

This chapter was adapted from: FAO Inter-Country Programme for the Development and Application of Integrated Pest Management in Vegetable Growing in South and South-East Asia. 2000. *Cabbage Integrated Pest Management: An Ecological Guide*. Vientiane, Lao PDR. However, any errors in this chapter are our responsibility.

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SUMMARY

Disease ecology means, the study of organisms that cause plant diseases in relation to their environment. Tea diseases are caused by pathogens (disease organisms) that include fungi, bacteria, viruses and nematodes. Most pathogens spread from infected plant material or soil. They are carried by wind, water (rain, irrigation water, ground water), insects, and by humans or tools (attached to clothing or shoes, and spread by pruning or cultivation tools).

Pathogens can infect a plant when:

- 1) the variety of that plant is susceptible to the disease,
- 2) the disease is present and virulent (able to infect the plant),
- 3) the environment (e.g. humidity, temperature) is favorable for the disease to develop.

Disease management is focused on changing or influencing one of these three elements to prevent the disease from attacking the plant. Knowing the ecology of a disease will give you clues on how to manage it!

Available fungicides and bactericides are often not effective enough to stop the major tea diseases, especially during prolonged periods of wet weather. If you decide that fungicides are necessary, fungicides should be used in combination with methods for altering the ecosystem such as adding organic material to the soil, use of shade trees, sanitation, etc.

The biological control fungus *Trichoderma* is widely available in many countries in South East Asia. *Trichoderma* can suppress several soil-borne pathogens. Other biological agents may become available in the future for control of plant diseases.

10.1 Pathogens and other micro-organisms

Diseases are an important part of crop protection, but they usually are difficult to understand in the field. One reason is because the organisms that cause disease are very small; farmers cannot see them and study them as easily as insects. Farmers usually recognize diseases by their symptoms, which are very diverse. Disease symptoms can include dwarfing of the plant; color changes; leaves that are spotted, wilted, or dead; roots that are deformed or dead; and other symptoms.

Plant diseases are caused by living organisms, called *pathogens*. The main groups of pathogens are fungi, bacteria, viruses, and nematodes. Because the organisms in these groups are so small, they are often called "micro-organisms". The characteristics of each group of micro-organisms are listed in the box below.



Farmers need to understand that most micro-organisms are not pathogens. Each of the groups of micro-organisms (fungi, bacteria, viruses, and nematodes) contains some members that cause plant diseases, but each group also contains many members that are beneficial. For example, most fungi and bacteria feed on dead organic matter, helping to break it down and make nutrients available for plants. In addition, some micro-organisms are true "natural enemies" of insect pests. Well-known examples are the bacterium *Bacillus thuringiensis* (Bt) and the virus NPV, which farmers can use to kill several pest insects.

Likewise, some fungi are natural enemies of plant diseases. These beneficial fungi are called *antagonists*, because they infect, attack or compete against (antagonize) the fungi that cause plant diseases. A well-known antagonist is the fungus *Trichoderma* sp., which can reduce root-rot diseases.

Groups of micro-organisms that contain pathogens:

Fungi grow as a "spider web" of tiny threads. You have probably seen a powdery or cottony "spider web" covering the surface of old bread or old fruit; this is one type of fungus. There are many different types of fungi; some live in the soil breaking up dead plant parts, others feed on living plants and cause wilts, leaf spots, root rots, and other symptoms.

Fungi have two general ways of reproduction:

1. Reproduction without spores: thread-like pieces of the growing fungus can break off and grow when placed in a suitable environment. Analogy: tea can reproduce by cuttings (pieces of the growing plant).
2. Reproduction by spores: spores are like "seeds" of a fungus. They are produced on the surfaces of the threads, especially under high humidity. Spores can be carried by wind or water. When spores land at a suitable place they germinate and the fungus grows a new "spider web" of tiny threads. If the new location has suitable conditions, then the fungus may once again produce spores. When conditions are not favorable, the fungus may develop a thick-walled "sleeping" stage that can "sleep" in the soil or on dead plant material during adverse conditions such as drought.

Bacteria are very small organisms and can only be seen through a microscope. To picture how small, imagine a jar full of sand. If each particle of sand were itself a tiny jar full of sand, then the sand grains inside the tiny jars would be about the size of a bacterium.

Many bacteria are useful as decomposers or natural enemies. Other bacteria can cause diseases of tea plants. Bacteria grow only in wet conditions, and require water to “swim” into plants.

To reproduce, bacteria multiply by cell division. In other words, the bacterium cell gets larger and splits into two cells. This can go very fast! For example some bacteria, under favorable conditions, may double every 20 minutes! That means that starting with one bacterium, there are over 4000 of them in about 4 hours. Usually, lack of food or accumulation of waste products prevents this high speed multiplication from happening.

Bacteria do not form spores like fungi, and therefore cannot be transported in dry wind. However, some bacteria can survive for a long time inside dead plant tissue or soil by surrounding themselves with a protective coating which prevents them from drying out.

Viruses are even smaller than bacteria. They can only be seen with a powerful electron microscope. Viruses exist only inside living cells and cannot live outside a plant or an insect vector. When a virus enters a plant cell, it “takes control” of the plant cell. Instead of producing plant tissue, the plant cell now produces more viruses.

Nematodes are tiny worms (about 1 mm long) that live in the soil. Nematodes have life cycles like insects: they usually mate, lay eggs, and have several larval stages. Some nematodes are useful natural enemies that kill insect pests. Other nematodes damage tea plants by feeding on the roots.

10.2 Where do pathogens live before they infect your tea bushes?

To plan how to manage a disease, it is important to understand how the pathogen grows and multiplies. Where does the pathogen live before it infects your tea bush? The answer depends on the type of micro-organism.

Many **fungi** that cause diseases on tea plants can survive for long periods **in the soil or on dead vegetation**. They survive either by using dead vegetation as food (decomposing it), or by “sleeping” in the form of a sleeping spore or other thick-walled structure. In addition, the fungi can survive by growing on **other living plants** near the tea plantation.

Most **bacteria** that cause diseases on tea plants survive in **other living plants** near the tea plantation. These host plants can include other tea plantations, some weeds, or some wild plants. In addition, some bacteria can survive for a long time in the soil or on dead vegetation by “sleeping”. Each sleeping bacterium cell surrounds itself with a protective layer that prevents it from drying out.

Viruses can survive and reproduce **only inside living cells** of a plant or of some insects. Viruses cannot survive on dead vegetation or in the soil. Viruses also cannot survive inside most insects. It is only certain sucking insects that carry living viruses inside them (especially aphids, whiteflies and leaf hoppers).

Nematodes are little worms that live in the soil. Most nematodes that cause diseases of tea cannot eat or reproduce unless they are on the roots of a living plant. Some nematodes require tea roots, but others can survive on roots of some weeds and some wild plants. Some nematode larvae (immature stages) can crawl a few centimeters through the soil in search of

new plant roots. Some nematodes can "sleep" for many months in the soil, waiting for living plant roots.

10.3 How pathogens move to new plants

Unlike insects, pathogens cannot walk or fly onto a tea bush. Nematodes can crawl for a few centimeters looking for plant roots. But most pathogens must be carried (for example, by wind or rain), or else the tea bush must come to them (for example, a tea root growing towards a fungus spore). Nonetheless, diseases can spread quickly from one plant to another, and also from one field to the next and even one village to another. Some common ways in which pathogens spread are described here.

Direct transmission through:

- Seed: pathogens can be carried on or inside a plant seed.
- Vegetative plant parts: infected transplants may carry diseases from nursery to the main field. Similarly, diseases can be transmitted from the mother bushes by infected cuttings.

Indirect transmission through:

- Growth of the pathogen: Fungi can spread over short distances by growth of the mycelium. For example wood rotting fungi can spread through the soil from one tree or trunk to the next by active growth.
- Wind: Fungi that produce spores on the surface of plants can be disseminated by wind. Examples are blister blight, gray blight, and (probably) dead twig diseases. There are examples of spores of some fungi that have been found over 4000 m above an infected field! Often wind blows the spores over certain distances and then rain may deposit the spores down onto another field. Some bacteria can be dispersed by wind-blown rain.
- Water: Flood or irrigation water may carry pathogens or spores, especially those in or near soil. The splashing of water during rain or heavy dews can spread fungal spores and bacteria to different parts of the same plant or to neighboring plants. An example of a water-carried pathogen is bacterial shoot blight; the secondary spread from initial infection results largely from splashing during rains. Water is not as important as wind for long-distance dissemination.
- Soil: Soil can contain plant debris that is infected with pathogens. Soil can also contain spores of fungi and bacteria, and larvae of nematodes. So, diseases can spread whenever soil particles are transported, for example attached to seedling roots or attached to tools or people's shoes.
- Insects, mites, nematodes: Small animals can move pathogens "by accident" when spores stick to the body of an insect or mite moving from one plant to another. More important is the case of some sucking insects that act as *vectors*. When vectors feed on a plant that is sick with virus, their mouthparts or saliva glands become contaminated with the virus pathogen. Then, when the vector moves to a healthy plant and starts feeding, the pathogen can enter the healthy plant and infect it. Most vectors are sucking insects such as aphids, whiteflies and leaf hoppers.

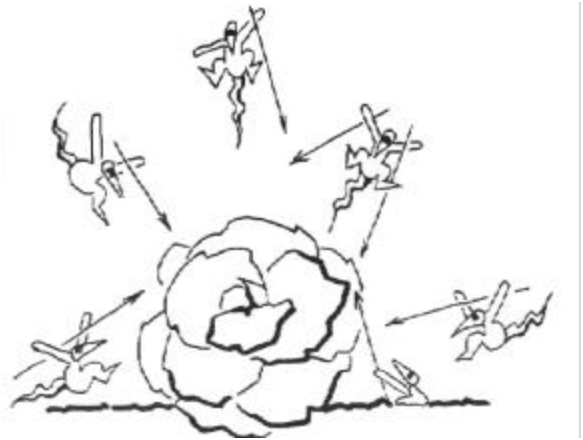
- Nematodes can also be vectors of pathogens. Also, nematodes create small wounds on roots that are entry points for bacteria and fungi in the soil.
- Humans, animals: Persons and animals spread diseases by walking and working in fields with infected plants, spreading spores sticking to the body. People also cause small injuries to plants (e.g. during transplanting, plucking, or pruning) that can be entry points for pathogens. Also, people can move a pathogen long distances by transporting diseased planting materials or infected soil particles.

10.4 How pathogens get inside a plant

Once the pathogen has come into contact with a tea bush, it must penetrate into the bush in order to grow. Each group of pathogens has different ways to penetrate into a leaf or a root.

Fungi are dangerous because they can penetrate an undamaged tea plant. To do this, some fungi produce special chemicals (enzymes) that dissolve the plant tissue and allow the fungus to enter. Or, fungi can enter a plant through natural openings like stomata (the “breathing cells” of a leaf). Of course, fungi can also enter through wounds on leaves, stems, or roots.

Some fungi live mostly on the surface of the plant, and have small “roots” that grow into the plant tissue to absorb food from the plant cells (example: powdery mildew; you can see it as a white downy mould on the upper side of leaves). Other fungi live inside the plant and may even use the plant vessels to spread through the plant (for example root-rots: the veins turn black due to the fungal infection).



Bacteria cannot actively penetrate plants and need wounds or natural openings to enter. Most bacteria require liquid water to survive and “swim” into the plant. Once they are inside the plant, they cause wet rots, wilting, and leaf spots.

A **virus** can infect new plants in 3 ways:

- through seeds or cuttings, if the mother plant was already infected
- through direct contact between two plants (wounds from two plants rubbing against each other, or roots growing together, etc.)
- indirectly through insects moving between plants. The main insects that move viruses from one plant to another are sucking insects like aphids, plant hoppers and whiteflies.

Virus diseases may take a long time to recognize as often the only effect on the crop is a gradual loss of vigor. Plants may be stunted, and yields are lower. Sometimes the signs are more obvious when red or yellow streaks or spots appear on the leaves (*mosaic*). But, it is often difficult to distinguish a viral disease from a mineral deficiency.

Most **nematodes** can actively penetrate plant roots by piercing them with their needle-like mouthparts. One type of nematode (root-knot nematodes) causes roots to form galls (swollen

areas). When roots are damaged, the leaves do not receive enough water or nutrients. This causes leaf symptoms that often are hard to distinguish from other diseases.

The differences in the ways of attacking a plant may be the reason that some diseases affect nearly all plants in a field, but other diseases only appear on a few plants. For example, blister blight can be present on nearly all tea bushes because it can actively penetrate the leaf tissue, but dead twig disease may only be visible on a few bushes because it needs a wound to enter the plant.

The infection process by some pathogens can be very quick. Damping-off in nurseries, for example, can kill seedlings in just a few days! That will usually be too short to even notice disease symptoms! Others just parasitize on a plant and do not cause the death of the plant - like gray blight: it can reduce the yield but plants will survive.

10.5 A disease or not a disease...? How to find out!

Knowing your enemy is the first step to winning the battle. So, as soon as a farmer sees some unusual symptoms on the tea bushes, he or she should work quickly to find out the cause. If the symptoms are caused by a disease, the farmer may still be able to do something to prevent it from spreading into the rest of the field (for example, by uprooting the diseased plants or by spraying a fungicide). Therefore, it is important to train farmers in recognizing early symptoms of a disease, so that they will still have time to prevent a disease from reaching a damaging level of infestation.

Often with some common sense and a thorough knowledge of a field's recent history, it is possible to find the cause for specific plant symptoms. The following are guidelines that may be useful in diagnosing problems of tea bushes (ref. modified from www21).

Guidelines for diagnosing tea problems

1. Identify the symptoms. Do the leaves have a different color? Do leaves or the whole plant have a different appearance, e.g. smaller size leaves or bushy plants? Are there any leaf spots or spots on the stems or fruits? Wilting of shoots or of the whole plant? Holes in the leaves or in the stem? Root abnormalities? Fruit rot?
2. Are all plants in the field affected? Are small areas in a field affected? Or only some individual plants?
3. Determine if there is a pattern to the symptoms. Are affected plants growing in a low spot of the field, poor drainage area, or an area with obviously compacted soil? Does the pattern correlate with current field operations? Are only young leaves, or only old leaves, affected?
4. Trace the problem's history.
 - When were symptoms first noticed?
 - What rates of fertilizer and lime were used?
 - What pesticides were used?
 - What were the weather conditions like before you noticed the problems - cool or warm, wet or dry, windy, cloudy, sunny?

5. Examine the plant carefully to determine if the problem may be caused by insects, diseases, or management practices.

Insects: look for their presence or feeding signs on leaves, stems and roots. Sometimes it's easier to find insects early in the morning or toward evening.

Diseases: look for dead areas on roots, leaves, stems and flowers. Are the plants wilting even though soil moisture is plentiful? Then check the roots for root rot symptoms or root deformations. Are the leaves spotted or yellowed? Are there any signs of bacterial or fungal growth (soft rots, mildew, spores, etc.)? Look for virus symptoms-are the plants stunted or do they have obvious growth malformations? Are all the plants showing symptoms, or are just a few scattered around the field?

6. Could there be nutritional problems? Chapter Eleven shows some deficiency symptoms for the major and minor nutrients. Ask the farmer about his or her fertilizer applications.
7. Could there be a nutrient toxicity? Boron, zinc, and manganese may be a problem here. Soluble salt injury may be seen as wilting of the plant even when the soil is wet. Burning of the leaf margins often is from excessive fertilizer.
8. Could soil problems be to blame? Soil problems such as compaction and poor drainage can severely stunt plants.
9. Could pesticide injury be at fault? Pesticide injury is usually uniform in the area or shows definite patterns. Insecticides cause burning or stunting. Herbicides cause burning or abnormal growth.
10. Could the damage be caused by environmental conditions? High or low temperatures, excessively wet or dry, frost or wind damage, or even air pollution? Ozone levels may rise as hot, humid weather settles in for long stretches. Look for irregularly shaped spots which may look similar to feeding of mites and certain leafhoppers. Ozone flecks are usually concentrated in specific areas of the leaf, while feeding damage from insects is spread uniformly across the leaf.

Very often, it is difficult to tell if a brown spot on a leaf is actually a disease, or just a little insect damage, or mechanical damage. Sometimes the symptoms of diseases are not very clear, or a different environment or climate makes a symptom look slightly different from the "theoretical" symptoms. In addition, there are non-living factors that can harm plants (for example, deficiency or excess of a certain fertilizer, sun burn, or pesticide burn). These factors can cause symptoms very similar to those of true diseases.

So, even after checking the guiding questions from the section above, farmers still might not be sure if the symptoms are caused by a disease. If farmers are not sure, one option would be to study the symptoms in a "disease zoo", located either in the field or inside a farmer's house (see the box below).

Studying diseases

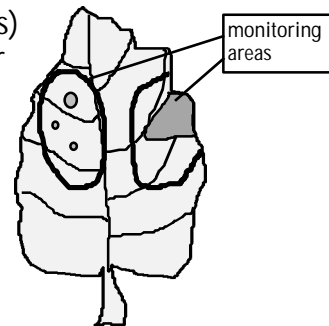
A "disease zoo" means studying the symptoms over a period of time. An example for leaf spots is given below.



Disease zoo for leaf spots:

Select one or a few plants in the field that have disease-like symptoms. Mark the plants with a stick and label the leaves that show the symptoms (you can put a tag on the leaf or draw a big circle with a waterproof marker pen around the spot you want to study). It is also possible to take some leaves off the plant and place them in a plastic bag or a glass jar, with a small ball of wet cotton around the cut base of the leaf or shoot. Or, put the leaf or shoot in a vase filled with water. Leaves taken off the plant do not last longer than about 5 days.

Draw the leaves with symptoms in detail (use hand lens) using color pencils. Check the following details: what color is the symptom, where is it located, do you see structures inside the symptom (e.g. black specks), what color is the plant tissue around the symptom, etc.). Measure the size of the symptom and note it down with your drawing. Also note down if it is a young or an old leaf and if the plant was located in the middle or more towards the border of the field.



Repeat the above after a few days: draw and measure the symptoms. If you find that the symptoms are growing, becoming bigger in size and maybe even have spores (you can sometimes find them as dusty powder or in small black pustules on the spot) it is very likely that you are looking at a disease. Check the symptoms found with the table in chapter 11, and with details on some of the major diseases of tea to confirm diagnosis.

A simple test to check for fungus pathogens

Most fungi produce lots of spores (“seeds”) in humid conditions. The spores look like bits of cotton or like powder, and are often colored white, yellow, or brown. You have probably seen this on old bread or old fruit.

If your tea has symptoms that you think are caused by a fungus disease, collect several of the affected parts (branches, leaves, etc.). Place them inside a plastic bag or a bottle, together with some moist paper or cloth. Then close the bag or bottle, and leave it in a dark place. Prepare another bag or bottle in the same way, but this time using healthy branches or leaves.

Check the bags or bottles after about 12 hours. Is there a cottony or powdery growth on the diseased pieces? If so, the disease is probably caused by a fungus. But be careful: once a leaf or stem has been killed, many fungi can start growing on it. These fungi do not cause disease, they are just using the dead plant as food (just like the fungi that grow on old bread or fruit).



Related exercises from CABI Bioscience/FAO Manual:

- 3.1. Description of disease symptoms
- 3.2. Identification of disease symptoms
- 3.3. Disease collection
- 3.4. Pathogen groups
- 3.8. Pathogen groups name game
- 3.9. Cultivating a fungus

10.6 Control or management?

It is important to realize that diseases require another way of thinking in order to have long-term control. Diseases must be *managed*, not controlled. But what is the difference and why is that important to know?

Management means a range of activities that support each other. Many of these activities should be done before transplanting of the crop, some even before sowing the seeds. Disease management is a long-term activity, sometimes it is a planning for several years. It is mainly focused on *preventing* the disease from coming into a field. It also aims at keeping disease pressure low in case a disease is present. Management usually needs the cooperation of several farmers working together to reduce overall diseases in an area.

Control is a short-term activity, focused on killing a disease or stopping the spread of it. The trouble with diseases is that you only see them when you see the symptoms. That means

infection already occurred at least a few days before. It also means that plants that look healthy today, may have disease symptoms tomorrow. Once a plant is infected, it is difficult to actually kill the pathogen. Especially when pathogens live in the soil and attack plants through the root system, they can only be *controlled* by proper *management* techniques like crop rotation or cultural methods. And those kind of methods usually have to be done before transplanting the crop!

Spraying fungicides, a typical short-term activity, may be a control option but only for a limited number of diseases and usually only partially. So a combination with cultural practices like sanitation is essential! It should be noted that some fungicides can kill natural enemies of insects. For example, copper-based fungicides can cause increased problems with mites (see Section 9.2.3). Other examples are given in Chapter Eight.

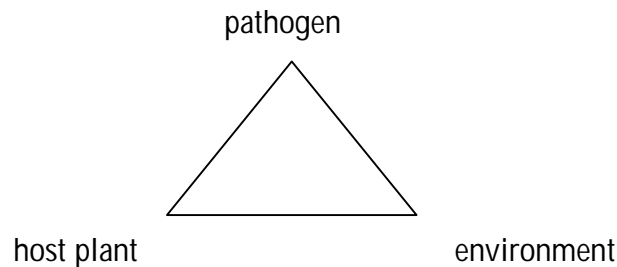
In order to make a good disease management decision, you have to know a few basic things about the disease. Things like: where does it come from, and how does it spread? Knowing this will give you a clue how to manage it. Soil-borne diseases are managed differently from wind-borne diseases!

But before talking about *control*, think about: how important is this disease, what damage does it do to my overall yield at the end of the season? What would be the effect of this disease to the crop in the next season? A few leafspots here and there may not reduce your yield. At what growth stage does the disease appear? What are the weather conditions, are they favorable for a quick spread of the leafspot? Yes, you may be able to temporarily stop the spread of those leafspots by applying fungicides. But what are the costs of those fungicides? What are the negative side-effects of fungicides to the natural enemy population? Will you win any *extra* income by a few spotless buds? That is what counts in the end!

Diseases can never be completely eradicated, so don't try! Instead, manage the disease at a tolerable level that balances costs and benefits (including economic and environmental).

10.7 When can a pathogen attack a plant? The disease triangle.

A disease is the result of interactions between three things: a pathogen, a host plant, and the environment. These interactions are shown in the *disease triangle*:



The disease triangle shows that a plant will get infected with a disease only when:

- the variety of that plant is susceptible to the disease, and
- the disease is present and virulent (able to infect the plant), and
- the environment (e.g. humidity, temperature, and natural enemies) is favorable for the disease to develop.

Disease management is focused on changing or influencing one of the three elements of the triangle to prevent the disease from attacking the plant. A few examples:

Changing the host plant can be: not growing a host plant (for example, planting some crop other than tea for a few years), or planting a resistant variety of tea.

Changing the presence of the pathogen can be: removing leaves with the spores of the disease from the field so that the disease cannot infect new plants (sanitation).

Changing the environment can be: using a proper planting density so that wind can dry the surfaces of the leaves. Wet leaves stimulate fungi to produce spores (for example, gray blight). Or, encourage natural enemies of pathogens by applying compost.

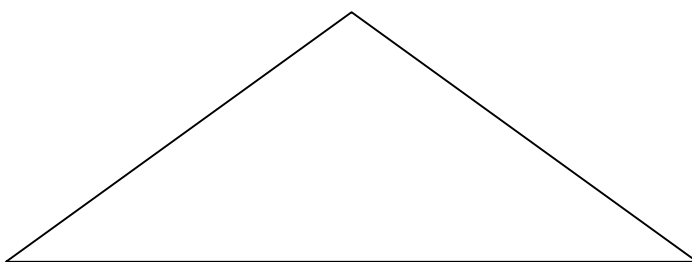
If any one of the three elements can be changed, then the disease triangle can be broken. By learning about the ecology of a disease, you can learn how to break its disease triangle and manage the disease.

Example: Analyzing the disease triangle to plan how to manage a disease (FAO workshop on management of soil-borne diseases, Hai Phong, Vietnam, 1999).

Participants of this workshop, mainly IPM trainers, discussed about disease development, with the objective to develop studies (Participatory Action Research) with IPM farmers on disease management. One of the diseases selected to prepare a disease triangle was bottom rot in cabbage. The following management methods for bottom rot resulted from the discussions:

PATHOGEN

- Practicing proper field sanitation (X)
- Using clean water source
- Uprooting diseased plants for composting (X)
- Practicing crop rotation



HOST PLANT

- Using less susceptible variety (including non-diseased seedlings and healthy plants) (X)
- Applying fertilizer properly (X)
- Keeping sufficient moisture (X)
- Practicing proper crop timing (X)
- Practicing crop rotation (X)
- Prepare field carefully
- Make high beds for good drainage
- Buying varieties from reliable shop

ENVIRONMENT

- Practicing proper crop timing (X)
- Using compost (to improve soil structure, increase soil nutrients, reduce soil-borne pathogens, strengthening activities of beneficial organisms) (X)
- Applying good irrigation methods
- Using *Trichoderma* (a beneficial fungus)
- Using proper transplanting density
- Not flooding furrows
- Proper weed control
- Applying lime (X)

(X) = already being done by all Vietnamese farmers (according to workshop participants).

10.8 Disease management: where to start?

Disease management starts with the identification of the problem. Once you have found the cause of the problem, and that it is a disease, the easiest way is to check if there are any changes you can make in the ecosystem that would help prevent the disease. For example, start with: where does the disease live before it enters your tea field? Maybe you can eliminate it at the source. How does the disease spread? Maybe you can prevent it from entering your field, or spreading from one bush to another.



Disease management: a matter of prevention

Knowing the characteristics of a disease will give you clues on how to manage it!

The table below summarizes some sources and carriers for important tea diseases.

DISEASE	SOURCE(S) and/or CARRIER(S)						
	contaminated seedlings or transplants	leaves or roots of infected tea plants	trees other than tea	soil	contaminated water	carried by wind	contaminated tools, people
blister blight	-	+	-	-	-	+	-
gray and brown blights	-	+	-	-	-	+	-
wet leaf blight	-	+	-	-	-	+	-
horse hair blight	-	+	-	-	-	+	?
bud decay	-	+	-	-	-	+	?
dead twig diseases	-	+	-	-	-	+	+
bacterial shoot blight	-	+	-	-	+	+	+
root rots	+	+	+	+	-	-	-
nematodes	+	+	+	+	+	-	+

The “+” symbols show what the important sources and carriers for a disease may be. The first step to managing the disease is to see if these sources/carriers can be influenced. By eliminating or reducing a source or a carrier of pathogens, disease may be reduced! Some examples of management practices are listed below. This list is not complete, check sections on individual diseases for a complete set of management practices.

<u>contaminated seedlings or cuttings:</u>	sanitation in the nursery, destroy infected plants before transplanting
<u>infected tea plants:</u>	pruning and burning infected leaves or stems, uprooting and burning diseased plants
<u>soil:</u>	crop rotation, soil sterilization or antagonists (for small areas)
<u>contaminated water:</u>	avoid planting down-hill of an infected field,
<u>carried by wind:</u>	cooperation with other farmers for sanitation practices, covering compost piles, windbreaks (though usually of limited value), apply compost teas to protect plants?
<u>contaminated tools, people:</u>	clean pruning tools between bushes, be careful not to damage plants when weeding, avoid working in the field when plants are wet.

Another factor to influence disease is the environment (see disease triangle, section 10.5). When you know what environmental factors stimulate or inhibit the disease, you can sometimes influence these. Soil temperature may be influenced by mulching; humidity can be influenced by proper drainage of the field, using proper planting density, etc.

Even with all the knowledge, it remains a difficult task to manage diseases. When all preventive activities fail, there may not be another option than to use a fungicide (see Section 10.10). However, from an ecological and an economical point of view, there is a lot to gain by setting up small experiments to test when and how to apply fungicides, to control diseases in your field, this season. Remember that natural enemies of insect pests, and antagonists that act as natural enemies of pathogens, may also be harmed by fungicide sprays.



Related exercises from CABI Bioscience/FAO manual:

- 1.4. Effect of pesticides on spiders and other natural enemies
- 3.6. Disease triangle to explain disease management
- 3.7. Demonstration of spread of pathogens
- 3.11. Simulating pathogen spread

10.9 Antagonists: the Natural Enemies of pathogens

Not only insects, but also plant pathogens have natural enemies. These are usually also fungi, bacteria, nematodes or viruses which can kill plant pathogens, reduce populations, or compete for nutrients or attachment to a host plant. Such micro-organisms are called *antagonists*. Sometimes, the term "biofungicide" is used for antagonists

Antagonists of pathogens are not yet well understood. However, the research that has been done has given promising results, and the study of antagonists has become a rapidly expanding field in plant pathology. When the environmental conditions are stable, such as in greenhouses, antagonists can completely protect plants from pathogens. In the field, disease control is likely to be more variable because the environmental conditions change from day to day (mainly temperature, moisture, nutrient availability, and pH). More research is needed on proper methods for the multiplication of antagonists as well as ways to formulate them so that they are convenient for farmers to apply. However, some examples of successful field use of an antagonist are described below.

Antagonists: how do they work? Some examples:

The fungus *Gliocladium virens* reduces a number of soil-borne diseases in three ways:

1. it **produces a toxin** (gliotoxin) that kill plant pathogens,
2. it also **parasitizes the pathogens** (uses them as food),
3. it **competes with pathogens for nutrients** and organic matter in the soil.

The biocontrol capacity of the fungus *Trichoderma harzianum*, recommended for control of several soil-borne pathogens, **competes with pathogens for nutrients** in the soil. *Trichoderma* fungi also **outcompetes pathogens for growing space in the area around the plant roots**, thereby preventing or reducing the impact of pathogens.

Others may **block the entry place** to the host plant. For example, when *non-pathogenic Fusarium* spp. blocks the entry, pathogen species of *Fusarium* cannot infect the plant.

Source: Copping, The Biopesticide Manual, 1998.

10.9.1 *Trichoderma* for root diseases and pruning wounds

The most "famous" antagonist is probably the fungus *Trichoderma*. *Trichoderma* species are produced and used in several countries in Asia, including Thailand, Philippines, Vietnam, and Indonesia (FAO-ICP Progress report '96 - '99). For example, the National Institute of Plant Protection (NIPP) in Ha Noi is producing *Trichoderma* sp. for use by farmers.

When applied to soil, *Trichoderma* fungi can suppress many root-rot pathogens. In addition, *Trichoderma* fungi often promote plant growth, maybe due to their role as decomposers. They may also aid in promoting soil fertility.

Some species of *Trichoderma* help heal the pruning wounds on pruned trees, by enhancing release of auxin (hormones) by the tree. Specific formulations of *Trichoderma* are commercially available to treat pruning wounds of trees.

Some *Trichoderma* species are:

- Trichoderma harzianum* – suitable for warm, tropical climates
- Trichoderma parceramosum* – suitable for warm, tropical climates
- Trichoderma polysporum* – suitable for cool climates
- Trichoderma viride* – suitable for cool climates and acid soils
- Trichoderma hamatum* – can tolerate excessive moisture
- Trichoderma pseudokoningii* – can tolerate excessive moisture

Gliocladium virens (previously known as *Trichoderma virens*) was the first antagonistic fungus to get approval of the Environmental Protection Agency (EPA) in the USA for registration. *Trichoderma* is often used as a spore suspension on carrier material such as rice bran. It can be used both to prevent and to cure plant diseases. However, application before pathogens are visible, as a prevention, always gives the best control. So, *Trichoderma* should be mixed into the soil a few days before planting or transplanting, or applied to pruning wounds immediately after pruning.

☹️ A negative effect of *Trichoderma* has been reported on mushrooms. *Trichoderma* can harm mushroom cultivation, possibly due to killing or inhibiting the mushroom fungi. More research is needed to study these effects, but in the meantime it is advisable not to use *Trichoderma* close to a mushroom production area (Harman et al., 1998).

10.9.2 Other antagonists

Although *Trichoderma* is already famous, many other antagonists may be interesting as well. In Philippines, for example, a fungus called Bioact strain 251, was isolated from the soil which controls nematodes. Spore solutions of this fungus are now commercially available as “Bioact” (FAO Dalat report (V.Justo), 1998).

Antagonists have been applied to the above-ground parts of plants, to the soil and roots, and to the seeds before planting. For example, one way to apply antagonists to the leaves is in the form of “compost teas” (see the box below).

Compost "teas" or extracts

These are water extracts of compost, also called *compost teas*. Compost teas seem promising as preventative sprays to suppress certain leaf diseases, and as a method to restore or enhance the population of micro-organisms in the soil. A number of researcher report that compost extracts were effective in the control of diseases such as late blight (*Phytophthora infestans*) of potato and tomato, Fusarium wilt (*Fusarium oxysporum*), and gray mold (*Botrytis cinerea*) in beans.

Compost extracts enable biocontrol of plant pathogens through their action on the leaf surface and on micro-organisms that are present there. A wide range of mechanisms, such as induced resistance, inhibition of spore germination, antagonism, and competition with pathogens, seem to contribute to the suppressive effect.

Factors influencing the efficacy of compost extracts include: age of compost; source of compost (animal manure based composts retain activity longer than composts solely of plant origin); type of target pathogen; method of preparation; mode, timing and frequency of application; and meteorological conditions. The efficacy of compost extracts can be enhanced by adding beneficial micro-organisms.

The methods by which compost water extracts are prepared are changing as growers and researchers try new methods. One method is to mix compost with cool tap water . The volume of the water should be about 5 -8 times the volume of the compost (for example, 10-16 liters of water mixed with 2 liters of compost). This mixture is stirred once and then allowed to soak for several days. Different people recommend different soaking times, but most recommend from 3-7 days. After soaking, the solution is strained through cloth and then applied with ordinary sprayers. Farmers can use farm-produced composts to experiment with extracts, and test its effects on diseases.



Related exercises from CABI Bioscience/FAO manual:

3.5. Beneficials among the pathogen groups

10.10 What about fungicides...?

Available fungicides and bactericides are often not effective enough to stop any of the major tea diseases, especially during prolonged periods of wet weather. Fungicides (if at all necessary) should always be combined with changes in how the tea is grown, such as sanitation, mulching, choice of tea varieties, etc.

No recommendations for the use of specific fungicides will be given in this guide. The types, brands, and doses of fungicides change frequently. Consult your local Plant Protection Station or Extension Center for specific recommendations. Also see Chapter Twelve for botanical fungicides.

Some key points to know about chemical fungicides:

- There are few effective sprays against bacterial diseases! As the name implies, "fungicides" are intended to be used against fungi.
- There are no sprays against virus diseases! (usually insect vectors should be prevented from entering the crop in areas where virus diseases are a problem). Fortunately, virus diseases of tea have not been reported in Viet Nam.
- Using fungicides to control soil-borne diseases usually is not effective: it depends on the pathogen how deep below soil surface it can live and it is unclear how deep the fungicide will go. Some pathogens live inside plant debris in the soil, where they are protected from fungicides. From an environmental point of view, it is dangerous to apply fungicides to soil. What is the effect on the beneficial micro-organisms that decompose organic matter? Will the fungicide contaminate the ground water? How long will the fungicide persist in the soil?
- Frequent use of fungicides may lead to fungus resistance to that type of fungicide. That means the fungus can no longer be controlled by the fungicide. So, if you must spray more than once per season against the same disease, try to use a different fungicide each time.
- Many fungicides can actually kill natural enemies of insect pests! For a study example, see box in Chapter Eight.



Calendar spraying

The application of pesticides at regular, fixed intervals during the season is known as calendar spraying. This practice can be effective in disease control, but may lead to excessive fungicide use or poorly timed applications over the duration of the growing season, resulting in a loss of money for the farmer and environmental pollution. More important, calendar spraying is not based on what is actually happening in the field, on agro-ecosystem analysis. It does not account for presence of beneficial micro-organisms like antagonists, tea growth stage, weather conditions etc. Therefore, from an ecological point of view, **calendar spraying should be discouraged whenever a better decision-making system, based on actual crop conditions, is available.**