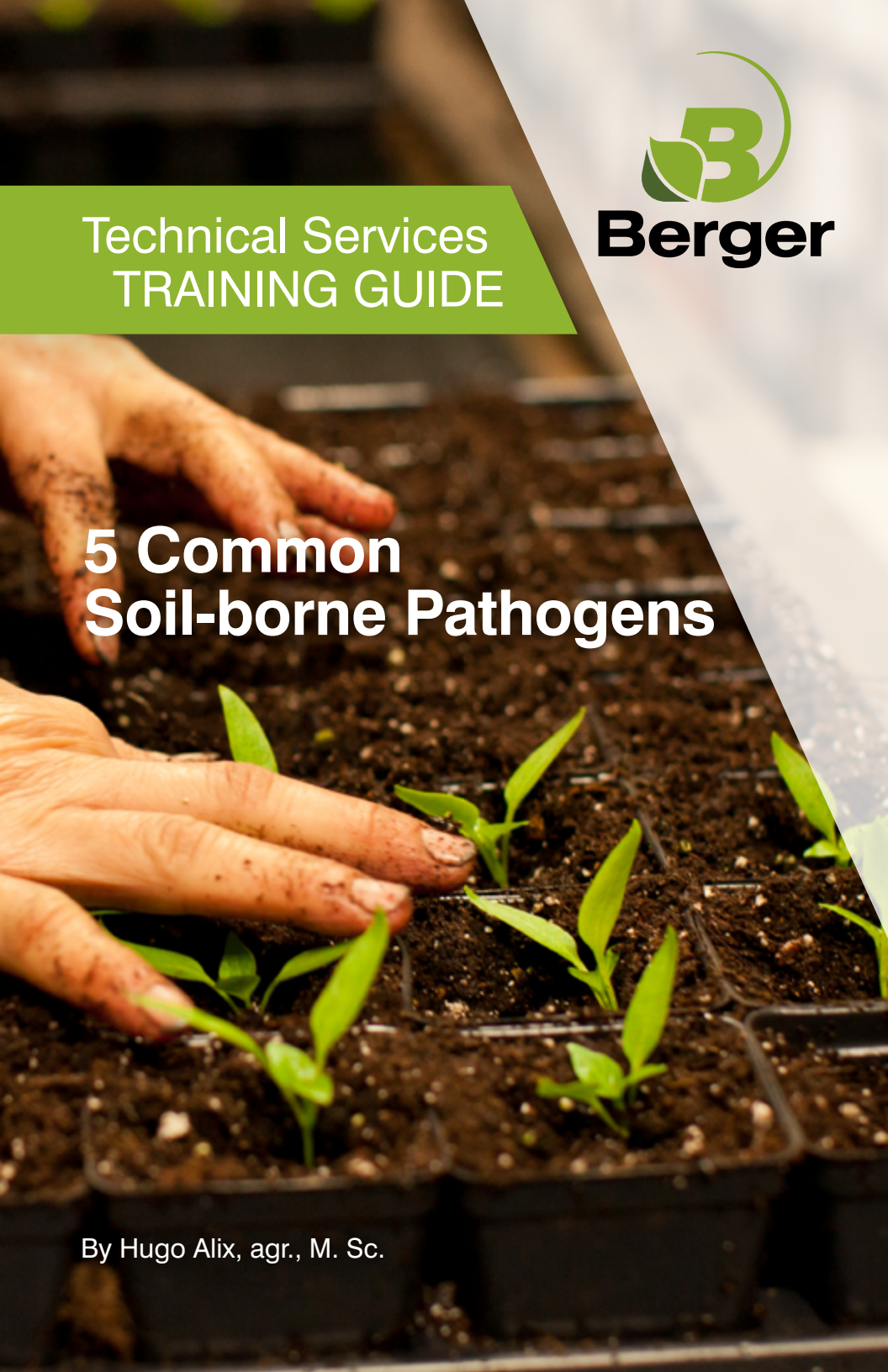
Technical Services
TRAINING GUIDE

Berger

5 Common Soil-borne Pathogens



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Introduction

The production of high value-added crops pushes growers to maintain more precise control over their environments, which is even more relevant in a context where the aim is to combine local production with increased productivity per unit of area. Today's technologies allow us to produce more on a smaller area, but the downside is that when a problem arises, it can have a major impact much greater than on more extensive production. The goal of this guide is to provide you with some tools to better prevent the emergence of soil diseases.

Factors influencing the development of diseases

Fertilization, pH, salinity of the substrate and water quality

The concentration of soluble salts, measured by the electrical conductivity (E.C.), and the pH of a substrate depend on the quantity, quality and type of fertilizer, water and substrate used. E.C. and pH are the two chemical parameters that you must absolutely monitor since they allow you to detect possible anomalies related to the fertilizers or the water source used (e.g., collective water, rainwater, wells, recycling, etc.).

These two parameters must be adjusted according to the species cultivated in order to have optimal growth and a healthy plant. A plant with all the nutrients needed at a proper time will be a vigorous plant and more resistant against pathogens attacks.

Lighting

Light is an essential parameter that you must control in your greenhouse. Because of weather variations and climate changes (seasonal or one-time events), it is essential to adjust the amount of light reaching the plants. Shading systems must be successfully adjusted to use natural light to its full potential, without causing damage to plants due to excess light. Spring and fall are two periods when frequent adjustments are necessary. Light-related damage will not directly affect the development of soil diseases, but it could weaken the plants, thereby opening the doors to diseases.

Temperature and humidity

Temperature and humidity are two other climatic factors that you need to control in order to achieve optimal plant development. These two parameters can play a major role in the development of soil diseases. A cool and humid environment provides ideal conditions for the development of many pathogens. It is therefore important to maintain an optimal temperature and humidity to avoid excessive temperature gradients, non-homogeneous air circulation, condensation, etc.

Winter is a season when you need to pay special attention to the temperature at night. If you hope to reduce your heating bill by lowering the temperature by a few degrees, you may observe the development of diseases or cold-damaged plants (chilling injury) (Pennisi and Thomas 2015). Also, a poorly maintained heating system, especially if it runs on diesel or gasoline, can produce gases that are harmful to plants. Ethylene is one of them. As a precaution, you may want to keep a few tomato plants as an indicator since they are very sensitive to ethylene, even at low concentrations.

Irrigation practices

Your irrigation practices can have a big influence on the spread of disease in your greenhouse. If you manually water your plants from the top, splashes can spread disease. Combined with wet foliage this creates an ideal environment for their growth. Capillary mats, an Ebb and Flow system, and drip irrigation are irrigation techniques that reduce the risk of disease propagation.

The volume, frequency and timing of irrigation are also important and greatly influence the occurrence of soil diseases. Watering with too much water, even at a low frequency, can lead to asphyxiation of the roots. The opposite is also true: watering your plants too frequently, even with small amounts of water, can also asphyxiate the roots of your plants. Similarly, if you bring too much water at the end of the day, the substrate may not have time to drain sufficiently, especially in winter when temperatures drop a lot at night as humidity rises. A subs-

trate that is too wet for too long is not recommended at all and greatly increases the risk of disease outbreaks. It is necessary to have long enough intervals between irrigation episodes to allow the substrate to dry sufficiently.

The source of your irrigation water can also have a direct impact on soil diseases. Surface well should be tested for pathogens such as *Pythium spp*., *Phytophthora spp*. or *Erwinia spp*. Many soil pathogens are transmitted through irrigation water. This is also the case when you recycle your water, it is important to make sure that it is not contaminated before re-injecting it into your system.

Cultivars

When choosing your cultivars, it is important to identify their susceptibilities to different diseases. The goal is not to have the cultivar that is resistant to the greatest number of diseases, but to have the cultivar that is resistant to the diseases that you often face or for which there is strong environmental pressure. Not all plant species have cultivars specifically identified as resistant to diseases, so it is important to use other factors, such as the length of the production cycle, light and humidity requirements, etc., to ensure that it fits perfectly with your geographical area and/or the different climate control options offered by your facilities.

Cleaning and disinfection

The last point, but finally the first one we should all pay attention to: greenhouse sanitation.

Whether it is during the purchase or production of your seeds, cuttings or plants, it is imperative to take all necessary measures to reduce the risk of contamination. If you deal with propagators, verify that their products are certified. Regardless of if they are certified or not, place them in quarantine in an isolated area and if you have the opportunity, take samples and have them analyzed to ensure their safety. Also, ensure that the equipment used has been disinfected and that your employees have been trained on how to limit contamination.

Pythium

Classification (Robert, Stegehuis, and Stalpers 2005)

Class: Oomycetes

Order: Pythiales

Family: Pythiaceae

Genus: *Pythium*

Characteristics

There are more than 300 species of *Pythium* and new ones are discovered every year. A large part of these species are pathogenic and may cause diseases that can be divided into two categories (Department of Plant Pathology and Environmental Microbiology 2021; Watanabe et al. 2008):

- Diseases affecting parts in contact with soil (seeds, roots, tubers, stem bases and fruits);
- Diseases affecting aerial parts (leaves, young stems and fruits).

Environmental conditions dictate which species will thrive: some species will thrive in cool and moist conditions (e.g., *Pythium irregulare* and *P. ultimum*), while others prefer higher temperatures (e.g., *Pythium aphanidermatum* and *P. myriotylum*) (Watanabe et al. 2008). The different species of *Pythium* are found in soils and surface waters all over the world. Like saprophytes or parasites, they live on dead plants or animals and produce different types of spores for breeding purposes (Agrios 2005; Michigan State University 2021):

Sporangia: Produced in or outside the substrate, they can germinate and directly infect plants, or produce zoospores.

Zoospores: They need to evolve in a wet environment with free water to be able to move.

Oospores: They can contaminate various equipment, survive several years in dormancy and move around in irrigation system.

Host plants

Different species of *Pythium* can infect a multitude of various plant species, from annuals to herbaceous and bedding plants (e.g., azalea, begonia, chrysanthemum, marigold, pansy, poinsettia, vinca, zinnia, etc.).

Symptoms

Infections by *Pythium spp*. might cause several diseases, sometimes common to other pathogens, such as damping-off, seed, root, stem, tuber and fruit rots. In pre-emergence, the symptoms result in a rapid degradation of the seeds until their complete destruction (Watanabe et al. 2008). In post-emergence, it is the roots, through browning and rotting of the cortex of the main roots and the pivot, and the part of the stem at ground level that will be infected. The contaminated area will become very humid and the germinated plants will “melt” (damping-off) (Department of Plant Pathology and Environmental Microbiology 2021; Blancard 2021). It is also common to see white mycelium developing on the decaying plants. Damage caused by *Pythium spp.* can also affect well-established plants. Symptoms can be identified on young shoots (wilting and yellowing leaves) or on older parts (aqueous necrotic lesions on the stem and/or leaves) (Ownley and Trigiano 2016).

Photo credit: Margaret Tuttle McGrath, Cornell University

Management

The development of diseases caused by *Pythium spp*. is promoted by (Gill and Smith-Fiola 2016; Agrios 2005):

- A substrate kept too wet
- A temperature generally too low, or too high depending on the species
- A high content of soluble salts
- An excess of nitrogen fertilization
- An infestation of shore flies or fungus gnats, which act as a vector of transmission

In order to control the development and growth of *Pythium spp.*, it is very important to monitor your greenhouse temperature and crop irrigation to ensure that the substrate is not saturated with water or kept wet for too long. It is essential to pay special attention to the transplants you purchase in order to detect a possible onset of root rot. Finally, like many other diseases, it is important to keep a clean and disinfected work environment: pots, working tables, storage areas, machines, pruning shears, watering knob, etc.

Photo credit: Margaret Tuttle McGrath, Cornell University

Phytophthora

Classification (Robert, Stegehuis, and Stalpers 2005)

Class: Oomycetes
Order: Peronosporales
Family: Peronosporaceae
Genus: *Phytophthora*

Characteristics

The word "*Phytophthora*" which comes from the Greek "Phyton" (plant) and "Phthora" (destroyer), means "destroyer of plants" (CNRTL 2012; H Ho 2018), and rightly so. There are more than 100 species, but this number is constantly going up due to the advancement of analytical methods (Ownley and Trigiano 2016). A large part of *Phytophthora* species cause diseases that affect seeds, transplants, mature plants, fruits or even trees. Several of them are common to those caused by *Pythium spp*. and can therefore sometimes be confused. Most of the species induce diseases, such as root rot, damping-off, stem rot (part close to the ground), tuber or bulb rot. However, some species can attack the buds, the fruit, or even burn the foliage and young branches (Agrios 2005). The best known species are *P. infestans* for potato and tomato late blight, *P. cinnamomi* for rhododendron wilt and *P. ramorum* for sudden oak death (Ownley and Trigiano 2016; Agrios 2005) (see Table 1 below).

Table 1. Examples of the most common diseases caused by *Phytophthora spp.*

Phytophthora spp.	**Diseases**
P. fragariae	Red stele of strawberry
P. megasperma	Root and stem rot of soybean
P. parasitica	Black shank of tobacco
P. citrophthora	Foot rot of citrus
P. cinnamomi	Root rots of forest and nursery crops and avocado
P. capsici	Cucurbits (squash, pumpkins), tomato, peppers
P. ramorum	Sudden oak death (SOD)
P. infestans	Late blight of potato and tomato
P. palmivora	Black pod of cacao

Source: Ownley and Trigiano 2016.

Many cases of infection by *Phytophthora spp.* are poorly detected, especially on plants at an advanced stage of development. Although there may be apparent symptoms (e.g., water stress, nutrient deficiency), infected plants are often rapidly weakened and become susceptible to other pathogens. This can lead to confusion as to the actual cause of death (Agrios 2005). It is therefore important to act as soon as plants begin to show symptoms in order to determine which pathogen is responsible. The symptoms and damage caused by *Pythium spp*. are very similar, but *Phytophthora spp.* act with much more virulence (Ownley and Trigiano 2016).

The breeding methods for *Phytophthora spp.* are the same as for *Pythium spp.* and both pathogens belong to the same group called "water molds," which means that they prefer free water in the substrate or soil in order to spread.

Host plants

Phytophthora spp. affect both seedlings of annual and ornamental plants, and fruit trees (Agrios 2005). Woody plants are, however, the most affected by *Phytophthora spp.*

Symptoms

Symptoms can develop on roots as well as on buds, leaves and stems. Symptoms typically result in (B.C. Ministry of Agriculture 2017; Agrios 2005):

- Root rot (destruction of rootlets and brownish necrotic lesions on the main roots)
- Leaf rot
- Water stress
- Nutrient deficiencies
- Leaves yellowing

Sometimes it is difficult to diagnose contamination by *Phytophthora spp.*, either because the symptoms are not sufficiently developed or because it looks like symptoms of other diseases that have become established as a result of the plant's diminished defenses. In this case, in order to know which pathogen is present, the most reliable option is to have samples analyzed by a diagnostic laboratory, requesting a

DNA test. Although this method will not be able to tell you whether the organism detected is still alive or already dead, it is nevertheless an excellent way to get a more precise idea of the situation.

Management

The best way to get rid of an infection by *Phytophthora spp.* is to prevent its occurrence.

As for *Pythium spp.* it is important to control your irrigation, to adjust the frequency, the number of drippers, the volume of water, and this, according to each species of plant. If your installations do not allow you this flexibility, you can always use different substrates with different porosity grades in order to have a substrate adapted to each of your crops.

Several factors can promote the infection by *Phytophthora spp.*:

- Substrate with high pH and/or electrical conductivity
- Inadequate soil temperature (influences the *Phytophthora* species that will establish itself)
- A substrate that is too moist

Other preventive measures exist, such as the use of resistant cultivars, the inspection and quarantine of purchased plant material as soon as it is received, or the implementation of a cleaning and disinfection protocol: an element which, today, should be almost systematic.

Photo credit: TriCal

Thielaviopsis

Classification (Robert, Stegehuis, and Stalpers 2005)

Class: Sordariomycetes
Order: Microascales
Family: Ceratocystidaceae
Genus: *Thielaviopsis*

Characteristics

When referring to *Thielaviopsis spp.* we generally think about black root rot, which is actually caused by *Thielaviopsis basicola.* The name of this disease reflects the color of the lesions it inflicts on the roots of infected plants. This black color is due to the black spores produces by the fungus in the tissues of the plants it has infected (Gill and Smith-Fiola 2016). *Thielaviopsis basicola* is spread by spores called chlamydospores which can survive for years in the soil and in equipment such as containers. The germination of these spores is stimulated by certain root exudates, a neutral or alkaline pH, and with an optimal temperature of development between 13 and 22°C (55 to 72°F) in a humid and poorly drained environment (Dubuc 2019; Walker 2008; Lessard and Tousignant 2020).

When black root rot is present, it is almost impossible to eradicate it other than by destroying the contaminated material. It is then necessary to proceed to a complete disinfection of everything that may have been in contact with the fungus, otherwise it will recur in the next crop.

Host plants

This fungus is susceptible to contaminate many species of woody or herbaceous plants. In greenhouses it is found mainly on pansies, vinca, calibrachoa, fuchsias, cucumbers and tomatoes, and in soil it can be found on tobacco, cotton, palm or pineapple (Lessard and Tousignant 2020; Walker 2008).

Symptoms

Here are the main symptoms that can be observed during an infection by *Thielaviopsis basicola* (Walker 2008; Lessard and Tousignant 2020):

- Growth delay
- Leaves may become chlorotic or purplish
- Wilting and defoliation
- Red and then black longitudinal lesions on infected tissues
- Root rot (presence of black spores inside) and stem base rot
- Reddish-brown lenticels

It should be noted that the diagnosis of this disease cannot be made only with an analysis of the aerial part of the plants, the symptoms being too common to other diseases, it is essential to examine the roots.

Management

The development of *Thielaviopsis basicola* is promoted by various factors (Gill and Smith-Fiola 2012; Walker 2008; Lessard and Tousignant 2020):

- A neutral or alkaline pH
- A humid and poorly drained environment
- A contaminated environment that is not cleaned and disinfected regularly
- The presence of shore flies or fungus gnats that act as transmission vectors
- The creation of splashes during irrigation

As already mentioned, once black root rot is present, it is almost impossible to get rid of it without removing everything that is infected. It is therefore important to start a crop in a clean and disinfected environment and with clean and disinfected equipment. It is also necessary to be very vigilant when transplants are purchased: establish a quarantine in an isolated place and, in case of doubt, have samples analyzed to detect the presence or absence of pathogens.

Photo credit: Margaret Tuttle McGrath, Cornell University

Rhizoctonia

Classification (Robert, Stegehuis, and Stalpers 2005)

Class: Agaricomycetes
Order: Cantharellales
Family: Ceratobasidiaceae
Genus: *Rhizoctonia*

Characteristics

The different pathogenic species of *Rhizoctonia* (the best known being *Rhizoctonia solani*) can grow under various environmental conditions and are often associated with diseases such as root rot, damping-off or stem canker (B.C. Ministry of Agriculture 2017).

This fungus grows preferably in the first few centimeters of the substrate, where the environment is drier/moderately wet (does not tolerate water-saturated or very dry environments) (Gill and Smith-Fiola 2016; Agrios 2005). It produces small (1 mm) and very resistant black sclerotia that can remain present in the soil indefinitely (B.C. Ministry of Agriculture 2017; Agrios 2005). Like many other pathogens, it can be spread via irrigation splashes, or directly in irrigation water. For most species, the optimal temperature for infection is between 15 and 18°C (59 to 64°F), but some can remain active up to 35°C (95°F) (Agrios 2005). The more plant growth is slowed down due to poor environmental conditions, the greater the risk of infection.

Host plants

The different species of *Rhizoctonia* attack almost all vegetables and ornamental flowers, several field crops, lawns and even ornamental perennials, shrubs and trees (Agrios 2005).

Photo credit: TriCal

Symptoms

Symptoms developed by plants can vary according to the infected species, the growth stage and the environmental conditions (Agrios 2005). However, the main symptoms observed are (Agrios 2005; B.C. Ministry of Agriculture 2017):

- Damping-off
- Root rot (reddish-brown and “dry” appearance)
- Stem rot or canker
- Lesions (burns) or spots on the leaves (those close to the substrate): occurs when the plants are too close together with a high air humidity
- Rotting of storage organs

Management

The control of the different pathogenic species of *Rhizoctonia* is very difficult. As for all other pathogens, but especially for this one, it is imperative to prevent its emergence. Even if some preventive chemical treatments can be recommended, only few are curative. The best solution remains the implementation of sanitary protocols for managing inputs, cleaning and handling. It is very important to inspect any plant material purchased outside and to quarantine it in an area isolated from the rest of the facility. It is also important to train staff on the practices to be adopted in order to avoid any risk of external contamination or internal spread if the pathogen does manage to enter. You can also sterilize your containers and/or substrate, and tools before use/re-use (Gill and Smith-Fiola 2016).

There are parasitoid microorganisms such as fungi, myxobacteria or mycophagous nematodes that can help reduce the impact of pathogenic *Rhizoctonia* species. It has also been shown that, on tomatoes, the addition of zinc can reduce the damage caused by *Rhizoctonia* (Van Alfen 2014). Moreover, adding calcium to the fertilization program strengthens the cell walls and increases their resistance to *Rhizoctonia* (and other pathogens) penetration (Agrios 2005).

Fusarium

Classification (Robert, Stegehuis, and Stalpers 2005)

Class: Sordariomycetes
Order: Hypocreales
Family: Nectriaceae
Genus: *Fusarium*

Characteristics

Fusarium spp. are necrotrophic pathogens extremely problematic in field crops, although they can do just as much damage in greenhouses. There are two main species responsible for most of the plant infections (Agrios 2005; MAAARO 2014):

- *Fusarium oxysporum*: responsible for fusarium wilt on many species
- *Fusarium solani*: cause roots, tubers, bulbs, stems (canker) and seeds rots, in addition to producing mycotoxins

It should be noted that these two species can also, like *Fusarium verticilloides*, *F. moniliforme* and many others, be pathogenic to humans (Dismukes, Pappas, and Sobel 2003).

Fusarium spp. are spread though chlamydospores (resistant spores that can survive for years in soils) and conidiospores that can move through water splashes, dust, hands or tools. Again, establishing a good sanitation procedure is a key element in the fight against *Fusarium spp*.

Host plants

Fusarium spp. affect cereal crops, vegetables, fruits, ornamental plants and trees. This is what makes this pathogen a major cause of yield reduction when it is present.

Symptoms

The symptoms of *Fusarium spp*. are similar to other soil pathogens (damping-off, rots, etc.). In the case of Fusarium wilt, the xylem vessels will wilt and show a brown or reddish discoloration. This symptom is specific to certain species, such as basil, cyclamen or chrysanthemum, while root rot generally attacks a greater number of species (Gill

and Smith-Fiola 2016). Infected root tissue usually turns red to dark brown, sometimes in the form of streaks on the roots or petioles.

With *Fusarium lateritium*, the stem canker often produces masses of orange spores, which are very characteristic, whereas this is uncommon with *Fusarium solani*.

Plant growth is generally delayed, the old leaves tend to turn yellow while the younger ones become stunted and mushy. The infection by *Fusarium spp*. often appears at the approach of flowering (MAAARO 2014).

Management

The development of *Fusarium spp*. is closely related to environmental variations. It is necessary to avoid (MAAARO 2014):

- Temperature variations
- Too high air humidity
- Over-fertilization (especially in ammonium) when the plants are already under stress
- Heterogeneous irrigation and in the extremes (too wet, too dry)
- pH variations

Once again, prevention is a must as well as the need to establish sanitary protocols and employee training. It is essential to monitor for any symptoms, on the aerial parts or on the root system, to act quickly when an infection is suspected: eliminate the affected plants and disinfect what may have been contaminated.

A healthy plant will be less likely to allow any pathogen to enter. Some studies also shown that, indirectly, the extra addition of zinc could stimulate the activity of *Pseudomonas aeruginosa* and *P. fluorescens* against *Fusarium* pathogenic species (Van Alfen 2014). On the other hand, high levels of iron and manganese could promote fusarium wilt (Agrios 2005).

Photo credit: Margaret Tuttle McGrath, Cornell University

Chemical and biological management

Chemical and biological controls exist for the various diseases mentioned above. It should be noted, however, that the certification of active ingredients used in fungicides may vary from country to country. The same is true for biological control agents, although this is less frequent. Moreover, the availability of the different chemical products often varies. That is why we recommend that you refer to a representative who can supply you with phytosanitary products.

There are several bacteria and fungi able to provide an effective control against several soil diseases (see Table 2 below).

Table 2. Main biological control methods for the five most common soil diseases.

	Pythium	***Phytophthora***	***Thielaviopsis***	***Rhizoctonia***	***Fusarium***
Bacteria					
Bacillus subtilis	x	x		x	x
Burkholderia cepacia	x			x	x
Pseudomonas aeruginosa					x
Pseudomonas aureofaciens	x				
Pseudomonas chlororaphis					x
Pseudomonas fluorescent	x	x	x	x	x

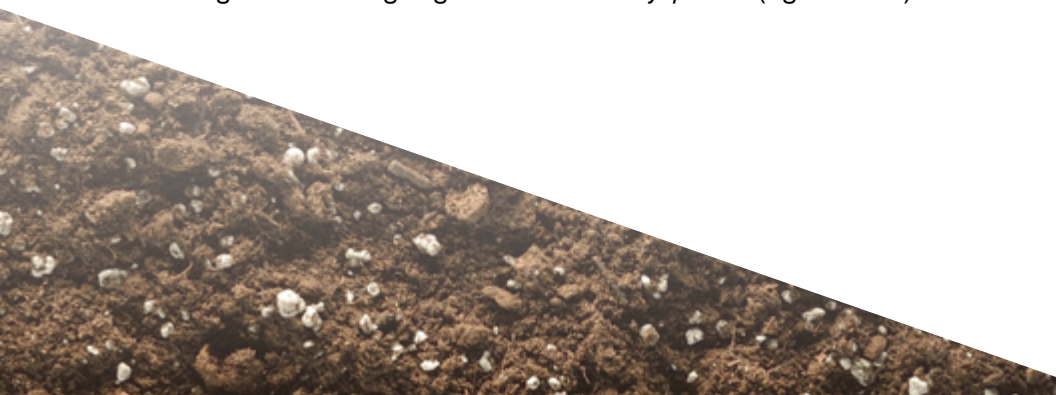
Table 2. Main biological control methods for the five most common soil diseases. (suite)

	Pythium	*Phytophthora*	*Thielaviopsis*	*Rhizoctonia*	*Fusarium*
Fungus					
Gliocladium catenulatum	x	x		x	
Streptomyces griseoviridis	x	x		x	x
Streptomyces lydicus	x	x		x	x
Trichoderma hamatum	x	x	x	x	x
Trychoderma harzianum	x		x	x	x
Trichoderma virens	x			x	x

Adapted from Agrios 2005; Gill and Smith-Fiola 2016; MAAARO 2014; Van Alfen 2014.

In addition to these different fungi and bacteria, there are “protective” species within the genus to which the pathogenic species belong, such as *Pythium nunn* and *P. oligandrum*, which can protect ornamental plants and vegetables from pathogenic species belonging to the genus *Pythium*.

Finally, mycorrhizae can also have an indirect beneficial effect by facilitating the plant’s access to nutrients and water, thus improving its vigour. Mycorrhizae have been shown to provide good protection for pine seedlings against *Phytophthora cinnamomi* and for tomato and Douglas fir seedlings against *Fusarium oxysporum* (Agrios 2005).



Why invest in a quality substrate

While reading through the information in this guide, you probably realized that the main factors influencing the incidence of soil diseases can be kept under control. While some parameters must be managed by the grower, the initial characteristics of the growing media should be handled by the soil supplier. Berger's expertise and know-how allow us to offer you a quality substrate that is easy to manage. This uniform structure and chemistry help mitigate the risks of soil diseases.

When purchasing a professional grade substrate, here is what Berger offers and you should expect from your supplier:

- Optimal ratio and blending of all the ingredients
- Great porosity providing adequate drainage and allowing gas exchange around the root system
- Stable structure and pH adapted to your needs
- Free of pathogens, pests, and weeds
- A uniform substrate from pot to pot and from production to production

Adequate water movement is critical in the fight against soil diseases. If the dynamics of water retention and drainage aren't well adapted to the growing conditions, the root environment may become more favorable for pathogens thus increasing the chances they will develop and thrive. Our quality control system assures you receive a homogeneous product with the desired physical characteristics. The predictable behavior of our growing media helps prevent the incidence of diseases.

Purchasing a high-quality substrate with optimal initial characteristics is essential, but how the growing media is handled is just as important. Here are a few key elements that should be respected to preserve the properties of the product:

- Store the substrate in a clean area, protected from sunlight, external contaminations (weeds, pathogens carried by wind/dust, etc.) and bad weather.
- Adjust the moisture content (55-65%) prior to potting to maximise the useable volume, reduce the presence of dust and optimize the porosity.
- Minimize handling and avoid damaging the growing media during the fluffing and potting operations as this may reduce the particle size and porosity of the product.
- Do not compact the substrate in your containers. If you are stacking pre-filled containers, avoid nesting them into the containers below by staggering them or using separators between the levels.

Upon request, Berger has the capability to include specific biofungicides into our products as a preventative measure. These add-ons are applied and blended homogenously during the manufacturing process to create custom blends adapted to your needs, saving you the hassle of doing it yourself. Finally, as a Berger customer, you also have access to a team of technical advisors, agronomists and biologists that can help you with crop management, disease identification, implementation of trials, and many more. Contact your Sales Representative for more details.

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Berger's Technical Services Team is there to provide support and assist you with technical questions and concerns.

- Review laboratory results
- Help set up and follow trials
- Help solve growing issues
- Give training sessions

Make sure you get the most out of it!

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