, fungicide spraying interval is 7 days if it is cool and humid, 10 days if it is dry. Regular field visit is very important to decide pesticide spraying time! Experiments can be conducted to test target leaf spot disease level and effectiveness of calendar spraying. One example of experiment is to spray at different times with certain disease level.

- Disease-forecasting programs have been developed to predict the rate of disease development based on weather patterns. Such programs could enable farmers to better time their fungicide applications but the success of forecasting programs varies.

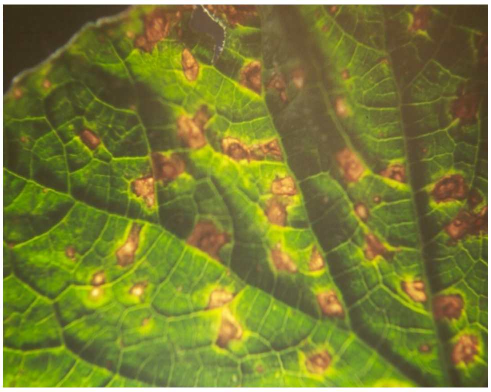
Points to remember about target leaf spot:

1. Target leaf spot is a serious disease that can cause death of plants and it does not cause severe loss of fruits.
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 target leaf spot infection occurs and environmental conditions are favorable for its spread, the disease is hard to control just by sanitation. Fungicide application may be needed. However, the timing and number of fungicides applications can be changed by studying the disease in the field.

12.7. Angular leaf spot - *Pseudomonas syringae pv. lachrymans*

(See Plate 4, Figure 7, Page 82)

Causal agent: Bacteria - *Pseudomonas syringae* pv. *lachrymans*



Photographs from Washington State University

Signs and symptoms

Symptoms on cucumber appear on leaves, stems, blossoms, and fruit. Spots on the foliage are variable in size and angular due to leaf veins that limit spot enlargement. Initially, spots are water soaked. In moist conditions, bacteria ooze from spots in tear-like droplets which dry to a white residue. Water-soaked spots later turn gray and die. As affected leaf tissue dries and shrinks, it may tear away from the healthy portion, leaving large irregular holes in affected leaves. Leaves approaching maturity are more susceptible than older leaves. Pistillate blossoms and very young fruits may drop from vines when infected. Fruit spots are smaller than leaf spots and are nearly circular. When the disease portion dies, the tissue becomes white to tan and may crack. Fruit lesions usually are superficial however, deep rots can results from infection by the leaf-spot bacterium and by secondary soft-rot bacteria which are able to enter the fruit through the injured epidermis. Fruit symptoms can develop during transit.

Source and spread

The bacteria can overwinter in association with seed. In some areas, the bacteria can survive one winter or possibly for two years in soil or debris from diseased plants.

The bacteria can be spread in drainage water. During rains, they can be splashed from infected seedlings, soil, or debris to plants. Before infection, the bacteria appear to be adsorbed by the leaf where most cells cannot be washed off and where they can remain viable at least six days without active growth. They are able to colonize buds on cucumber plants and have been shown to persist there for 19 days.

Once symptoms appear and the bacteria are abundant on plants, the bacteria are transferred readily on hands, clothing, tools, equipment, and harvest containers used by workers.

Infected fruit may be symptomless at harvest. During storage and transit, symptoms can develop. When infected cucumbers are saved for seed, the seed can become contaminated with bacteria during the fermentation process used when extracting the seeds.

Importance of plant compensation

Angular leaf spot occurs in all continents. Economic loss is variable. In nature, the disease appears on cucumber, gherkin, muskmelon, pumpkin, squash, and watermelon.

Role of environmental factors

Moisture is the environmental factor that is most limiting to disease development. Angular leaf spot is promoted by wet conditions, frequently associated with rainfall and sprinkler irrigation. Infection is promoted by water congestion of leaves, a condition associated with extended periods of rainfall and high relative humidity. After infection, these same conditions favor enlargement of spots. A relative humidity of at least 95% is necessary for characteristic angular lesions to develop on leaves. Two weeks of dry weather arrests disease development. Disease develops over a wide temperature range, but is favored by 24ºC to 28ºC. A high temperature of 37ºC for five days does not arrest disease development. Excessive nitrogen levels result in increased levels of disease.

Natural enemies and antagonists
Unknown

Management and control practices

Prevention activities:

- Using healthy seeds and disease-free plant materials is a major method to prevent target leaf spot. Use seeds from disease-free plants only. Growers should apply all methods to treat seeds well. Seeds that are stored for three years may be free of fungus. Sometimes fungus-infected seeds can be treated well in the dry areas where target leaf spot does not occur. Many seed treating methods are reported effective such as dipping in hot water, salt solution, etc. Other methods can be applied too, such as letting seeds germinate in the laboratory and evaluating its disease infection level.
- Location: select field with good drainage to be sure that there is no water running from fields with cucurbit residues.
- Crop rotation: Cucumber should be rotated with plants other than cucurbit crops in a schedule of at least one, preferably two, years. It would help to eliminate hosts for bacteria. In sub-tropical areas, bacteria may not exist in the soil, so it is not necessary to do crop rotation.
- Resistant and tolerant varieties against angular leaf spot may be available. However, the resistance may not be sustainable in all growing areas. It would be advisable to test some varieties to check the resistance against angular leaf spot under local conditions.
- Crop remains should be removed and destroyed immediately after harvest. Make a compost pile and cover it with a layer of soil. Do not use this compost on cucumber or any susceptible cucurbit crops unless it is completely decomposed. Infected crop left-overs are a very important source of new infection!
- Infection rate can be reduced by maintaining good plant vigor and minimizing injury to plants. Plant vigor is influenced by several factors including adequate fertilization and proper moisture contents of the soil during transplanting and growing. Increase the organic matter in the soil as much as possible, especially by using well decomposed manure and do not apply too much nitrogen. This will increase fertility. The use of nitrogen fixing legumes in the crop rotation scheme can also increase the fertility of the soil and eliminate some of the inoculum.
- Disease spread from leaves to fruits may be suppressed by harvesting fruits when leaves are not wet.

Once there is an infection in the field

- Disease-forecasting programs have been developed to predict the rate of disease development based on weather patterns. Such programs could enable farmers to better time their fungicide applications but the success of forecasting programs varies.

Points to remember about angular leaf spot:

1. Angular leaf spot is a serious disease that can cause death of plants and severe loss of fruits.
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 bacteria. However, too much pruning results in lower yields.
4. Once angular leaf spot infection occurs and environmental conditions are favorable for its spread, the disease is hard to control just by sanitation. Fungicide application may be needed. However, the timing and number of fungicide applications can be changed by studying the disease in the field.

12.8. Curly top virus

(See Plate 4, Figure 8, Page 82)

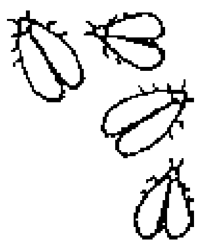
Causal agent: Curly top virus

Cucumber curly top virus occurs in all cucumber growing areas worldwide, even it appears more in tropical areas. The disease has been identified for more than 80 years but it is still considered as the most serious virus disease in cucurbits. It causes the most severe damage for all cucumber growing areas worldwide.

Signs and symptoms

Infected plants may be stunted, with rather erect, rigid leaves. The leaves remain small and leaflets are rather spoon-shaped, rolled or curled. Leaves have a yellow color between the veins. Symptoms appear especially on young leaves on the top of the plant. Plants may be excessively branched.

Source and spread



The curly top virus is spread by aphids and whitefly (*Bemisia tabaci*). Transmission of this virus is quick. When the whitefly starts feeding on a cucumber plant, the virus is transmitted within a few minutes.

Trials have shown that there is a direct relation between the population of whiteflies and infection rate; the more whiteflies there are in the field, the more infection with leaf curl may occur. The virus is not transmitted mechanically.

Much of the initial infection may occur already in the nursery. Plants infected in the nursery become sources of virus which greatly favor disease spread within the crop after transplanting.

Role of environmental factors

Infection follows whitefly population; the larger the whitefly population is, the more problems there are with curly top virus disease. In Vietnam for example, curly top virus is most severe from October to November and March to April, especially when it is warm and sunny and there is not so much rain.

Importance of plant compensation and physiological impact

The effect on fruit-setting and consequent yield is particularly severe if infection occurs just before and during flowering. Yield losses of over 50% have been reported in certain cucumber-growing areas.

Natural enemies and antagonists

Unknown.

Management and control practices

Prevention activities:

- Use resistant varieties against curly top virus.
- Controlling the aphids, striped cucumber beetles and whitefly is an important prevention measure against curly top virus. See section 13.5 on whitefly prevention and control methods.
- Calendar spraying of mineral oil weekly from germination until flowering stage, helps prevent disease infection. In addition, mineral oil can also control vectors such as aphids or white fly.
- Barrier crops such as sunflower, sesame and sorghum may reduce leaf curl virus infestation in cucumber. The barrier crop should be sown around the main fields at least two months before transplanting cucumber seedlings in the fields.
- Proper sanitation practices help reduce the source of virus infection. This includes removal of crop residues and weeds. Curly top virus in cucumber also affects weeds such as *Vernonia cinneria* and Synedrella *nodiflora*.

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.
- Note: there are no pesticides that prevent or cure virus diseases!

Sanitation: remove plant parts….to where?

☺ It was noted that some farmers practice field sanitation very properly by removing all crop residues from the field after the final harvest.

However, after collecting all plant left-overs they threw them to the field borders. From there, spores of many fungi can easily infect the next crop or a neighboring crop. ☹

- Take crop left-overs away from the main field for destruction, decomposing or as food for farm animals. When placed on a compost pile, cover the plant material with a layer of soil or straw. Wind-borne diseases such as late blight can still infect the field from a compost pile!

Points to remember about curly top virus disease:

1. Curly top virus disease, caused by a virus, can cause yield reduction when infection occurs just before or during flowering.
2. Curly top virus disease is transmitted by aphids, striped cucumber beetles and whiteflies.
3. Control of whitefly is an important prevention and control practice (see section 13.5)
4. Removing and destroying all virus-infected plant material (including weeds) helps to reduce the source of virus infection.
5. Pesticides cannot prevent or cure virus diseases!

12.9. Gummy stem blight - *Didymella bryoniae*

(See Plate 4, Figure 9, Page 82)

Causal agent: Fungus --*Didymella bryoniae*

Photographs by NC State University and Tom Isakeit

Signs and symptoms

This disease is particularly damaging to stems and foliage of cucumber, cantaloupe, and watermelon. It causes fruit rot known as black rot on many cucurbits. Seedlings may die following infection of hypocotyls or cotyledons. On older plants, leaf symptoms appear as circular, tan to dark brown lesions on which numerous black fruiting bodies may occur. Stem lesions begin as elongated watersoaked spots that frequently exude an amber colored gummy substance and later dry and crack open. The stem is frequently girdled resulting in death of the vine beyond this point.

If disease appears on older plants, wounds develop slowly on climbing stems at the middle of rows. Disease-infected climbing stems are often wilted at the second half of season.

Source and spread

The gummy stem blight fungus is both seed-borne and soil-borne. Both serve as primary sources of inoculum for disease cycles. Artificial inoculation of watermelon seed has shown that within 12 hours the fungus can infect a seed deeply enough to preclude eradication of the fungus by a 4-minute soak in a 5.25% sodium hypochlorite solution. Comparable seed infection is possible during the seed extraction fermentation process. Seeds can also be externally contaminated with air-borne spores that are present during extraction.

The fungus can survive in fields in the absence of host plants for at least two years. It probably survives as dormant mycelium or chlamydospores in host debris. In greenhouses, the fungus survives in dry plant debris on the soil surface; less inoculum survives in buried debris in moist soil.

Importance of plant compensation

Gummy stem blight was reported first in France in 1891 on cucumbers. Now it occurs in all continents. It is most severe in tropical and subtropical areas, but also is reported frequently in areas with temperate climates and in greenhouses.

The disease damages each area of the cucumber stems, and sometimes expands to other climbing stems of the plant, making it wilt and die. The disease often occurs at the cutting point for pruning. The plant may develop additional stems to compensate. In many cases, however, the disease infects the main stem and even causes the plant to die.

The disease may spread to fruits, causing fruit rot. These fruits are often on or nearby infected stems. Infected fruits may rot while they are still on the plants. In many cases, the fungus stay inside fruits and cause fruit rot after harvest. This may cause 23-35% fruit loss during delivery and storage.

Role of environmental factors

The optimum temperature for infection is 24-25ºC in watermelon and cucumber. Moisture is more important for disease development than temperature. Peak ascospore dispersal occurs after rain and during dew periods at night. Free moisture on leaves for at least one hour is necessary for infection and further continuous leaf wetness is required for lesion expansion.

Natural enemies and antagonists

Unknown

Management and control practices

Prevention activities:

- Rotating cucumber with non-cucurbit crops helps to reduce disease incidence. Cucurbit crops should not be grown in the field continuously for two years in order to limit disease damage.

- Cucumber seeds should be collected from disease-free fruits. Seeds of infected plants or greenhouses should not be collected. Seed collection should be done in a clean environment to avoid spore spread.
- The use of resistant varieties will reduce disease incidence.
- Bed mulching or net house materials affect disease development. The fungus will not produce spores if beds are covered by plastic materials, such as PVC. Ultraviolet rays, that are necessary for spore formation, are prevented by these materials. Using polyethylene or polyamide will increase disease incidence.
- Killing insect-vectors, such as aphids helps to avoid disease spread to healthy plants.
- Cucumber fruits should be stored under conditions of 10^{o}C right after harvest to avoid disease infection during storage. Reducing broken fruits during harvest and delivery gives similar results.

Once there is an infection in the field

- Fungicides can reduce disease infection. Some copper fungicides or organic fungicides, such as Maneb and Mancozeb were used to control this disease. Requirement of fungicides depends on time of disease occurence and its spread speed. Pruning infected leaves and destroy them outside fields, sometimes helps to reduce disease infection. Fungicides often should be applied before disease because fungicides create protection layer for leaves, preventing spore from germination. New leaves are produced regularly and rain may wash off fungicides regularly, thus fungicides should be applied often, but frequency depends on disease level, crop growth development stage and weather conditions. Sometimes, fungicide spraying interval is 7 days if it is cool and humid and 10 days if it is dry. Regular field visit is very important to decide pesticide spraying time! Experiments can be conducted to test target leaf spot disease level and effectiveness of calendar spraying. One example of experiment is to spray at different times with certain disease level.
- Disease incidence will be reduced if potassium is applied during the young fruit stage.
- Disease-forecasting programs have been developed to predict the rate of disease development based on weather patterns. Such programs could enable farmers to better time their fungicide applications but the success of forecasting programs varies.

Points to remember about gummy stem blight:

1. The disease can reduce yield if plants are infected before and during flowering stage.
2. Disease can occur on fruits during storage.
3. Pesticides can be used if disease appears.
4. Remove and destroy infected plant materials, including weeds to reduce disease infection.

12.10. Cucumber mosaic virus - *Cucumber mosaic virus*

Causal agent: *Cucumber mosaic virus*

Photograph from Cornell University

Signs and symptoms

Cucumber mosaic virus (CMV) damages cucumber, melon and squash seriously. CMV causes severe plant stunting; prominent foliar yellow mosaic, malformation, and drastic reduction of leaf size and stem internodes. In early stages of growth, systemic symptoms consist of prominent downward leaf curling, mosaic, and reduced leaf size. Flowers of severely affected plants may have prominent abnormalities and greenish petals. The intensity of foliar and fruit symptoms depends on the species and cultivar infected, the age of the plants, and environmental conditions. Infected fruits become distorted and often discolored and usually remain small. In severe affected fruits, seed production is negligible.

Disease spreads quickly in winter and spring, when there are a lot of aphids. In northern Vietnam, the disease seriously damages vegetables during the late winter season. Young plants are more susceptible than older plants.

Source and spread

The life cycle of CMV varies among different geographical areas although the major factors of life cycle are the same. At the beginning, the virus stays on host crops and in some kinds of seeds. The virus often spreads to cucurbit crops through insect vectors, such as aphids. There are more than 60 aphid species that transmit CMV, including *Myzus persicae* (Sulzer), *Macrosiphum euphorbiae* (Thomas), *Aulacarthum solani* (Kaltenbach). Generally, the virus is acquired by immature aphids within one minute but their ability to transmit the virus declines and is lost within two hours. The efficiency of transmission depends on several factors, such as vector biotype, virus strain, environmental conditions, and season.

CMV is easily transmitted mechanically and although there is no evidence that it is seed-borne in cucurbits, it can be carried in the seeds of 19 other plant species. It can be transmitted from perennial trees or wild trees to other crops through insect-vectors. Thus, the disease source survives year-round in the fields.

CMV can also be transmitted through mechanical wounds, especially in net houses where crops were planted manually or from infected seeds or by cucumber beetles.

Role of environmental factors

Duration from disease infection to the appearance of the first disease symptom for young plants is 4-5 days and 14 days for older plants. Disease development is faster at temperatures of 26-32^{o}C, compared to 16-24^{o}C. Disease is often more serious in the season of short day length and when there is lack of sunlight.

Disease incidence increases proportionally with aphid populations and disease sources. The higher the aphid population and the more disease sources there are available near the growing area, the faster disease infection happens and the more damage to the crop occurs.

Importance of plant compensation

CMV is of worldwide distribution and can infect about 800 plant species, including both monocots and dicots. The host range includes many well-known vegetable crops (carrot, cucurbits, legumes, lettuce, onion, pepper, spinach, tomato, etc.), ornamentals, woody and semi-woody plants (banana, etc.).

The disease may give serious effects to yield and fruit quality if disease infection happens before and during flowering stage. It is reported that CMV may cause 50% yield loss in main cucumber growing areas.

Disease infected plants are stunted and have weak compensation ability. In some cases, plants may die if they are damaged by aphids and other pests at the same time.

Natural enemies and antagonists

Unknown

Management and control practices

Prevention activities:

Control methods for CMV on cucurbits include reducing initial disease source and reducing disease spread.

- Eliminate or reduce initial disease sources which appear on weeds, disease-infected cucurbit crops on cucumber growing areas, stop growing cucumber near infected fields, destroy disease-infected crop residues, and practice field sanitation. The importance of this method is proper identification and elimination of disease source.
- Use resistant varieties. In cucumber, resistance to CMV has been derived from a Chinese cultivar. This resistance has been widely explored and most American cucumber cultivars and a large number of those available outside the United States are now resistant to the virus.
- <u>Seeds should be treated before sowing</u>, for example dipping in hot water of 55^{o}C for 60 minutes, or in hot temperature of 70^{o}C for two days or 40°C for four weeks.
- Killing aphids is an effective control method. Various aphid control methods are applied such as using chemicals, predators of aphids (spider mites, lady beetles, etc; see part 13.2). Now, many studies show that using mineral oil extracts is

effective in controlling aphids and minimizing harmful effects to human health and environment.

- Rotate cucumber with other crops. Cucumber should not be grown for two seasons in a year to reduce the disease pathogen.
- Cucumber should not be intercropped with other crops. CMV has wide hosts on different crops. Intercropping in this case will cause stronger disease development and more severe damage.
- Mulching with polyethylene sheets or rice straw helps to suppress development of insect vectors such as aphids, resulting in slower infection and at the same time reduces weeds that may harbor pathogens. This method can improve yield for some cucurbits. Using black and white nylon is more effective than using the black one only.
- Growing barrier crops around the cucumber field reduces virus infection on cucumber and other cucurbit crops.

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.
- Minimizing mechanical wounds during transplanting helps to avoid virus spread.
- Spraying mineral oil extract weekly reduces disease infection and virus spread.
- Spray chemicals to control aphids.
- Note: There are no pesticides that prevent or cure virus diseases!

Points to remember about cucumber mosaic virus:

1. CMV may reduce yield and fruit quality if disease infection happens before and during flowering stage.
2. Most management methods are preventive or minimize infection and spread.
3. CMV spreads by aphids.
4. Controlling aphids is a very important preventive method (see part 13.2).
5. Eliminate and destroy virus-infected plant materials, including weeds to reduce disease sources.
6. Pesticide can not prevent or control CMV.

12.11. Physiological disorders

Physiological disorders or non-parasitic diseases are caused by adverse environmental conditions. Major causes of these disorders include excessively high or low temperatures, soil-moisture disturbances, sun burn, pesticide burn, and deficiency or excess of a fertilizer/nutritional element.

Some common physiological disorders for cucumbers are listed below.

12.11.1. Bitter fruit

Most cucurbit species have bitter compounds called cucurbitacins in their foliage. Cucurbitacins are thought to be toxins produced by these plants as a defense against insects and herbivores. Most cucurbit cultivars have been selected by plant breeders to have low cucurbitacin contents in the fruits. Ornamental gourds are an exception and may have high cucurbitacin content. Some cucumber cultivars are bitter-free in their foliage as well as their fruit.

Bitter fruits are occasionally produced by standard cultivars when the plants are exposed to drought during fruiting. The fruit have an unpleasant taste but are not dangerous to eat. The problem is remedied by irrigating during fruit production or by growing bitter-free cultivars.

12.11.2. Pollination problems

(See Plate 5, Figure 10, Page 83)

Photographs from the Pollinator website

Field-grown cucurbits require pollination for fruit development. In order to get proper pollination and avoid misshapen fruits, growers should try to provide one bee per plant. Cucumber flowers, however, are generally not as attractive to bees as other crops. Thus, bees should not be put into cucumber fields until after the crop has begun to flower to prevent the bees from establishing foraging patterns in other crops. Insecticides should not be applied near hives or in the fields when the bees are working (from sunrise until early afternoon). Pollination is less effective at temperatures above 32^{o}C, so the cucumber crop should be planted to avoid flowering during times of the year when temperatures reach that range. Poor pollination can be avoided by selecting suitable varieties for each season, each location.

12.11.3 Moisture Stress

See Plate 5, Figure 11, Page 83

Water deficit: Water deficits have a significant effect on practically all metabolic and physiological plant processes. As soil moisture is depleted, water transport gradually diminishes, thus lowering plant water potential and turgor pressure and increasing vapor pressure deficits between the plant and the surrounding atmosphere. The normal metabolism of a plant can change, depending on the severity and duration of the stress. Water stress often reduces vegetative and reproductive growth, photosynthesis, transpiration, ion uptake, translocation, and it may render the plant more susceptible to insects and diseases. Drought before anthesis may delay flowering, reduce plant stature, and change sex expression (from female to male). Water stress while fruit are enlarging can reduce both yield and quality. Fruits are often smaller and softer than normal. Levels of fruit sugars, minerals, and vitamins can be drastically altered (usually lowered) by drought episodes.

Excess water: Under flooding, plant roots receive decreasing amount of oxygen, depending on the duration and severity of the stress episode. Crop damage due to excess water is not as frequent and widespread as drought. It can cause unusual phenomenon for plant parts above ground. At near 100% soil water saturation, the cucumber crop can become yellow and stunted.

13. Major insect pests of cucumber

Summary

Leafminer (*Liriomyza sativae*) is the major pest in both temperate and tropical areas in Asia. Other pests, such as spider mite (*Tetranychus cinnabarinus*), beetle (*Diabrotica*) and thrips (*Thrips* sp.) can cause severe damage. Flea beetle (*Phyllotreta* sp.), aphid (*Aphis gossypii*) and cutworm (*Agrotis* sp.) can be a problem in nurseries.

Biocontrol options exist for many insect pests of cucumber, such as predatory mite for spider mite control and ant for aphid control. Other naturally-occurring biocontrol agents such as predators (ladybeetles, spiders), parasitoids and pathogens (e.g. fungi killing aphids) can locally, and in some seasons, give additional control.

Most biocontrol options should be part of an IPM programme that include farmer training.

Several cultural practices such as weed removal, removing infested plant material, use of trap crops, and hand-removal of egg masses and larvae can provide additional insect control. For several cucumber insect pests, insecticide use is not effective or economical and may in some cases (e.g., whitefly) even aggravate pest problems. Most insect management options focus on prevention of high populations, and biocontrol, either by conserving and augmenting naturally occurring natural enemies or by releasing/applying biocontrol agents.

In the following sections an indication of the number of generations per year, and the duration of parts of the insect's life cycle are given. It is emphasized that these figures are indications only as they depend on local climate (temperature, humidity, etc.). In general, insect development is faster in warmer climate. The actual duration of the life cycle of a specific insect or natural enemy from your area can be checked by setting- up an insect zoo experiment.

13.1. Leafminer fly - *Liriomyza* sp.

(See Plate 1, Figure 1-3, Page 79)

Photograph from Bio Bee Biological Systems

Leaf-mining flies in the genus *Liriomyza* Mik are among the most injurious insects attacking cucurbits in the United States. Two important species are *L. sativae* Blanchard and *L. trifolii* (Burgess).

Description

Adult leafminers 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 are pre-oviposition periods 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 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. The duration of the pupal stage ranges from 9-19 days. Many overlapping generations occur during a growing season.

Plant damage

Losses in cucurbits due to leafminers are difficult to measure. Most researchers believe that leafminers 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 leaf distortion and premature leaf abscission resulting in sun-scalded fruit.

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

Natural enemies

Some parasitic wasps belonging to *Eulophidae*, such as *Diglyphus isaea* Walker and *D. begini* are reported to be adult and pupa leafminer fly parasites in Peru. Other species of *Opiinae*, *Tetratischinae* are also considered as major parasites of leafminer fly.

Management and control practices

Prevention activities:

- Avoiding growing cucumber or legume crops consecutively in the same field will give high preventive effectiveness.
- Mulching by black or white polyethylene sheets is effective. Fields can be also covered with straw to prevent adults from laying eggs on the base of the plant.

Once leafminers are present in the field

- Remove damaged leaves and carry out field sanitation to reduce pest population. Damaged stems should be used to do compost, or removed far from the cucurbit and legume fields.
- Put traps (such as yellow sticky traps or sweet and sour trap) that are effective for catching leafminer adults.

Sweet and sour traps to catch leafminer adults

During Winter-Spring season 2003-2004, ToT participants in Hanoi put sweet and sour trap (40% sugar + 40% vinegar + 10% alcohol mixed with Padan at a dose of 1.5/1000 + water) to catch cucumber leafminer adults. The results were very positive. The percentage of crops damaged by leafminers was significantly reduced in fields with traps. This method was applied also in FFS fields and similar results were attained.

(*Source: Mr. Pham Dinh Tho, ToT facilitator, Hanoi 2003*)

- Rotate with crops that are not hosts of leafminers.

✍Points to remember about leafminer fly:

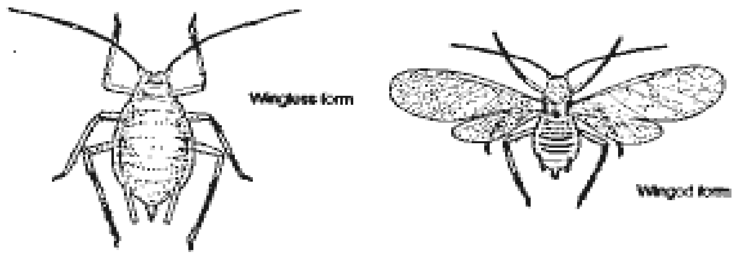
- The plant is damaged due to pest mines inside leaves.
- Pesticides are not effective anymore if leafminers are inside leaves.
- Control methods such as putting traps to catch adults should be done at the beginning of the season.

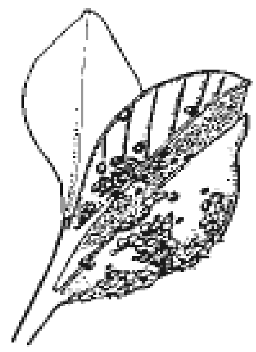
13.2. Aphids - *Aphis gossypii*

(See Plate 1, Figure 4, Page 4)

Description

Aphids are a serious pest, damaging most of the cucumber growing areas in the world.





From Stoll

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 syphons (looking like small antennae) at the back of their body. Syphons are a good way to recognize aphids. Colonies of these aphids are usually found on the undersides of cucumber leaves.

The aphids can reproduce asexually. 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 overwinter and young nymphs emerge when the temperature rises. All winged aphids are females. In the tropics, most unwinged aphids are probably also females. Most reproduction in the tropics will be asexual so males are not needed.

Life cycle

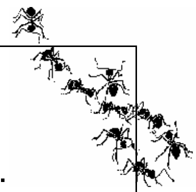
In the cooler areas of its distribution, the cucumber aphid overwinters as small, shiny black-colored eggs laid particularly around leaf scars of stems of plants that remain in the field throughout the winter. When the temperature rises, the aphids hatch and colonize the new emerging flowering stems or harvested vegetable crops that have not been ploughed in. The 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 infested 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 in unfavorable weather. Early damage to the growing point of a cucumber plant distorts the head. Even when young plants are infested only lightly, the leaves of the plants when 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 syphons. Honeydew can make the leaves sticky and several fungi species grow on the honeydew producing black sooty molds on the leaf and fruit surfaces. This lowers the photosynthetic ability of the plant and reduces fruit quality.

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 damage, cucumber aphids also transmit the mosaic virus to cucurbit crops. Good crop hygiene (uprooting and destroying virus infected plants), rather than trying to kill the aphids, is the only way to reduce 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.



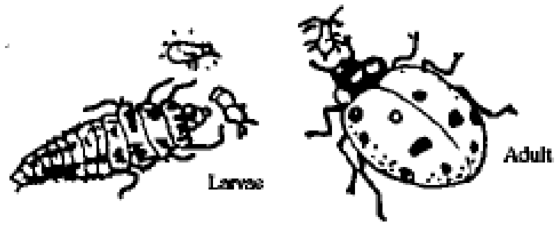
Aphids as mild cows for ants...?!

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

The weather is a major natural agent restricting the build-up of cucumber 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 or syrphids and parasitoids like the wasp, *Diaeretiella rapae* are important natural enemies of the cucumber 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 fungus growth on the body. These



Lady beetle : an important predator of aphids fungi can spread quickly to reduce aphid populations.

Management and control practices

Prevention activities:

- Healthy, vigorous 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 fertilization is done or when the soil structure is poor.
- Host plant resistance: There is little chance of producing a cucumber variety with a durable resistance to cucumber 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, crucifers, legumes 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.
- Undersowing with clover may help to reduce aphid infestation. In a study where cucumber was undersown with white clover, cabbage aphid population was reduced with 90%! (Finch, 1996).
- Spraying mineral oil or oil extracts every 7 days from 3-true leaf-stage until beginning of flowering stage will limit aphid damage. Mineral oil can prevent damage of other sucking pests, such as thrips, spider mites and white flies.

Once aphids are present in the field

- Monitor the field regularly to check population growth. Cucumber 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 infested 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 production and at low infestation, aphids can be washed off from the plants with water or rubbed by hand.
- Small populations can also be removed by removing the infested 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 the weather is warm and dry, chances are that the aphid population will expand very quickly and cause damage to the growing points of the plants. Monitor the field carefully for 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.

- Soap solutions (concentration of 0.5 % (5 g per liter)) kill aphids instantly.
- Botanicals such as neem solutions may control aphids. Good results have been 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 stired firmly. The procedure released spores from the fungus into the water and the water became infectious for aphids. Then the solution was filtered through a cloth (to remove large particles) 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 the cucumber aphid and other pest insects! Balance the benefits of spraying against the harm done to the beneficials! When applying insecticides is considered necessary, apply only on those plants that have aphid colonies, not on all plants. This reduces the amount of pesticides needed and may save some of the beneficials present in the field.

Points to remember about aphids:

1. Aphids have many natural enemies.
2. On small scale production and low infestation, aphids can be removed by hand rubbing, washed off with water spray, or destroyed by removing and destroying infested leaves.
3. Localized (infested 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

13.3. Striped and Spotted Cucumber Beetles - *Diabrotica* spp.

Coleoptera, *Chrysomelidae*

(See Plate 2, Figure 6, Page 80)

Photographs from PennState and University of Minnesota

Description

The beetles have yellow and green bodies with black spots and stripes, black heads and measure about 0.6cm length. Eggs are oval, orange yellow in color and are laid in the soil or lying on the host plants. The larva is 0.6-1.2 cm long, its body turns brown to white, has a brown head, and it has a brown spot at the end of the tail. In spring, the larva often attacks roots and stems within 2-6 weeks.

Life cycle

The adult beetle is about 6 mm. long and is marked with four yellow and three black stripes. The adult enter reproductive diapause in early autumn and hibernate in trash, soil, or woodland litter. Emergence in spring is closely related to the appearance of host plants, and mating beetles are noticeable on young cucurbit seedlings. The yellow orange eggs are laid in the soil around the bases of stems and hatch in 7-10 days. The elongate, whitish larvae feed on the root system and after 2-4 weeks of feeding, form a cell in the soil and pupate.

Plant damage and plant compensation

In general, there is only one generation of the cucumber beetle in a crop season in the cold regions and two generations in the warm regions toward the South.

The larva and adult of the cucumber beetles cause harm to the cucumber and other plants such as different types of melon, courgette and pumpkin, asparagus, eggplants, potato and some fruit crops like tomato and green peas. Cucumber beetles damage more than 270 crop species within 29 families including flowers and ornamental plants!

The adults spread leaf curl virus and bacterial wilt diseases. These diseases caused by virus and bacteria in fact overwinter in the beetles' intestine. When these beetles resume eating, they spread diseases from one plant to other plants. The symptom of infected plants is wilting and death. In spring, the adults feed on the tips and leaves of seedlings. In summer, the adults mainly live on the flowers and pollens of the flowering plants. In autumn, they move to settle on the higher plant parts and eat grass and wooden stemmed plants. They also cause brown rot disease on hard skinned fruits.

The adult of the cucumber striped beetles brings the highest damage on crops in the cucurbits.

Natural enemies

Some parasitoids and predators of cucumber beetles are recorded including parasitic *tachinid* flies, parasitic *braconid* wasps and the parasitic nematode, *Hexamermis* spp., bä c¸nh cøng qu©n nh©n, lacewings and bä rïa ¨n trøng.

Management and control practices

Prevention activities:

- Intercropping bean (any crops within the legume family) or white radish with cucumber can drive the beetles away. The seeds of radish can be sowed in the same furrow with cucumber.
- Planting attractant/repellant plants: Some crops such as mustard, daisy flower, dry lotus, radish, etc. are effective in driving the cucumber beetles away. If you want to use the perennial daisy to drive them away, you should use those with pungent smell such as the perennial daisy from Africa, France and Mexico. The normal perennial daisy is able to attract the cucumber beetles so it is possible to use them as traps.
- Land preparation should be done carefully or land excavation should be done in autumn in order to destroy eggs.
- Mulching can be done by spreading or covering any kind of onion on the soil surface of the field. In addition, covering furrows with a thick straw layer can prevent adults from moving from one plant to another.

Once cucumber beetles are present in the field:

- Apply the picking method by using a portable hoover to collect adults when it is still dark during the day. Then, put the adults in a plastic bag and destroy them.
- Mix 28 g of wooden ash with 28 g of hydrogenated lime (powder) into 4.5 liters of water. Spray this mixture on the upper and lower surfaces of leaves. You can also spray a mixture of chilly, water and garlic.
- Cheat the cucumber beetles by putting a flat aluminum sheet around the crop root to reflect the light on the leaf lower surface. This method also helps plants as they get more light.
- If the damage by beetles can not be controlled, use insecticides such as *pyrethrum* or *rotenone*. By using this method, you also can kill adults when they eat flower pollens.
- Putting sticky traps on the home garden and small farms is an effective tool to kill beetles! Cut wood into small rectangular pieces of 19 x 25 cm for use as hard cover. Color these pieces with yellow paint then put some whisky, wine or other sticky substances on it. You can put these traps in the field to catch the cucumber beetles.

You can also stick pieces of cotton dipped in Eugenol oil to the traps to attract female beetles. An example of this oil containing 60-90% Eugenol is the Jamaica pepper oil. The courgette flowers contain *indole* (C_8H_7N) which is a very attractive substance to adults. If you have a lot of this flower, you can grind them and put them onto the traps. Set up traps vertically into the soil but not higher than 30cm. Many beetles will stick to the traps. Collect the beetles and destroy them. Put the substances again and reuse the traps.

- Make a furrow with the depth and width of 7 x 7 cm and fill up with wooden ash. Wet the ash so it will not be blown away by wind or stick on plants as ash can be toxic to plants and cause leaves to drop.
- Release parasitic nematodes to the soil before sowing. The species *Hexamermis spp.* lives on adult cucumber beetles. Many studies have shown that up to 90% of the cucumber beetle adults are infested by this parasitic nematode. Use the beneficial nematodes to kill the adults in the mulching layers, sowing furrows and surroundings of plant roots.
- Treat the soil with neem oil: Neem oil is effective for killing eggs. The oil can be sprayed much into soil to kill eggs and larvae. However, it is not effective in preventing adults. More studies about the use of this oil should be carried out but the results so far have been very positive.
- *Use biocontrol product, such as Ma. to spray when beetle population on plants is low*

Points to remember about cucumber beetles:

1. It is difficult to control cucumber beetles by chemicals.
2. Preventive methods such as field sanitation, soil treatment before planting, etc. are all useful.
3. Natural enemies are not effective for the management of cucumber beetle adults.

13.4. Spider mites - *Tetranychus* sp.

(See Plate 2, Figure 3-4, Page 80)

Two species of spider mites – the twospotted spider mite, *Tetranychus urticae* Koch, and the carmine, *T. cinnabarinus* – are important foliar pests of cucurbits throughout the United States. Other species may also feed on stems and foliage but are of minor importance.

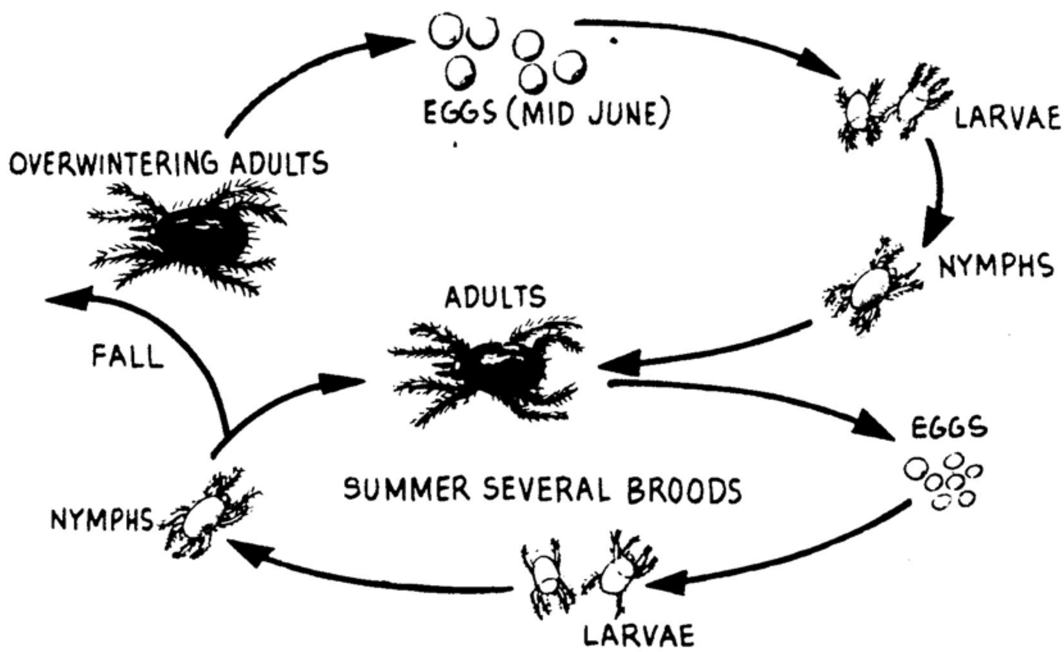
A mite is not an insect!?

A mite has eight legs, instead of the six that insects have. Also, mites do not have a “waist” like insects do and they do not have wings and antennae. Together with spiders, mites form a separate class of the *Arachnida*.

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, measure about 0.5-1 mm long and just visible to the naked eye. They are protected by fine webs which they spin on the leaf surface. The adults are orange-red to yellow-brown in color. Spider mites move slowly and cannot fly.

Life cycle

In general, all spider mites have an incomplete life cycle or metamorphosis. Female spider mites lay eggs on the lower surface of leaves and covers the eggs by a membrane to prevent them from being damaged by other insects. A female spider mite can lay 15 eggs per day and the oviposition period lasts for about three weeks. The development period from egg to the mature phase lasts about ten days in conditions of continuous hot weather. This reproductive rate results in a rapid increase of spider mites inhabitants in the field. It is considered that the spider mites live in soil, on plant debris for a long time before attacking plants. The spider mites overwinter in the mature phase and start reproducing when the weather is hot and dry.



Spider mite life cycle: egg, 6-legged nymph, 8-legged nymphs, adult

(Source: M.Perring et al, 1996)

Host range
The red spider mite has a very broad range of host plants, including many vegetable crops, ornamental plants and trees. It does the most damage on cucurbit crops, such as cucumber, water melon, bottle gourd and wax gourd, etc.

Plant damage and compensation
Spider mites damage cucurbits 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 poor 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 silvered appearance to the leaf. This eventually results in reduced production. The cucumber fruits are attacked only when mite populations are very high.

Natural enemies

- Predatory mite, *Phytoseiulus persimilis* is an orange-red mite, about 1 mm long. This mite cannot fly but moves around much quicker than the spider mites. In India, this predatory mite has proved to be effective against 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 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 and gourds as well as strawberry in China. Numerous research findings are available on how to mass-produce and conserve this predatory mite.

- The gall-midge, *Feltiella acarisuga* is a commercially available natural enemy of spider mite. It is very successful in European countries. The adult midge is about 2 mm long, pink-brown and 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 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 spider mite control needs to be further investigated.

- Larvae of the green lacewing, *Chrysopa* sp. are predators of spider mite.

- Ladybeetle adults and larvae feed on spider mites.

How effective one predator is and 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).

◎Circle of life: mites and predatory mite reproduction examples

In a study from China, 50 red 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

Prevention activities:

- 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 structure, applying modest rates of nitrogen, help prevent mite infestation.
- Spraying mineral oil or oil extract every seven days from 3-true leaf-stage until the beginning of flowering stage helps to limit red spider mite damage. Mineral oil also prevents damage of other sucking pests, such as aphids, whiteflies, and thrips.
- 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 such pest. Cucumber can be rotated with crops, such as garlic, onion, and basil to control red spider mites.
- Keep plant moisture as high as possible. It helps to prevent red spider mites from increasing. Keeping plant moisture can be done by reducing plant 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 infested plants, not on all plants. Most botanicals are not very effective against mite eggs. Application will have to be done at least weekly.
- 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 spider mite and may even result in more crop damage. See box above. In addition, 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 in very localized areas, on infested plants 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 spider mites, the plants at a later stage were less attractive to 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 of this method for pest control, the idea of tolerating low levels of insects or mites in the crop and not to try for 100% control could be considered.

☑**Points to remember about red spider mite:**

1. Red spider mite damages mostly in dry season.
2. Red spider mites do not damage young leaves, but mostly older and lower leaves.
3. Red spider mites have 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.

13.5. Whitefly - *Bemisia tabaci*

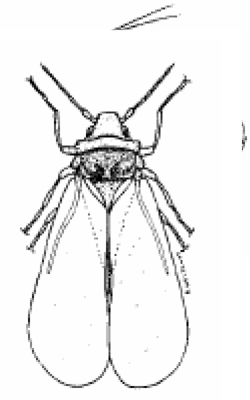
Bemisia is a very common species of whitefly. However, there are several other species of whitefly, for example *Aleurodicus dispersus* (spiraling whitefly), and *Trialeurodes vaporariorum* (common whitefly).

Other English names: tobacco whitefly, cotton whitefly or sweet potato whitefly.

Whitefly species currently are known to attack over 500 species of plants representing 74 plant families.

They have been a particular problem on members of the squash family (squash, melons, cucumbers, pumpkins), tomato family (tomato, eggplant, potato), cotton family (cotton, okra, hibiscus), bean family (beans, soybean, peanuts), and many ornamental plants.

Description and life cycle


adult whitefly

The adult whitefly is very small: about 1 mm long, silvery-white in color and with wings of a waxy texture. It is found often on the underside of the foliage where it sucks the plant sap.

When a plant containing whiteflies is shaken, a cloud of tiny flies flutter out but rapidly resettle. The adult has four wings and is covered with a white, waxy bloom. Adults can fly for only short distances but may be dispersed over large areas by wind. Females usually lay their first eggs on the lower surface of the leaf on which they emerged, but soon move upwards to young leaves. The female may lay 100 or more eggs. The egg is pear-shaped and about 0.2 mm long. It stands upright on the leaf. The eggs are anchored by a stalk which penetrates the leaf through a small hole made by the female. Water can pass from the leaf into the egg, and during dry periods when there are high numbers of eggs, the plant may become water-stressed. Eggs are white when first laid but later turn brown. Early in the season, eggs are laid singly but later they are laid in groups. They hatch in about 7 days.

When the nymphs hatch they only move a very short distance before settling down again and starting to feed. Once a feeding site is selected the nymphs do not move. All the nymphal instars are greenish-white, oval and scale-like. The last instar (the so-called "pupa") is about 0.7 mm long and the red eyes of the adult can be seen through its transparent back. The total nymphal period lasts 2-4 weeks depending on temperature. Nymphs complete three moults before pupation.

Eggs and early instar nymphs are found on the young leaves and larger nymphs are usually more numerous on older leaves.

Attacks are common during the dry season. Whiteflies disappear rapidly with the onset of rain.

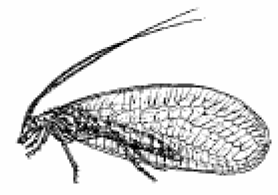
Plant damage and plant compensation

Direct crop damage occurs when whiteflies suck juices from the plant. With high populations plants may wilt, turn yellow and die.

Whiteflies also excrete honeydew, a sweet sticky fluid which may cover the leaves completely. On this honeydew, black sooty molds grow and the leaves may turn black in color. This reduces the capability of the leaves to produce energy from sunlight (photosynthesis) and may lower harvest quality.

In some hosts, damage can result from whitefly feeding toxins that cause plant disorders such as irregular ripening of tomato. Plant viruses also can be transmitted by whiteflies, such as leaf curl in tomatoes. Plant disorders and virus transmission are of particular concern because they can occur even when a whitefly population is small. In general, the older the plant when infected with virus or the later the onset of plant disorders, the less damage to the crop, so preventative action is critical.

Natural enemies



Chrysoperla carnea

Whiteflies are controlled by predatory insects such as green lacewing (*Chrysopa* sp.) or lady beetles (*Coccinellidae*); by parasitic wasps such as *Encarsia* or *Eretmocerus* species; and fungal diseases such as *Beauveria, Paecilomyces and Verticillium* species.

There may be many more natural enemies of whitefly in your area!

Natural enemies of whitefly, to name but a few ...

Studies carried out between 1985 and 1987 in Andhra Pradesh, India, on cotton showed the occurrence of nymphal parasitism of whitefly due to the aphelinids *Eretmocerus serius*, *Eretmocerus* sp. and an unidentified aphelinid. Populations of predators included the coccinellids *Brumoides suturalis, Verania vincta, Menochilus sexmaculatus, Chrysoperla carnea*, and the phytoseiid *Amblyseius* sp. Fungal pathogens found included *Aspergillus* sp*., Paecilomyces* sp. and *Fusarium* sp. (Natarajan, 1990).

Parasitic wasps usually are more effective at low pest population densities, whereas predators are more effective at high population densities. Parasitism can be quantified by counting the number of empty whitefly pupal cases with a circular exit hole (created by the emerging adult wasp) rather than a "T" shaped split (created by the normal adult whitefly emergence).

Numbers and activity of whitefly parasites and predators can be encouraged by avoiding broad-spectrum insecticides, planting of refuge crops, and in some areas-augmentative releases.

Whitefly mortality from pathogenic fungi often reaches high levels in greenhouses where relative humidity is constantly high and spores naturally accumulate. Pathogenic fungi can be applied as a spray treatment and are effective at any population density. Insect pathogens used for whitefly control must be applied with good coverage and under proper environmental conditions (high relative humidity) to be effective. The fungus, *Verticillium lecanii* is commercially available in Europe for the control of greenhouse whitefly. Other products are being tested in commercial production fields and greenhouses, but the economic feasibility of their use has yet to be determined.

Another fungus, *Peacilomyces fumosoroseus,* is also commercially available for whitefly control. It can be applied as a spore solution and it has some activity against aphids, thrips and spider mites.

Management and control practices

Whitefly management in a crop will depend greatly on the severity of and the number of whiteflies to cause the damage. Very few whiteflies are required to transmit viruses, so where this is the major concern, a farmer will want to avoid even small numbers of whiteflies. Where low levels of whiteflies are tolerable, other methods such as biological control can be more effective.

Prevention activities:

- Plant resistant cucumber varieties when available. Check local seed supplier in areas where whitefly is a serious problem.
- Proper monitoring of the whitefly population should be done regularly to detect early infestation. The easiest method for monitoring whiteflies is leaf inspection. Sampling 100 leaves per field (one leaf on each of 100 randomly selected plants) can provide a very good estimate of the average whitefly population density in the field, but fewer samples are usually all that is needed to make a control decision.
- The movement of whitefly adults can be monitored with yellow sticky traps. This method can provide a relative measure of general population trends over an extended area. In some areas in China for example, these traps are widely used in both greenhouses and in the open field. Careful monitoring of the types and numbers of insects caught on the traps should be done as yellow traps may also attract large numbers of useful natural enemies! When this happens, the traps are better removed from the field.
- Spraying mineral oil or oil extracts every seven days from the 3-true leaf-stage until beginning of flowering will limit thrip damage. Mineral oil can prevent damage of other sucking pests, such as aphids, spider mites and white flies.
- Destroy old crop residues that harbor whitefly infestations unless large numbers of natural enemies of whitefly are detected. Destroy all crop residues infected with virus.
- Susceptible crops should not be grown continuously because whitefly populations expand rapidly if there is a continuous supply of food.
- Avoid planting next to crops infested with whitefly and avoid carry-over from infested plant material.
- To protect seedlings, insect netting or screen cages of very fine wire mesh, placed over nurseries, helps reduce initial whitefly infestation of young plants. This is especially useful to prevent early infection with virus diseases, transmitted by the whitefly. Floating row covers (generally made out of a light fiber mesh and placed over newly planted crops) also exclude whiteflies during the vegetative growth of the crop. Screen cages and floating row covers work very well for early-season protection, but can be expensive and often have to be removed at flowering for proper pollination to take place.
- Under field conditions, there are several types of barriers that can reduce whitefly problems. These include reflective mulches that tend to repel whiteflies, oil-coated yellow mulches that act as a trap for whiteflies, and intercropping, e.g. with sorghum. See box below.
- Planting time also can be an effective tool to avoid whiteflies because they reproduce more rapidly under hot, dry conditions. Thus, planting during or shortly after rainy season allows crops to be established and even mature before conditions are favorable for rapid population increases.
- Establishing a host-free period by careful choice of planting site and date can reduce whitefly populations. This practice requires regional cooperation to be effective.

- Avoid unnecessary applications of pesticides to prevent secondary outbreak of whiteflies (due to elimination of natural enemies).

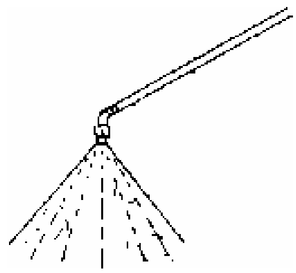
Once whiteflies are present in the field:

Chemical control of whiteflies is both expensive and increasingly difficult. Many systemic and contact insecticides have been tested for control of whiteflies, but few give effective control. In addition to the cost of treatment, other factors involved in chemical control decisions are:

- the need for thorough coverage: Whiteflies are located on the undersides of leaves where they are protected from overhead applications. Immature stages (except for the first one) are immobile and do not increase their exposure to insecticides by moving around the plant,
- the risk of secondary pest outbreaks (due to elimination of natural enemies),
- the risk of whiteflies developing insecticide resistance (a very serious threat!), and
- the regulatory restrictions on the use of insecticides.

Spraying insecticides resulting in MORE whiteflies??!!

There is a possibility that treating a resistant whitefly population with certain insecticides could actually accelerate population growth. This could be because more eggs are laid when the insect is under biochemical stress, or because natural enemies are eliminated.



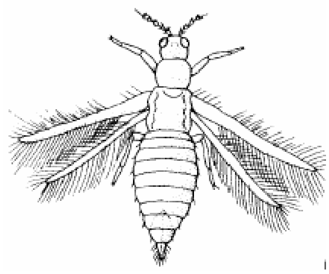
To minimize this potential problem, insecticide applications should be used as little as possible, judiciously and combined with non-chemical control tactics.

Points to remember about whitefly:

1. Whitefly can be an important pest in cucumber because it transmits leaf curl virus.
2. Whitefly has many natural enemies which can keep populations low.
3. Avoid unnecessary application of pesticides to prevent secondary outbreak of whiteflies due to elimination of natural enemies. Treating pesticide-resistant whitefly populations in addition, can accelerate population growth.

13.6. Thrips - *Thrips* sp

(See Plate 2, Figure 5, Page 80)Various species, most common: *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.

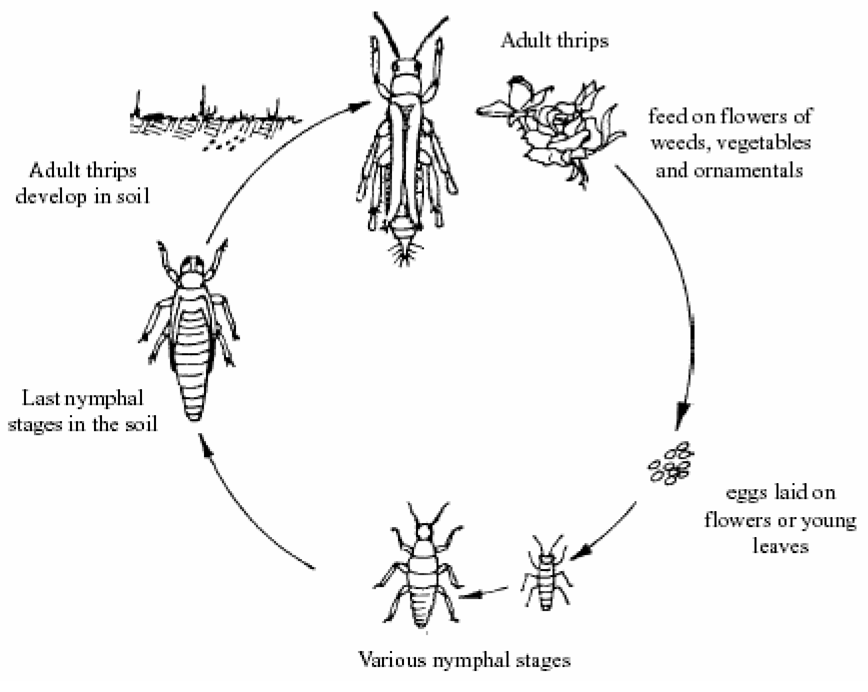
Thrips are gregarious insects and large numbers are often found together on single leaves. The insects can be found during the day at the base of the plant, on the underside of the leaves, at the sections with healthy tissue that border areas of brown or damaged tissue. Pupae are found in the soil.

Thrips move frequently to new locations to make more feeding incisions. They 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 pre-pupal 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.



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

Nymphs moult 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, the pre-pupae changes 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 of thrips span 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 watermelon, muskmelon, bottle gourd, cucumber, chili pepper, tomato, eggplant, and potato crops.

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 silvered 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* eats various thrips species; both hatching eggs and larvae. Predatory mites also eat 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 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 peppers.

- 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); the larval predator, *Bilia* sp. and *Orius* sp. (both bugs) 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.

- 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.

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 build 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….☹

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 ten years.

Management and control practices

Prevention activities:

- Resistant varieties: Differences in varietal reaction to thrips attack have been recorded in a number of vegetables, but not in cucumber. The erratic nature of thrips infestation makes screening for host-plant resistance in cucumber difficult. The breeding for resistance of cucumber to other insect pests such as leafminer and shoot borer, which in most areas is the most serious insect pest of cucumber, 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 (sun)light deters aphids and thrips and they will not land on the crop but fly elsewhere. For best prevention, 50% of the soil should be covered with the reflecting mulch.

- 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 the 3-true leaf-stage until beginning of flowering will limit thrip damage. Mineral oil can prevent damage of other sucking pests, such as aphids, spider mites and white flies.
- Intercropping: There are no consistent effects reported on thrips populations. Not advisable.
- To reduce thrips infestations at seedling stage that 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.

☑**Points to remember about thrips:**

1. Thrips have probably become an important pest as a result of increased use of pesticides that have 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.

14. Harvesting

The cucumber crop is ready for harvest about 45-60 days after sowing, depending on cultivars and growing conditions. The fruits take about 7–10 days from setting to reach marketable stage. Fruit size during harvesting depends on the purpose of use or market requirement. Fruits for salad or slicing are picked when they are 15-25 cm long; for pickles they are harvested when they are 5-15 cm long. The fruits should be picked at 2-day intervals.

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Common Pests and Diseases of Cucurbits

Plate 1

Fig. 1: **Leafminer adult**
(see section 13.1,page 57..)
(Source: L.D. Chandler, 1998)

Fig. 2: **Larvae of leafminer**
(see section 13.1,page 57..)
(Source: L.D. Chandler, 1998)

Fig.3: Mining on a cucumber leaf
(see section 13.1,page 57..)
(Source: L.D. Chandler, 1998)

Fig. 4: **Aphids**,***Myzus persicae***
(see section 13.1,page 59.)
(Source: T.M. Perring)

Fig. 5: Thrips underneath the leaves,
See section 13.6,page 73)
(Nguån: AVRDC, 2000)

Plate 2

Fig. 6: **Adult of striped cucumber beetle**
(See section 13.3,page.63.)
(Source M.P. Hoffmann)

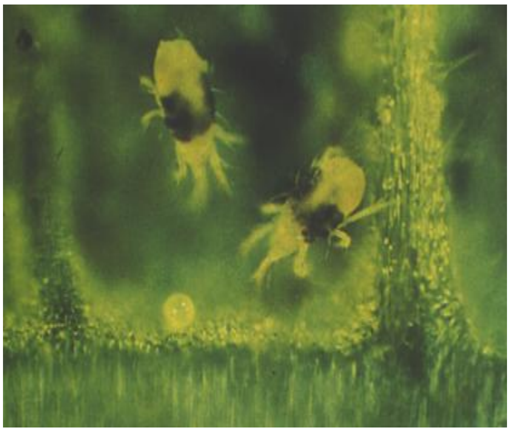

Fig.7: **Adult of spider mites**
(see section 13.4, page.65.)
(Source: T.M. Perring)

Fig. 8: **Damage to a cucumber leaf by spider mites**
(see section 13.4, page.65.)
(Source: T.M. Perring)

Plate 3

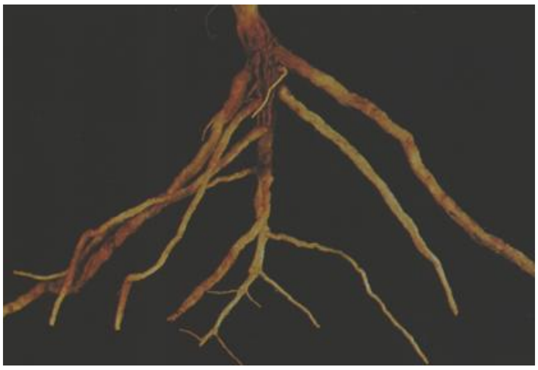

***Fig. 1. Pythium* root rot**
(see section 12.1, page 25
(Source: W.D. Gubler, 1998)

***Fig. 2* : *Fusarium* wilt** of greenhouse-grown cucumber
(see section 12.2, page32)
(Source: D.J. Vakakounakis,

***Fig. 3:* Bacterial wilt**
(see section 12.3, page 29)
(Source: R.X. Latin and M.P. Hofmann, 1998)

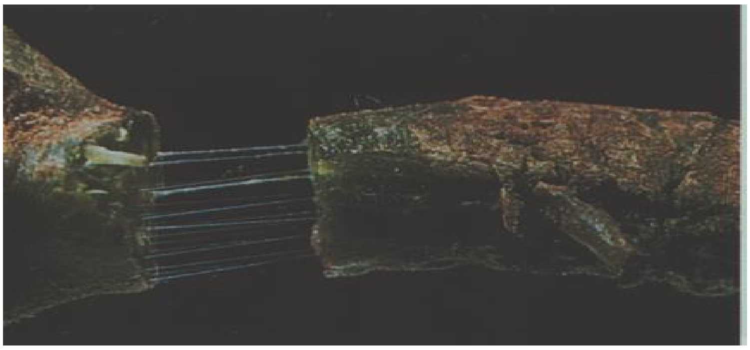

***Fig. 4:* Bacterial wilt**
Sticky strand test on cut stems, with bacterial slime streaming from xylem tissues
(see section 12.3, page 29)
(Source: R.X. Latin and M.P. Hofmann, 1998)

Plate 4

Fig. 5: **Powdery mildew**
(see section 12.4,page 40)
Fungal growth on the upper and lower surfaces of leaves
(Source: T.A. Zitter vµ M.T. McGrath, 1998)

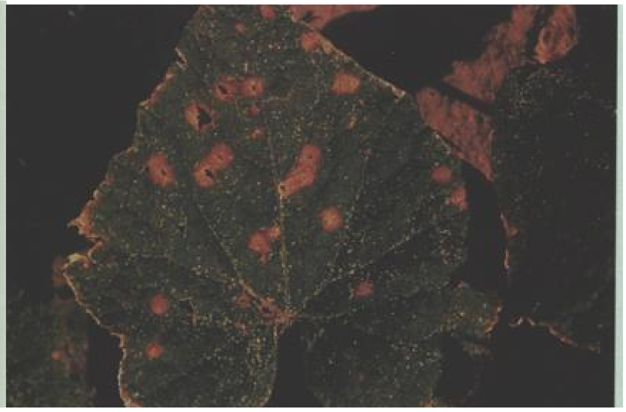

Fig. 6: **Target leaf spot**
(see section 12.6, page 42.)
Cucumber leaf lesions
(Source: T. H. Wehner, 1998)

Fig. 7: **Angular leaf spot of cucumber**
(see section 12.7, page 44)
Leaf lesions
(Source: P.H. Williams, 1998)

Fig. 8: Curly top virus
(see section 12.8, page.47)
(Source: T.A. Zitter , 1998)

A **B**

Fig. 9: **Gummy stem blight of melon**
A. Foliar symptoms ; B. Stem canker
(see section 12.9, page49)
(Source: T.A. Zitter and B.D. Bruton, 1998)

Plate 5

Fig.10: **Poor pollination**
(see section 12.11, page 55)
(Source: T. H. Wehner, 1998)

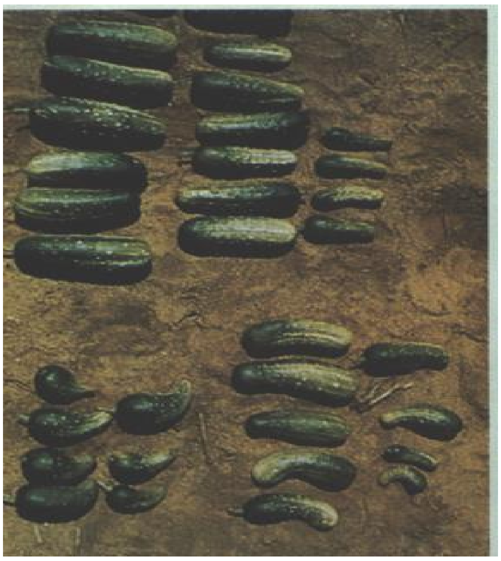

Fig.11: **External symptoms of moisture deficit in cucumbers**
(see section 12.11, page 55)
(Source: J.E. Staub, 1998)