# IDENTIFICATION AND CONTROL OF MAJOR DISEASES AND INSECT PESTS OF VEGETABLES AND MELONS IN GEORGIA

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# PREFACE

Horticultural crops are a significant and expanding component of agriculture in Georgia. Open-field horticultural crops production in 2015 has been estimated to be 48,000 hectare (ha), and about 200 ha for year-round greenhouses vegetable production. According to the National Statistics Department of Georgia, the 2014 vegetable production covered less than 50% of the per capita demand of about 93 kg.

The shortage in vegetable production is offset by imported products from neighboring countries like Turkey and Iran and from other sources overseas. Despite significant efforts from the Ministry of Agriculture to increase production over the past several years, the average yield per hectare of important horticultural crops has not increased significantly. The low yield is partially due to the fact that most vegetable production is done by small farmers who have difficulty accessing information for successfully controlling pests, for applying proper fertilizers, and for obtaining high quality seeds and other planting material, like vegetable varieties that are disease resistant or have other favorable horticultural characteristics, that will help them cover the high demand for vegetables in the country. Currently, there are approximately 43,430 small vegetable farmers in Georgia. Most of these small farmers are highly motivated to adopt innovative production techniques to help increase the production on their farms.

This book provides information to help Georgian vegetable farmers recognize important plant diseases and insect pests affecting their crops and to develop and employ strategies for their control. The first chapter is an introduction highlighting the general principles of plant pathology for vegetables and melons. The chapter also discusses integrated concepts of disease management, which will be helpful in implementing correct preventive measures to reduce the risk from diseases. The second part of the book deals with diseases (caused primarily by bacteria, fungi and viruses) affecting specific vegetables such as tomatoes, cucumbers, cabbages, and other important vegetable crops and melons grown in Georgia. Vegetables and Melons covered in the booklet are ordered according to the Georgia alphabet. The field guide provides photos and charts, which will help users identify diseases by symptoms. The field guide also contains disease management strategies, which were developed to include the use of currently registered disease control chemicals (primarily fungicides) that have been approved by the Georgia Ministry of Agriculture.

Publication of this booklet is funded by USAID as part of the Strengthening Extension Advisory Services in Georgia (SEAS) Project. The authors of the field guide are Prof. Vladimer Baramidze, Mr. Andro Khetereli, and Dr. Mosbah Kushad. Editors include Dr. Mike Ellis, Mr. Ben Mueller, and Dr. Roger Williams. Special thanks are given to Dr. Roland Smith, Ms. Lisa Basishvili, Lucas Leanne, Bentsen Molly, and all members of the project.

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# CONTENT

## PLANT DISEASE

Plant diseases represent a complex problem, the same as diseases of humans and animals. Damage caused by diseases is manifested both in radical decrease of productivity and loss of quality of commodity value of produce. It is currently calculated that pests, diseases, weeds, etc. destroy half of the products grown in the world. Along with the increase of human population numbers, demand for food products is growing daily, which gives greater significance to knowledge and prevention of plant diseases.

Healthy plants can be grown only if we understand what the causal agents of plant diseases are. It is also important to know how they spread and how we can limit their spread in order to effectively manage them. Plant diseases can generally be divided into two large groups. There are abiotic diseases, which are not caused by living organisms. They are caused mostly by improper environmental conditions such as excessive heat or cold, excessive soil moisture and mineral deficiencies in soil. They can also be caused by the misapplication of pesticides, especially herbicides. Biotic diseases are caused by living parasitic organisms such as fungi, bacteria, and nematodes. In order for infection to develop in a plant, existence of the following three main factors is required: a susceptible host plant; environmental conditions conducive to disease development, and the pathogen (Fig 1.0).

Pathogen type and interaction with the host plant are of great importance for disease development. It is also necessary to know the contributing and hindering factors of the disease, as well as those environmental conditions (soil, moisture, humidity, meteorological conditions, etc.) in which the plant has to grow and develop. When these factors affect the plant negatively, the plant weakens and becomes susceptible to diseases. If we understand all of these conditions, we will be able to develop effective disease management programs for the disease.

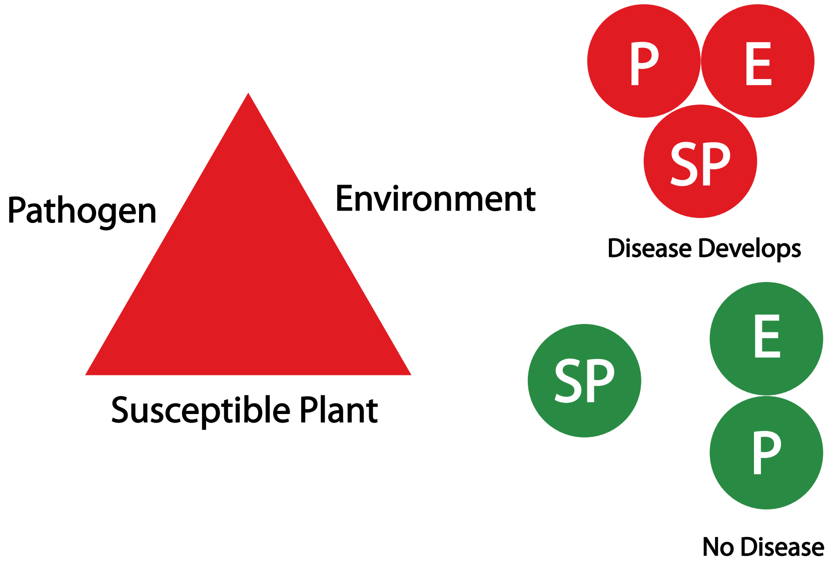



*Figure 1.0 Disease development triangle. (P) Pathogen (E) Environment (SP) Susceptible Plant. In order for the disease to develop, the combination of these three factors is necessary. When one of the factors is lacking, disease does not develop.*

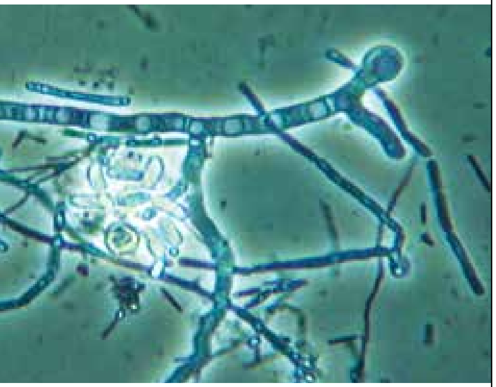


*Figure 1.1 Fungal hyphae. Source: Fungi Kingdom*

## BIOTIC FACTORS (PLANT PATHOGENS)

### Fungi and Fungal-Like Organisms

**Morphology:** Most fungi have a vegetative body composed of filaments, which are called mycelia. Individual branches of mycelium are called hyphae, which are mostly thin and thread-like. The length of mycelia varies from several microns to several meters in different species of fungi. Some fungi contain one or two nuclei in each cell. Others consist of multiple nuclei, which can be separated by a cross wall (septa). Mycelia grow at the ends of hyphal tips. Many fungi produce specialized structures for long term survival in soil such as sclerotia and chlamydospores. They also produce many specialized structures for use in asexual and sexual reproduction (Fig 1.1)

**Reproduction:** Fungi reproduce in two main ways: asexual and sexual reproduction. Fungi which are capable of both sexual and asexual reproduction are called perfect fungi. Fungi that are capable of only asexual reproduction are called imperfect fungi. Asexual reproduction can be vegetative or occur through the production of spores. Vegetative reproduction takes place by means of the fungus mycelium or through the formation of other specialized structures such as rhizomorphs, sclerotia, chlamydospores, and conidia. In asexual reproduction, there is no meiosis (reduction division) and there is no sexual recombination of genetic material. The fungal structures remain the same genetically. During sexual reproduction, meiosis (reduction division) and sexual recombination of genetic material occurs. This results in the production of spores which are genetically different. Different types of fungi produce different types of sexual spores in specialized structures.

**Ecology:** Some types of plant pathogenic fungi known as non-obligate parasites spend part of their life cycle in the living host organism and part of it on plant parts (debris) existing in the soil. Some other types of fungi are known as obligate parasites or biotrophs, which can grow and reproduce only on living host plants during their whole life cycle. Some of these obligate parasites include the fungi that cause powdery mildews, downy mildews and rust diseases. Based on ecology, fungi are divided into the following groups.

- **Non-obligate -** Most plant pathogenic fungi and bacteria can live on either living or dead hosts and on various nutrient media. These are called non-obligate parasites. Non-obligate parasites can be facultative saprophytes or facultative parasites, depending on whether they are parasites or saprophytes.
- **Facultative saprophytes** - can grow on hosts as parasites, but can also continue growing and reproducing on the host's dead tissue. These fungi are mainly soil pathogens, which have a wide range of host organisms and can remain in the soil for many years.
- **Facultative parasites –** are organisms that are usually parasitic but may live as saprophytes in the soils.
- **Biotrophs –** spend their whole life cycle on living host organisms and only their spores or other resting structures can survive in soil or on the surface of plant parts. There they become dormant until they find themselves on the host organism again, where they can infect, reproduce and grow, causing plant diseases.

#### Control

More means exist for control of fungal diseases than for bacterial and viral diseases. In order to properly control fungal diseases, it is first necessary to know, which fungal disease we are dealing with and what its ecology is. The following disease management strategies are currently used for controlling fungal diseases.

**Genetic Resistance:** Currently there are many varieties of vegetable crops that are resistant to specific fungal diseases. For example, there are some hybrid potato varieties, which are resis-tant to Phytophthora (late blight).There are also some tomato varieties with resistance to Fu-

sarium wilt, that can be planted on land infested with Fusarium. When disease resistance is

available for important diseases, it should be used whenever possible.

**Agricultural (cultural) practices:**

- Use of disease-free seeds and planting materials
- Balanced mineral content (fertility) in the soil
- Efficient water management
- Sanitation-removal of infected plants or plant remains (debris;
- Crop rotation
- Growing plants in environments unfavorable for fungal diseases
- Proper harvest handling, in order to avoid mechanical damage, cutting, etc
- Properly selected storage temperature
- Proper spacing and thinning of plants
- Soil solarization

**Chemical treatment:**

- Use of soil fumigants for the control of certain soil borne fungi
- Use of fungicide seed treatment
- Selection and use of effective fungicides for controlling diseases in the field or greenhouse. Emphasis must be placed on protecting the plants from infection
- Post-harvest treatment of produce with fungicides during storage

**Biological control:** Selection and use of effective biological control materials and products when available.

**Quarantine service:** Is used to separate and restrict the movement of infected plant material. The introduction of plant material that may contain diseases is enforced at the borders of Georgia. Before the plant material can enter the country it must have the phytosanitary certificate which is issued by an accredited laboratory that states the material is disease free.

## Bacteria

There are approximately 1600 types of bacteria known in the world (Fig 1.2), some of which are harmful for agriculture and some very useful, as, for example, they take part in disintegration of organic matter. Approximately over 100 types of bacteria cause plant diseases, which has a negative effect on agricultural crops.

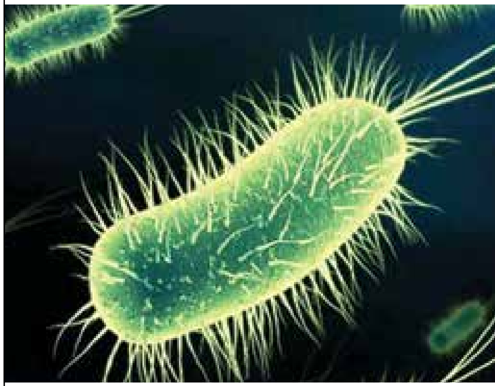


*Figure 1.2 Bacteria, prepared by 3D program. Source: Acuariovida*

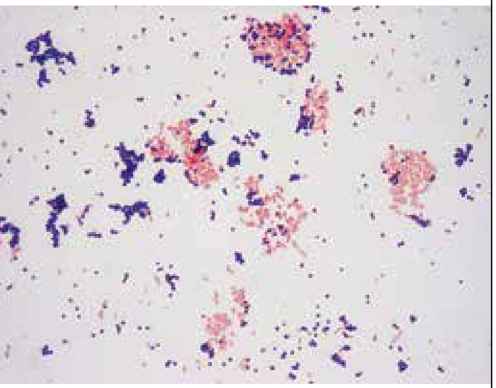


*Figure 1.3 Gram-positive (Blue) and gram-negative bacteria (red). Source: Micro Blog*

Bacteria can be rod-like, spherical, spiral and threadlike (containing filaments). Some bacteria can move through liquid space by means of flagella. Some do not possess flagella at all and are unable to move. Many types of bacteria, at the vegetative stage, reproduce through cell division. Bacterial diseases spread anywhere where it is warm and humid and are extremely severe in humid tropics.

**Morphology:** Most of the plant pathogenic bacteria are rod-like. If rod-shaped bacteria develop spores, they are called bacilli. Cell walls of many types of bacteria are surrounded with a viscous, sticky substance, which is thin and forms a mucous layer. Most of the plant pathogenic bacteria have threadlike branched flagella which makes them mobile. Some types of bacteria have one flagellum each, some have several (polar flagella). Those with a single flagellum are called monotrichous. Lophotrichous bacteria develop flagella on one side, while the surface of peritrichous bacteria is covered with flagella. A small number of bacteria are immobile, while most of them move by means of flagella.

Bacteria, which can be colored based on Gram's Method, are gram-positive, while those that cannot be colored are gram-negative. The difference between gram-positive and gram-negative bacteria is a peptidoglycan layer (Fig 1.3).

**Reproduction:** Rod-like phytopathogenic bacteria reproduce by asexual means, which is known as binary division. This is when cytoplasm internal membrane is divided in the central part of the cell, as a result of which two completely identical parts are created. When cell wall formation is completed, both layers separate, split, and two cells appear. Before the cell wall and cytoplasm separate, this is when genetic material is accumulated, doubled and redistributed between two newly-formed cells. Plasmids are also doubled and redistributed between new cells. Bacteria reproduce extremely quickly. In favorable environment conditions, they reproduce every 20-50 minutes.

**Dispersal:** In most cases, plant pathogenic bacteria mainly develop on host plants as parasites. They live on plant surfaces, especially on buds, as well as on plant wounds and in soil, as saprophytes. There are amazing differences between types, in terms of quality of their development. Phytopathogenic bacteria may exist as biofilms. Some pathogens, e.g. Erwinia amylovora, which causes phytophtorosis on pear, forms a population on the host and develops in uninterrupted infection cycles, from plant to plant, often by means of the insect vector.

Bacteria are transmitted on the same plant, as well as from one plant to another by means of water, insects, other animals and humans. Bacteria themselves can cover only extremely small distances, using flagella. Rainfall also transmits and spreads bacteria from one plant to another, as well as from the soil to lowest parts of the plant. Insects not only transmit bacteria, but also contribute to their inoculation into plants. During their movement, birds, rabbits, etc. spread from plant to plant various types of bacteria, which live on their bodies. Humans transmit them during various agricultural practices, e.g. planting or seed transportation, when infection frequently spreads.

**Control**

Controlling bacterial diseases on plants is more difficult than controlling most fungal diseases. There are very few chemicals for control of bacterial diseases; therefore, the emphasis for controlling bacterial disease must be placed on the use of genetic resistance when available and the use of effective cultural practices.

**Genetic resistance:**

- When available, use varieties with disease resistance against important bacterial diseases

**Agricultural (cultural) practice:**

Use bacteria-free seed and planting material

- Sanitary-hygienic measures: disinfesting workers hands of grafting tools, etc.
- Sanitation: identification and removal of infected plants and infested plant debris from the planting
- Crop rotation

**Chemical treatment :**

- Use of solutions containing copper, in order to minimize the risk of spreading of the disease inoculum
- Application of antibiotics when available; they can reduce the spread of bacteria and aid in preventing infection
- Control disease carriers such as insect vectors.

**Biological control:** Selection and use of effective biological control materials and products when available.

**Quarantine service:** Used to separate and restrict the movement of diseases in plant material. The introduction of plant material that may contain diseases is enforced at the borders of Georgia. Before the plant material can enter the country it must have the phytosanitary certificate which is issued by an accredited laboratory that states the material is disease free.

## Viruses

Viruses are pathogens causing infection, which are so small that it is difficult to see them through light microscopes. The simplest viruses consist of nucleic acid, which is surrounded with a layer of protein. Viruses carry genetic information in nucleic acids, which code three or more proteins. All viruses are obligate parasites, which depend on the host's cell mechanisms for reproduction. Viruses infect all types of organisms: animals, plants, fungi and bacteria.

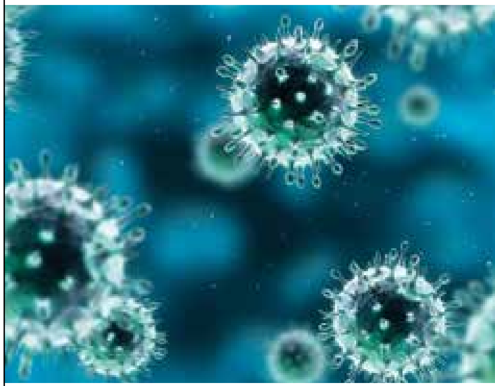


*Figure 1.4 Viral particle, prepared by 3D program. Source: Virologypedia*

**Morphology:** Viruses have a simple structure, which consists of two main parts, nucleic acid and protein. The protein forms a protective shell around the nucleic acid. The protein shell of a virus is called a capsid. Certain viruses have an outer membrane, which contains lipids and proteins (lipoprotein membrane)

**Reproduction:** Similar to other organisms, information required for the reproduction of viruses is contained within the nucleic acid. A very small number of plant viruses contain DNA; most of them contain RNA, similar to informational RNA of a cell. Hence, viruses have a very wide range of genetic variation and consequently, reproductive cycles and lifestyles of different viruses vary greatly.

Since all viruses are obligate, biotrophic parasites, their lifecycle begins with the virus particle penetrating into the host's cell. The virus invades the cytoplasm of the plant cell through wounds which result from mechanical plant damage. The next phase of viral infection is partial or complete separation of the viral protein shell within the cytoplasm of the plant cell. After this, expression of the viral genes takes place through the transcription and translation process. Translation of the virus RNA causes formation of viral proteins in the cytoplasm. Viruses form three types of protein: replication proteins, which are responsible for nucleic acid synthesis; structural proteins, which cause formation of the protein shell (capsid) and the so-called movement proteins, which transport the virus through plant cells. The next stage of the reproduction cycle is the spread of the virus into the plant's neighboring cells. Viruses travel from cell to cell by means of narrow channels, called plasmodesmata. Reproduction time fluctuates between one to several hours. Viruses initially spread into the phloem, and then move into surrounding tissue. It takes several days for the plant to become infected completely.

**Control**

Once a plant is infected by a virus, there is no treatment that will cure the infection. Therefore, control of viruses must be preventative; the following methods are recommended to control virus diseases.

**Genetic resistance:** The use of plants that are resistant to the virus is the most effective means of control. Unfortunately viruses are extremely variable and can change their genetics very rapidly. It is common for a virus to change genetically in order to break down or overcome disease resistance in plants. When effective disease resistance is available, it should be used.

**Agricultural (cultural) practice:** It is important to search for (scout) virus infected plants in the planting and remove and destroy them as soon as they are detected. If they are not removed, they will serve as a source of inoculum that can spread the disease.

- Always use certified virus-free seed and planting material
- Sanitary-hygienic measures: disinfestations of grafting tools, workers hands and other tools or structures
- Properly planned crop rotation
- Control weeds in and around the planting or greenhouse that can serve as a source of inoculum for viruses
- If the virus is spread or vectored by an insect or other organism, the vectors must be controlled

**Chemical treatment:** There are no chemical treatments for the direct control of virus diseases. Once a plant is infected, it is infected for life.

- Chemicals can be used to deactivate the virus on pruning and other tools that can transmit the virus
- Chemicals such as insecticide and nematicides can be used to control the vectors of virus diseases

**Biological control:** Selection and use of effective biological control methods or products when they are available

**Quarantine service:** Used to separate and restrict the movement of diseases in plant material. The introduction of plant material that may contain diseases is enforced at the borders of Georgia. Before the plant material can enter the country it must have the phytosanitary certificate which is issued by an accredited laboratory that states the material is disease free.

*Figure 1.5 Light microscope picture of nematode. Author: Ernest C. Bernard*

### Nematodes

Nematodes are non-segmented, round worms. Most are microscopic and cannot be seen with the naked eye. There are approximately 28,000 different species of nematodes, of which almost 16,000 are parasites (Fig 1.5). They are spread globally and are present in virtually every gram of soil. Their length varies from less than one mm to 8.4 meters (sperm whale nematode). They live at the bottom of the sea, in fresh water, and in soil. Nematodes can cause plant diseases. These nematodes are plant parasitic nematodes (phytohelminths) and the diseases they cause are referred to as phytohelminthosis. Phytohelminths feed on the contents of plant cells and can easily cause mechanical damage to plant tissues and disrupt life functions.

**Morphology:** Nematodes have oblong, spindle or thread-like bodies, 80 cm to 8 m long, which are filled with liquid. They have no blood circulation or respiratory organs. Their digestive system consists of the orifice, pharynx and anus. The neural system is represented with circular nerve rings surrounding the pharynx. Sense organs are usually bristles and papilae, some of which have primitive chemo and photoreceptors. Nematodes feed by means of a stylet, which is a needle-like structure (mouth part), by which nematodes can pierce plant cells, inject degrading enzymes and extract nourishment from the plant.

**Ecology:** Based on their location in or on plants, nematodes are divided into several groups:

- Endoparasites – which penetrate roots completely and live inside the root
- Ectoparasites – they live on and feed on the outside of the root
- Semi-endoparasites – part of the organism in the root

**Control**

Management of nematodes is difficult. The most reliable practices are preventive methods, to reduce and avoid

**Genetic resistance.** When available, use varieties that have resistance to the nematode.

**Agricultural (cultural) practice**

- Use nematode-free seed and planting material
- Avoid the introduction of soil (which may contain nematodes) on the roots of transplants, on tools, and on equipment
- Properly selected seed (crop) rotation

**Chemical treatment**

- Use of soil fumigants when appropriate
- Use of nematicides when available and appropriate.

**Biological control**: There are several naturally occurring organisms that provide some level of biological control of nematodes. There are several fungal species that attack nematodes as well as other nematodes that feed on plant parasitic nematodes. These natural biological control organisms aid us in the control of nematode diseases.

**Quarantine service:** Soil importation in Georgia is restricted. Moreover, it is illegal to import plants with soil on the roots.

### Plant Parasites

Plant diseases can also be caused by flowering plants. Although their number is low, parasitic flowering plants are extremely harmful for certain agricultural crops. These parasites are divided into three large groups: (1) Epiphytes, which use plants as supports; (2) Hemi-parasites, which are capable of producing chlorophyll (for example, viscum and melampyrum) and; (3) true parasites that feed on organic substances taken from plants, e.g. cuscuta, orobanche, anagallis.

**Control**

**Agricultural (cultural) practice**

- Use seed and other planting material that is free from flowering parasites
- Mechanically remove parasitic plants from the planting and destroy them.

**Biological control.** Currently there already exist certain preparations against invasive plants in Georgia. For example, against orobanche, we have developed a biological control agent at Agricultural University of Georgia.

**Quarantine service.** Before the plant material enters the country it must have the phytosanitary certificate which is issued by an accredited laboratory that they does not contain seeds of invasive plants.

*Figure 1.6 Tomato sun scald. Source: Owentree*

## ABIOTIC FACTORS

Abiotic factors that affect plant growth include temperature, soil moisture, soil and water pH, solar radiation, and soil mineral content.

### High temperature

High temperature can cause sun burn and desiccation of the fruit and the foliage (Fig 1.6). High temperatures above 32ºC result in bleaching of fruit color, formation of water soaked spots on the fruit skin, and wilt and dryness of foliage. High soil temperature also kills young plants and can severe damage to the root system.

*Figure 1.7 Tomato catface caused by low temperature. Source: Owentree*

### Low temperature

During low temperature, plants well-suited to warmer climates, such as wheat and beans, undergo more damage. Low temperature causes freezing of young leaves and meristem damage and may also cause the so-called catface symptoms in tomatoes (Figure 1.7). Low temperature can also cause excessive sweetening of potatoes as a result of starch hydrolysis into sugar. Damage depends upon how long the tubers are exposed to the low temperature. At early stages of development of potatoes, low temperatures damages vascular tissue causing a ring-like necrosis on the stems and shoots, while damage to tubers causes net-like necrosis.

### High soil moisture content

High soil moisture damage is common in areas with heavy rain or due to over irrigation. In general, poor drainage can cause serious damage to most plants, resulting in wilting, and yellowing of leaves, root rot, and fungal infection, especially with phytophtora (Fig 1.8). High soil moisture results in rotting of roots due to low oxygen supply. Lack of oxygen can cause hypoxia and collapse of root cells, and a favorable environment for anaerobic pathogens, which form nitrites that are toxic to plants.

**Herbicide Injury** Herbicides are heavily used by the agricultural industry to control weeds competing with various crops. Several types of injuries have been reported as a result of excessive and/or improper use of herbicide. These injuries include foliage turning yellow or brown, delay in flower, fruit, and leaf growth, early or late leaf and fruit drop, and in severe cases, death of the crop. Most of the damage is caused by not following the manufacturer's recommendations. Some formulations of herbicides are more volatile than others. For example, the ester form of 2, 4-D is more volatile than the amine form. In situations of heavy wind, spray of herbicides, especially the ester form of 2, 4-D, is more likely to cause drift and injury than in situations with clam wind.

*Figure 1.8 Symptoms of tomato wilting, due to low soil moisture content. Source: Discover Life Organization*

### Soil pH

Alkalinity and acidity (pH) of soil, water, and other solvents are measured on a scale of 1 to 14. When the pH is at 7, then these mediums' pH is considered to be neutral. However, when the pH is below 7, these mediums are considered acidic and when the pH is above 7, they are considered as alkaline.

As listed in Figure 1.9, nitrogen, phosphorus, potassium, calcium and magnesium are not soluble at acidic conditions (low pH). Only iron, manganese, copper and zinc are soluble at low pH. At moderate alkaline soil (pH above 7), nitrogen, phosphorus, magnesium and calcium are soluble. However, iron, boron, and manganese are less soluble. Only soluble nutrients are available for the plant to take up from the soil.

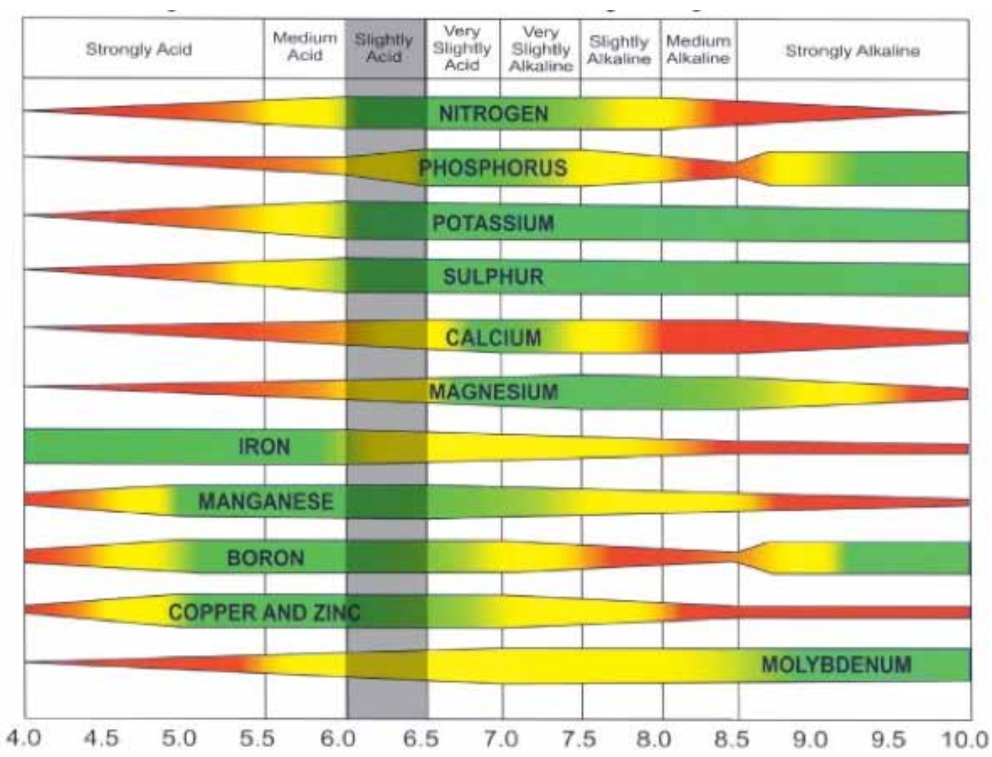



*Figure 1.9 How soil pH affects availability of plant nutrients. Gray area depicts a neutral pH of soil, when all nutrients are soluble. Source: Colorado State University Extension*

### Mineral deficiency

Plants need minerals in order to exist. Certain elements, e.g. nitrogen, phosphorus, potassium, calcium, manganese and sulfur are consumed by plants in larger quantities. These elements are called macronutrients, while other nutrients are needed by the plants in smaller quantities. These are called micronutrients. Both macro and micronutrients are considered as essential for plant growth. Symptoms of various nutrient deficiencies develop as a result of low availability of these nutrients (**See Annex**: Nutrient Deficiency).

### Toxic effects of minerals

In certain cases, soil contains excessive levels of minerals, which may harm plant health. Apart from the fact that minerals differ in their toxicity coefficient, plants also differ based on their level of sensitivity to these minerals. For example, some plants are damaged by a very small amount of nickel, but are tolerant to significant amounts of aluminum. In certain cases, some element may hinder the process and functioning of absorption of another element, which causes deficiency of the latter. Excess amount of sodium or magnesium in the soil results in deficiency of calcium. Toxic doses of copper, magnesium, and zinc result in iron deficiency. Excessive amounts of sodium chloride increases soil pH causing so-called alkaline damage. Such damage varies among plants and is manifested as chlorosis, growth delay, foliage burn, wilt and death of seedlings. Certain plants, e.g. wheat and apple, are extremely sensitive to alkaline soils. It has been demonstrated that toxic levels of magnesium, copper, aluminum, and iron often cause damage to plant foliage. For example, excessive amounts of magnesium can cause leaf curl in cotton and bronziness of apple leaves.

*Figure 1.10 Symptoms of hail damage in tomato. Source: Wikimedia Commons*

### Hail damage

Hail damage depends on the plant's development stage, as well as the size of hail and its duration (Fig 1.10). Damage caused by frost and hail can often be confused with pest damage. Severe hail often defoliate trees, resulting in poor fruit set for the following year. Areas prone to spring frost are not suitable for growing fruit trees and vegetables. Temperature drops below freezing during bloom can destroy an entire crop. Site selection is very critical for reducing frost damage. Sites with good air drainage is essential for early and late frost damage.

## DISEASE DIAGANOSTIC

Quick and accurate diagnostics of the disease is necessary before we plan relevant preventive measures. This is the first stage, which, if implemented improperly, may have grave results. Moreover, this will help us to avoid disease epidemics. In order to determine with which disease we are dealing, it is first necessary to know how a healthy plant looks. At the next stage, we must observe disease symptoms and signs. Finally, we need to have information about conditions of the environment, where the plant grows: temperature, soil composition, used agro-technical practice, preceding crop, diseases known to exist in this region, etc.

### Differentiation between abiotic and biotic factors

In order to accurately determine whether the symptoms are due to abiotic or biotic factors, it is essential to conduct proper diagnosis by observing disease signs, symptoms and their dissemination in field conditions.

- If symptoms are spread to all plants in the field, in most cases we are dealing with abiotic damage. During biotic damage, only the host plant group becomes infected.
- Symptoms caused by abiotic factors occur mostly at the same stage of development in various plants, while biotic infection induces various disease stages on various plants and plant parts.
- To differentiate between biotic and abiotic is the disease separating line. During abiotic damage, diseased tissue is separated from the healthy tissue, while during biotic diseases there is a transitional area between diseased and healthy tissue.

In the case of abiotic factors, it is necessary to conduct leaf, fruit, and/or soil testing in order to determine the adequacy of the minerals taken up by the plant.

### Collecting samples

In order for samples to be collected properly and not be further infected during transportation, it is necessary to observe minimal sanitary standards. (1) Determine the host plant. If it is unknown, collect adequate sample of infected and non-infected tissue. (2) Observe symptoms while collecting samples. If possible, uproot the whole plant and place it in paper bags; never use a plastic bag. (3) Sample has to contain both diseased and healthy parts of the plant. (4) To avoid contamination, avoid placing infected and non-infected tissue in the same container. Write variety, date, location, and stage of development of each of the collected plant tissue on the bag and in your notebook. For leaf nutrient analysis, collect fully developed leaves from the middle section of a one year old shoot. Collect shoots from various parts of the plant. Do not collect diseased or damaged tissue.

### Laboratory tests for disease identification

Diseases often cannot be diagnosed correctly just by knowing the symptoms and signs. In order to do this, it is necessary to inspect materials in laboratory conditions in order to correctly identify the cause.

### Incubation in growth chamber

In order for the pathogen to begin growing in the laboratory, it is necessary to place it in a humid chamber. Outside laboratory conditions, this can be done by placing a wet sheet on a petri dish or in a plastic box, which creates sufficient humidity for the pathogen to start growing so that it can be observed and isolated. Viral diseases cannot be identified with this methodology. Several molecular biology techniques or the inoculation of indicator plants are required for the identification of diseases caused by viruses.

Isolation of a fungal pathogen often requires growing it on growth medium in petri plates, which enables us to separate specific fungal parasites. Also in the case of

## DIAGNOSTIC FORM SAMPLE

1. Cereal or plant name ______________________________

2. Describe the general picture of disease spreading ______________________________

______________________________

3. Describe symptoms on the plant ______________________________

______________________________

4. Picture ______________________________

______________________________

5. When did symptoms appear: Day __________ Week __________ Month __________

6. Describe conditions before symptoms appeared Temperature ______________________________

Rain __________ Other ______________________________

7. Crop rotation:
two years ago ______________________________ one year ago ______________________________

8. Soil type ______________________________

9. pH ______________________________

10. Soil test results ______________________________

11. Adding nitrogen ______________________________

12. Use of chemical substances:

Fertilizer ______________________________ form of use ______________________________

Herbicide ______________________________ when did you use it ______________________________

Insecticide ______________________________ when did you use it ______________________________

13. Chemicals used the previous year ______________________________

14. Condition of surrounding plants ______________________________

bacteria, part of the plant is crushed in water and a suspension is transferred to the growth medium, from where bacteria can be separated. When an organism is isolated, it is necessary to identify it. In order to identify the disease, qualified laboratory personnel are required who will be able to identify it accurately under the light microscope. Simultaneously with disease identification, it is necessary to determine whether this organism is the primary cause of the disease. In order to do that, it is necessary to repeat Koch's postulate and infect a healthy plant with the organism, identified by us. If the inoculated plant develops the same symptoms as the diseased plant and we can re-isolate the same organism, then we are dealing with the organism which is the primary cause of this disease.

### Modern Diagnostic Tests

As we have already noted, disease identification plays the greatest role in disease prevention. Hence, new technologies have appeared on the market that enable us to identify pathogens quickly and with high sensitivity, which in turn makes it possible to avoid conducting classical, long (four- to five-day) laboratory experiments.

**Immunostrips** – are quick and enable us to identify diseases without any laboratory research under field conditions. Agdia (www.Agdia.com) is one the main manufacturers of these types of products and has many of the identification strips for identifying bacteria, fungi and viruses.

**ELISA** – (Enzyme Linked Imunosorbant Assay) is a method which makes it possible to determine existence of specific antigens (virus, mycoplasma, bacteria, etc.). Antigen-specific antibodies are produced in mammals, which enables us to identify the disease with 95-100% accuracy. ELISA is often used in immunostrips.

**PCR** – Polymerase Chain Reaction is a biochemical method in molecular biology which enables us to amplify genetic codes of specific pathogens. This technology can be used on bacteria as well as fungal diseases and viruses. Reagents for PCR tests are produced in Georgia by L.T.D "Oxygen". www.oxgen.ge

**Next Generation Sequencing** – is a molecular biological technology, by means of which we can determine genetic sequence of the pathogen. It is nowadays being widely introduced in phytopathology, which will enable us to identify diseases with 100% accuracy in near future.

## INTEGRATED MANAGEMENT OF PLANT DISEASES

In order to effectively prevent and manage plant diseases, we need to develop a disease management program that integrates all available methods of disease control. These include: (1) the development and use of disease-resistant varieties; (2) the use of cultural control (agricultural) practices that aid in disease management; (3) selection and use of effective disease control chemicals when appropriate. (4) Biological control when available; and (5) the use of regulatory practices such as Quarantine protection (see Fig. 1.11). The integrated method of plant disease control enables us to carry out complex control programs for the prevention of diseases. It should be noted that the general approach to plant disease control is usually preventative or protectant. It is directed at the prevention of plant diseases rather than treating them after the plant is infected.

**Genetic Resistance:** The development and use of disease-resistant varieties is the most efficient and economical method for controlling plant diseases. Classical plant breeding and genetic transformation techniques, has resulted in many varieties of several vegetable crops with resistance to many important plant diseases. For example, there are widely used varieties of tomato, eggplant and other vegetable crops, that are resistant to Fusarium wilt. With soil borne diseases such as Fusarium and Verticillium wilt, it is not possible to grow susceptible varieties in areas that are infested with these fungi. The use of resistant varieties allows us to grow valuable vegetable crops in areas where it was not possible before. The use of resistant varieties also greatly reduces our need to use expensive disease control chemicals such as fungicides.

**Cultural Control Methods (Agricultural Practices):** The use of effective cultural practices are very important for control of plant diseases and are an integral part of the integrated disease management program. Any practice that helps to make the environment less conducive to disease development is of great value. At times, these methods may be the best or only means of controlling a specific disease. Some important cultural (agricultural) practices includes.

- **Crop rotation**. This practice enables us to increase soil quality and at the same time to block the cycle of plant pathogens from overwintering in the soil. Crop rotation reduces pathogen populations by removing a suitable host plant for the pathogen to survive on from year to year. Carefully planned crop rotation practices can aid in increasing soil fertility, preventing soil erosion, and preserving the water balance. All of these benefits enable us to have healthy and productive plants.
- **Selection and use of pathogen-free seed and other planting materials**. In order to prevent the introduction of plant diseases (pathogens) into our fields and green houses, it is necessary to use certified (disease free) planting materials. Seed and other planting materials have to be pure to variety, clean and of high quality. If they do not meet these criteria, they do not emerge properly and in many cases, they produce plants that are infected with diseases.
- **Soil.** In order for plants to be healthy and productive, it is necessary for the soil to have the proper pH and mineral content to provide adequate nutrition for the plants. Apart from chemical composition of the soil, attention must also be paid to its physical condition. Practices such as deep plowing may place soil borne pathogens deeper in the soil where they are not able to survive.
- **Sanitation practices.** These are aimed at reducing or eliminating plant pathogens. It is important to inspect the planting regularly and remove plants that are diseased and destroy them. Many diseases overwinter in plant remains (debris).With such diseases, it is necessary to collect and destroy old plant remains. For example, potato and beet remains can contain a number of important viral, fungal and bacterial plant pathogens. Also, attention should be given to sanitary conditions of agricultural equipment. For example, potato virus X spreads by means of contaminated agricultural equipment and humans walking through the plants. Soil cultivation equipment should be washed regularly, in order to avoid transfer of pathogens from one location to another.

**Direct protection of plants by means of chemical control:** Chemical substances that are toxic to pathogens are used for plant protection world-wide in the field, in greenhouses, and sometimes in storage areas. Based on the type of pathogen they control, chemicals are classified as fungicides, bactericides, nematicides, or herbicides.

Certain chemicals have a broad spectrum of activity and are effective against a wide range of pests or diseases. For example, some fungicides are capable of controlling fungi in several different genera and families, unlike others, which affect only one or a few species of fungi. Due to their expense, disease control chemicals are generally used only on higher value crops. In Georgia, sixty percent of chemicals are used for fruit disease control, while 25 percent are used on vegetables. Some chemicals are used for protecting the parts of the plant which are aboveground. These are generally referred to as foliar treatments. Other chemicals are used as seed protectants. Some chemicals are used for disinfesting the soil in greenhouses, wounds on trees and as post-harvest treatments for fruits and vegetables in storage areas. Insecticides are used for controlling the insects that transmit certain diseases. Some chemicals have therapeutic effect. However, most chemicals are used primarily as protectants and are aimed at preventing plant diseases rather than trying to eradicate or cure them after infection has occurred.

**Biological control:** This implies the use of super parasites against organisms causing diseases. All pathogens (fungi, bacteria, nematodes and viruses), have their own pathogens. For example, bacteriophages or phages are viruses that are natural pathogens of bacteria. Some microorganisms produce antibiotics that are toxic to pathogens. Some bacteria produce fermentation products which destroy pathogen structures such as cell walls. Microorganisms with such qualities are used as antagonists for bio-control of diseases. Scientists are using microorganisms such as these to produce new biological control products that are effective for controlling many plant diseases.

**Regulatory protection:** Plant quarantine (quarantine inspection) is an important tool for pest and disease control. Its main goal is to protect a country or region from

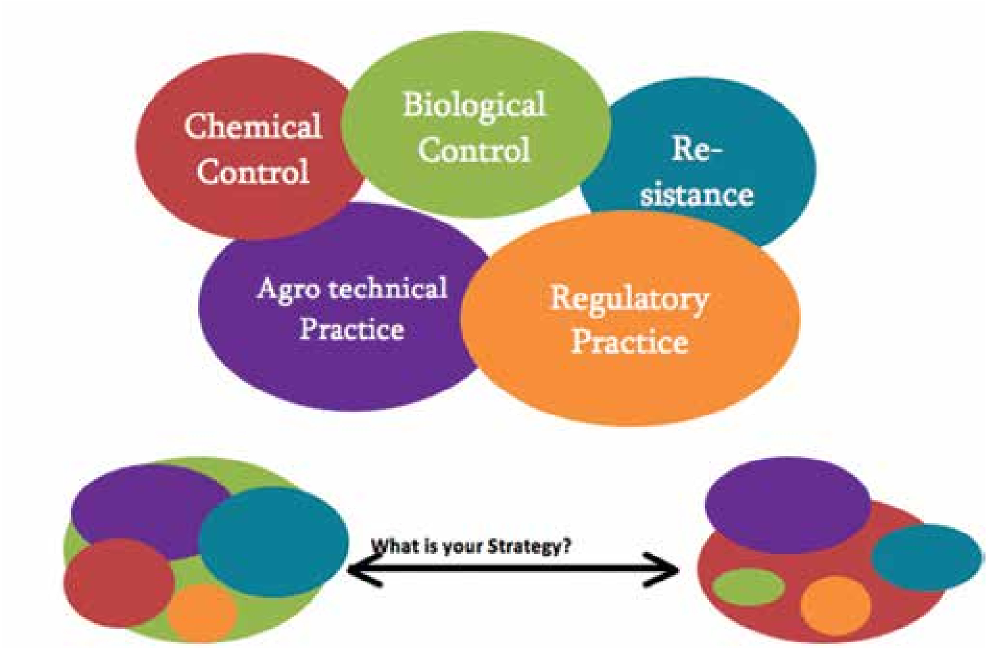
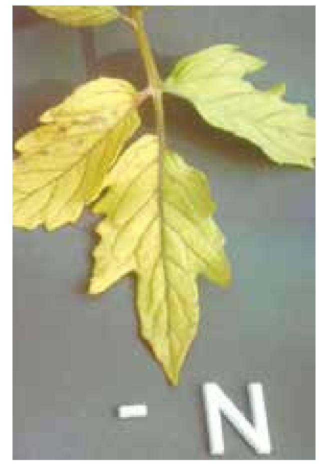
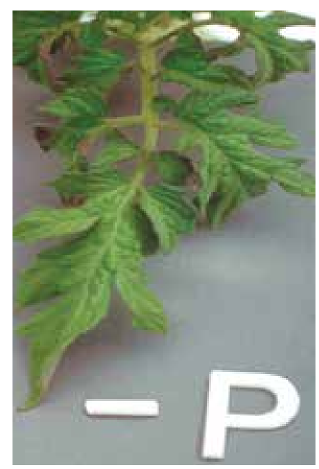
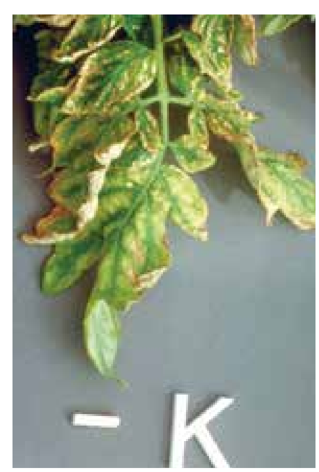
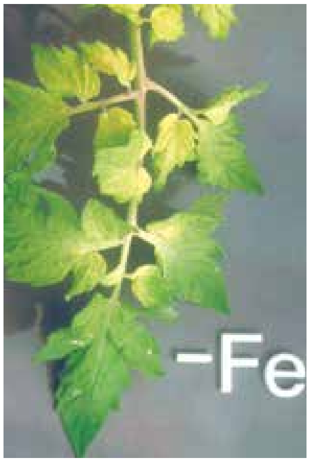
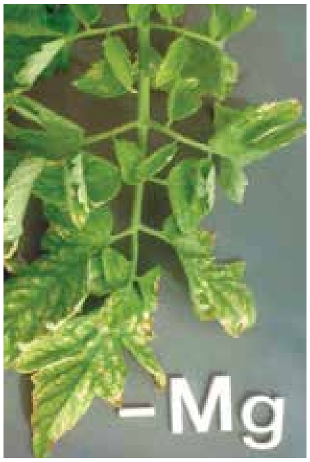


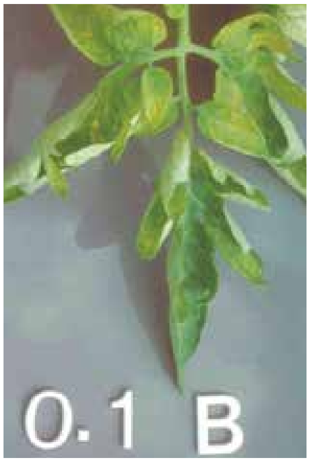

*Figure 1.11 Schematic illustration of integrated disease management strategies*

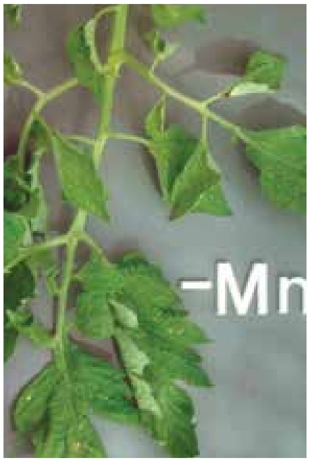
the importation of exotic pests and diseases that are not currently present. When an alien or exotic pathogen enters a new area, they can result in severe epidemics due to the lack of natural biological control organisms in the new environment. It is necessary and very important, in any country to introduce and develop quarantine systems which will prevent the importation of plant pests and plant diseases as well as plant products and soil from other countries. Regulatory responsibilities may also include pathogen prevention through the production of plants in locations where plant pathogens are not present or endemic. For example, to produce virus-free potato tubers, potatoes can be grown in high-mountainous regions, where the vector of this virus is not present. This same procedure can be used with other crops and plant diseases

## ANNEX 1. NUTRIENT DEFICIENCY

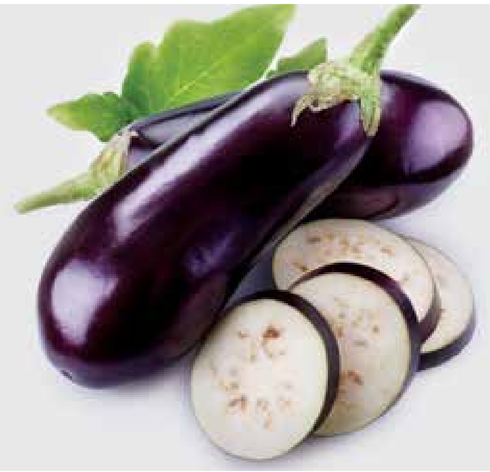
| Mineral | Function | Symptom | Picture |
|---|---|---|---|
| **Nitrogen (N)** | Represented in almost all plant substances | Plant growth is weak and its coloring is light green or yellow, finally becoming reddish |   |
| **Phosphorus (P)** | Represented in DNA, RNA and plant phospholipids | Plant growth is weak and orange lines are noticeable on foliage |   |
| **Potassium (K)** | Catalyst of most reactions in the plant | Plant's stem is weak, dieback begins. Leaf chlorosis and graying of leaf tips begin, multiple gray spots also appear |   |

| Mineral | Function | Symptom | Picture |
|---|---|---|---|
| **Iron (Fe)** | Catalyst of chlorophyll formation | Leaves start turning yellow, but plant veins remain green |  |
| **Magnesium (Mg)** | Component of chlorophyll and various (ferments) | Leaves develop chlorosis and may curl upwards and begin turning yellow |  |
| **Calcium (Ca)** | Functions in membrane conductance, forms salts with the presence of pectin | Young leaves curl, their size is abnormal and they are covered with gray spots. Bottom of fruit begins to rot (blossom end rot) |  |

| Mineral | Function | Symptom | Picture |
|---|---|---|---|
| **Boron (Br)** | Participates in sugar transportation | Plant growth is weak, chlorosis is visible on foliage and leaves curl. Cells on fruit, around stems, stiffen |  |
| **Sulfur (S)** | Component of amino acids and coenzymes | Young leaves are pale in color or yellow, without any spots |  |
| **Zinc (Zn)** | Zinc is used in oxidation of auxins and sugars | Necrosis can be observed on the leaves, between veins. Number of leaves on a plant also diminishes |  |

| Mineral | Function | Symptom | Picture |
|---|---|---|---|
| **Manganese (Mn)** | Component of reactions which participate in the plant's respiration, photosynthesis, and nitrogen consumption | Leaves begin to develop chlorosis but small veins remain green |  |
| **Molybdenum (Mo)** | Main component of nitrogen reductase | Symptoms are very similar to nitrogen deficiency symptoms, but lack of molybdenum is not generally characterized with reddish coloring |  |
| **Copper (Cu)** | Component of oxidation ferments | Leaf tips turn yellow, leaves change color and curl |  |

# EGGPLANT



Eggplant (Solarium melongena var. exculentum), also known as aborigine and berinjal, is a member of the Solanaceae family, which includes peppers, tomatoes, and potatoes. There are several types of eggplant fruits grown commercially. They range in color from the most commonly planted deep purple/black varieties, rose, lavender, and white, to fruits with streaks of purple or pink. Fruits also vary greatly in shapes and sizes ranging from small and large oblong varieties (including the commonly grown blocky varieties), long, thin, cylindrical (Oriental varieties), and bite-size baby varieties. Another type of eggplant (Solarium integrifolium), commonly known as Scarlet, Japanese Golden Eggs, Turkish Orange, or Pumpkin-On-a-Stick, is grown in Asia and Africa. This type has red and orange fruits that are usually small and hollow.

### Climatic Requirements

Eggplant is a warm-season crop that requires between 65 to 85 days from transplanting to reach marketable size. The optimum soil temperature for seed germination is between 24° and 32°C, while the optimum temperature to start transplanting in the field is above 18°C when the danger of frost has passed. Transplants grow best when air temperature is between 24° and 30°C.

### Soil Requirement

Eggplant can grow successfully in most soils, however, plants do best in well-drained sandy loam, loam, or clay loam soils with a good supply of organic matter and an optimum pH of 6.0 to 6.5. When cover crops are used, they should be plowed under at least one to two months before planting in order to allow for proper decomposition. To minimize the risk of soil-borne pests, eggplant should not be grown following other members of the same family like tomatoes, peppers, potatoes, or within two to three years following eggplant production in the same field.

### Fertility Requirements

Soil analysis is very important for growing any food crop profitably. Collect soil samples from each plot that you intend to crop, either in the winter or early spring. Depending on soil pH, apply the recommended amount of lime (if soil pH is low) or gypsum (if soil pH is adequate) at least two to three months before planting. If soil analysis indicates that magnesium is low use dolomite lime, and if magnesium level is adequate then apply non-dolomite lime.

Application of appropriate amounts of other nutrients at the correct time will make significant improvements to the quality and quantity of fruits produced and can promote earlier harvest. A general recommendation for eggplants is to apply about 60 to 70 kg per hectare of actual nitrogen and 90 to 120 kg per hectare of each of phosphorus and potassium. When soil analysis has not been done apply about 1,000 kg per hectare of fertilizer such as 6-12-12 or 5-10-15. Be sure the fertilizer placed within the rows is banded or mixed well before transplanting. Broadcast and incorporate 50 percent of the fertilizer before transplanting and apply the remaining half within two of weeks after transplanting.

When fruits start to set, side dresses the rows with 25 to 35 kg of nitrogen per hectare and then twice more with the same rate at 10 to 14 day intervals. Nitrogen side dressing applications is preferably added as calcium nitrate, but it does not have to be incorporated. Calcium nitrate but not ammonium nitrate reduces the incidence of blossom end rot in eggplant fruits. For more information about blossom end rot control refer to the tomato and pepper chapters.

### Seed Rate and Spacing

It is estimated that 100 grams of seed will produce about 9,000 transplants. Transplants should be between 15 and 25 cm tall with four to eight leaves, but they should not have any flower buds, flowers, or fruits. Transplants are usually spaced at 60 to 75 cm apart within a row and 100 to 120 cm apart between rows.

Because of the short time between planting and harvest (60 to 90 days), it is recommended that eggplants should be established from transplants rather than by direct seeding. In some areas, two crops can be harvested from the same plants. After the first crop, the top of the plants are cut back to the soil surface. Within a few days, new leaves emerge from latent buds on the stems and new flowers and fruits develop within 85 to 90 days. A dose of calcium nitrate may be applied when at least six leaves have emerged from the remaining shoots.

### Harvesting and Postharvest Handling

Because fruits are ready for harvest in the middle of the summer, fruit should be harvested in the coldest part of the day, usually early in the morning. Fruits should be kept cool by spraying them with potable water and keeping them in shaded areas. Fruits should be cooled as soon as possible. However, eggplant fruits are very susceptible to chilling injury at 10°C or lower temperature. The best temperature to store eggplant fruits is between 12° to 13°C with 90 to 95 percent humidity. Fruits will keep for about seven to ten days at this optimum temperature.

## EGGPLANT DISEASES

There are several important diseases that affect eggplant. The most important diseases caused by fungi include: grey mold, Phomopsis blight and fruit rot, Verticillium wilt and early blight. Cucumber Mosaic is the most important disease in Georgia that is caused by a virus. Stolbur is an important disease that is caused by a phytoplasm and bacterial spot is the most important disease caused by bacteria.

*Figure 2.1 Symptoms of gray mold on eggplant. Source: Caring Plants*

## Eggplant Diseases Caused by Fungi

### Gray Mold

**Causal Agent – Botrytis cinerea.** The causal fungus is a saprophyte that can colonize dead or dying tissues of many plants species. It is a common post-harvest pathogen on many fruit and vegetable crops world-wide. It survives as sclerotia in infected plant debris on top or in the soil. It can also survive in the soil in the absence of plant debris for at least two years, and on various surfaces in storage and packing facilities. Leaves, petioles and fruit can be infected in the field, and ripe fruit can be infected during storage. The fungus enters and rapidly colonizes wounds made during harvesting and handling procedures or other causes. The fungus may also penetrate tissue directly. Free water on the surface of the plant promotes infection. The optimum conditions for infection and disease development are temperatures ranging from 18° to 23°C, high humidity and prolonged periods of wetness.

**Disease Symptoms:** The disease develops both on green in the field and ripe fruit, during storage. Fruit develops dark wet spots. Under favorable conditions, the spots increase in size and eventually may cover the entire fruit surface. Especially under conditions of high humidity, disease areas become covered with a thick gray layer of fungus mycelium and conidia. This layer of gray fungal growth is very characteristic of the disease and is how the disease got its name "gray mold."

**Control**

- Use proper agricultural production techniques that minimize damage to the plant and tap root and results in healthy vigorous plants. Handle plants carefully during harvest and packing to prevent damage;
- Maintain optimal storage conditions (temperature: 1° to 2°C, relative air humidity: 80-85 percent);
- Sanitation - Careful and thorough cleaning and disinfesting of storage and packing areas;
- Sanitation - Remove and destroy infected plant parts and fruits in the field and in storage. Special care should be given to removing infected fruit during sorting and packing;
- The use of effective fungicides can be useful in controlling the decease.

### Phomopsis Blight and Fruit Rot

**Causal Agent – Phomopsis vexans.** The fungus survives in crop debris on top of and in the soil. The production of eggplant in the same field year after year without crop rotation results in a buildup of the fungus in the soil and the disease continues to get worse. The fungus is also seed borne and can be introduced into new plantings on infected transplants. Disease development is favored by hot, humid and wet weather conditions. The fungus spreads primarily by splashing water from rainfall and overhead irrigation.

*Figure 2.2 Symptoms of phomopsis blight. Source: WikiGardener*

**Disease Symptoms:** The disease most commonly affects the fruit; however, it can also affect leaves and stems in the field. Symptoms on fruit begin as pale sunken areas which are oval in shape, these areas grow bigger and become depressed; lesions may coalesce to cover all or most of the fruit. As the spots merge the fruit rots. Rotted fruit becomes covered with small warts, may be deformed and finally dries down and mummifies. Seed from such fruit can be infected with the fungus. Infected seeds can survive to carry the fungus into new plantings, or die. As seedlings emerge from diseased seeds, they commonly dampen off and die. The causal fungus can also affect the root neck of the emerged plant, which wilts and rots at the neck, turns dark brown and finally collapses. Stems of diseased plants develop black dots. When leaves become diseased, their surface forms round or angular black spots, with a thin margin. Diseased foliage does not cause significant damage to the plant, but the fungus reproduces on infected leaves increasing inoculum for spreading the disease to the fruit. When stems are diseased, damaged areas turn light in color. When damaged areas surround the stem, the part of the plant which is above the damaged area first wilts and then dries and eventually dies.

**Control**

- Always start the planting using disease free seed or transplants;
- Crop rotation - use a rotation that excludes the production of eggplant for at least two to three years or longer;
- Sanitation - Remove and destroy infected plant parts and fruits in the field and in storage. Special care should be given to removing infected fruit during sorting and packing;

*Figure 2.3 Symptoms of verticillium wilt. Author: Lindsey du Toit*

*Figure 2.4 Symptoms of alternaria solani in eggplant. Source: Plant Village*

- The disease is seed borne so effective fungicide seed treatments are recommended;
- The use of effective fungicides can be useful in controlling the disease.

### Verticillium Wilt

**Causal Agent – Verticillium dahliae.** Verticillium wilt can be a very serious disease on eggplant. The fungus has a very wide host range which includes most of the plants in the Solanaceae family including: tomato, potato, pepper, and many others. The host range also includes many fruit and vegetable crops that are not in the Solanaceae family. The fungus produces survival structures called microsclerotia that allow the fungus to survive in soil indefinitely. The disease is favored by cool temperatures.

**Disease Symptoms:** Symptoms usually appear at the bloom or budding stages of the plant. Symptoms appear first on lower leaves and then spread upwards on the plant. Symptoms include yellow blotches on lower leaves followed by a rapid yellowing of the entire leaf and the edges of affected leaves often roll inwards.

Leaves that are severely infected turn brown, dry up and die. Often, only the leaves at the tip of the plant do not wilt and remain green.

**Control**

- Select and use disease resistant varieties when available;
- Crop rotation is of limited value because the fungus can survive indefinitely in soil. However, crop rotation can help to reduce the population of the fungus in the soil. If crop rotation is used, use a rotation that excludes the production of eggplant and other susceptible crops for at least three to four years or longer;
- Sanitation - Remove and destroy infected plant parts and fruits from the field;
- Soil fumigation.

### Early Blight

**Causal Agent – Alternaria solani.** The disease is very common and can infect most plants in the solanaceae family. The fungus infects and damages eggplant leaves and fruit. Under condition favorable for disease development, the disease can result in defoliation and fruit rot resulting in severe crop loss. The disease can spread very rapidly after fruit set. The risk of fruit infection increases with rapid alternations between rainy and hot, dry weather.

**Disease Symptoms:** On leaves, brown-black spots develop that can cover most of the leaf surface. In time spots develop characteristic concentric rings of light and dark color within them. Severely infected leaves turn yellow, dry, and eventually die, resulting in defoliation of the plant. On fruit, large sunken lesions often with concentric rings similar to those on leaves develop at the stem end of the fruit. Affected areas on fruit often have a black velvety texture. In time the fruit may completely rot. Invasion of affected fruits by secondary rot organisms increase the potential for fruit rot.

**Control**

- Sanitation - Remove and destroy infected plant parts and fruits from the field;
- Destroy any volunteers solanaceous crop plants and weeds (tomato, potato, nightshade, etc.) from within and near the planting;
- Use crop rotation that excludes the production of eggplant and other susceptible crops for at least two to three years or longer;

- The application of effective fungicides is important for controlling this disease. Begin fungicide applications at the first sign of disease.

## Eggplant Diseases Caused by Viruses and Phytoplasmas

### Cucumber Mosaic Virus (CMV)

**Causal Agent – Cucumber mosaic virus:** Cucumber mosaic virus can infect a large number of crop plants and weeds, especially in the solanaceae family. Limited spread of the virus may occur in the field through the handling of plants by humans. The most important means of spread is by Aphids. At least three species of aphids (and probably more) are vectors of the virus and are very efficient in spreading it.

*Figure 2.5 Symptoms of cucumber mosaic virus. Source: Diseases-Pepper and Eggplant*

**Disease Symptoms:** Leaves near the top of the plant are small, wrinkled and often have a yellow-green mosaic pattern. Leaves may be deformed. Lower leaves develop chlorotic spots with dark circumferences. Flowers that form on infected plants are often sterile.

**Control**

- Destroy any volunteer solanaceous crop plants and weeds (tomato, potato, nightshade, etc.) from within and near the planting. These plants can act as a source of the virus if they become infected;
- Control the aphid vectors that are responsible for most of the virus spread through the use of effective insecticides.

### Stolbur

**Causal Agent – Phytoplasma.** Spread of this disease depends significantly upon intensity of reproduction of the pests, which transmit the phytoplasma. The most important vectors are insects in the hyalestes family such as crickets. Cricket larvae overwinter on roots of various plants, of which field bindweed is especially significant. Stolbur is characterized by clearly expressed cyclic nature; after epiphytoty ends, considerable weakening of disease spreading can be observed.

*Figure 2.6 Symptoms of stolbur in eggplant. Source: Legumicultura*

**Disease Symptoms**: First signs appear as weak chlorosis and shrinking of leaves. Later on, diseased plants can be easily distinguished from healthy ones, since higher leaves develop strong chlorosis and only the tissue located near leaf veins retains green color. Leaves tear and are violet in color. With time, damage spreads to lower leaves as well. Simultaneously with this process, leaves begin to fall. Only young leaves, located at the tip of the plant, do not fall. Fruit formed before disease occurrence wilts.

**Control**

- In strongly damaged fields, it is recommended to plant eggplant early, in order to be ahead of the flights of transmitting insects, which begin in the beginning or middle of June;
- Eggplant should be planted as densely as possible;
- Seeding corn or sunflower between eggplant plants is effective, as it complicates flying of insect pests;
- Timely chemical spraying against crickets (advantage should be given to systemic chemical preparations with a prolonged effect).

*Figure 2.7 Symptoms of bacterial spot in eggplant. Source: Canadian Food Inspection Agency*

## Eggplant Diseases Caused by Bacteria

### Bacterial Spot

**Causal Agent – Xanthomonas campestris.** The disease is caused by bacteria and it can affect several other plants in the solanaceae family. Plants may become diseased both in open field production and in plantings protected by high tunnels or green houses. The pathogen survives in crop debris in and on top of the soil and in seeds. Infected seeds and transplants are the most important source of inoculum for the disease. The pathogen is not soil borne in the absence of plant debris. The bacteria penetrate leaves and fruit through natural opening or wounds. The optimum temperatures for disease development range from 15° to 30°C. The bacteria can be spread from plant to plant by splashing water from rain or overhead irrigation, contaminated tools and implements and worker's hands.

**Disease Symptoms** :The disease manifests itself on the plant's foliage, fruit and stems. Leaves develop small black spots with yellow halos or margins, which, in time, grow to the diameter of 2-3 mm. Spots on stems and leaves, are oblong in shape. Fruit initially develops bulging dots with wet (water-soaked) edges, which later grow in size, reaching the diameter of 6-8 cm and finally develop into ulcers. If plants become diseased at initial stages of development, they usually die. If infected plants survive the quantity and quality of harvested fruit is greatly reduced.

**Control**

- Always start the planting with disease free seed or transplants. If disease free seed cannot be obtained, hot water treatment of infected seeds should be considered;
- Use crop rotation that excludes the production of eggplant and other susceptible crops for at least two to three years or longer;
- If the disease occurs in greenhouses, it is necessary to replace the soil or disinfect it.
- Sanitation - Remove and destroy infected plant parts and fruits from the field or green house;
- Storage facilities, greenhouse benches, trays, implements and equipment should be thoroughly disinfested with chlorine (40 grams per liter of water);
- Chemical control - Foliar sprays (Copper, manganese) can be also used in field during the growing season or on transplants in the greenhouse.

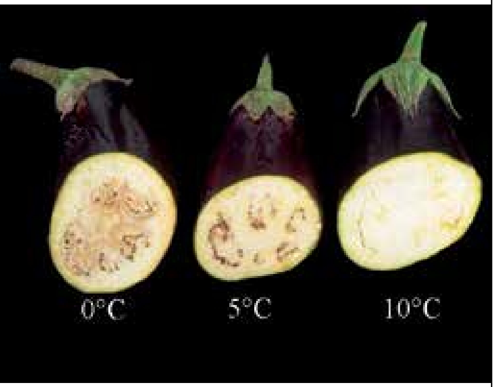



*Figure 2.8 Symptoms of chilling injuries. Source: Canadian Food Inspection Agency*

## Physiological Disorders

**Chilling Injury.** Chilling injured fruits develop pitting, bronzing, and pulp browning if stored for long period below 10°C. Chilling injured fruits are not marketable.

**Bruising.** Eggplant fruits are very susceptible to bruising injury. Proper handling of eggplant fruit during harvest very is important. Fruits should be harvested in plastic rather than metal buckets and should be stored in cardboard with appropriate ventilation holes. Boxes with single cells, rather than loose fill, are preferred for fruit storage.

The potato *(Solanum tuberosum)* belongs to the solanaceae family of flowering plants. Potato has become one of the most important staple foods around the world, ranked third after rice and wheat. In addition to being an important source of carbohydrates, potatoes also contain several vitamins and minerals including vitamin A and C, niacin, phosphorous, and potassium. According to the UN Food and Agriculture Organization, world production was estimated at 365 million tons (Source: FAOSTAT, 2014). Prior to 1990, the bulk of world production was in the US and Europe. However, in 2005 more potatoes were grown in the developing world than in the US and Europe.

### Climatic Requirements

Potato plants are very adaptable and will almost always produce a decent crop, even when the soil and growing conditions are less than optimum. They can grow from sea level to up to 4,700 meters above sea level. Potatoes are very aggressive rooting plants that will produce the best crop when grown in full sun. Plants will not start to grow until the soil temperature has reached about 7°C. During tuber formation (bulking), vines often compete with the tubers for the same limited nutrient resources. Therefore, excessive vine growth during bulking reduces tuber growth. Several factors can shift the balance between vine and tuber growth, and one of these is temperature. High soil temperature often delays tuber growth and encourages foliage growth. For russet cultivars, like Russet Burbank, the optimum soil temperature for tuber growth is about 16°C, while the optimum air temperature for vine growth is about 25°C. It is possible to maintain cool soil temperatures when plants are healthy and have a full canopy that will provide shade to keep the soil temperature close to 16°C for optimum tuber development. Potato plants produce the best crop when grown in light, loose, and well-drained soils, with a slightly acidic pH in the range of 5.0 to 6.5.

### Cultivars

There are more than 4,000 native varieties and more than 180 species of potato growing mostly in the Andes region of South America. Potato tubers can be eaten at any stage of development. Typically, however, a commercial viable crop requires between 100–150 days to grow. Several means of classification are being used in potato including the following:

- **Use.** Fresh market and processing varieties.
- **Skin finish.** Russet and non-russet varieties. The most widely planted variety is Russet Burbank.
- **Colour.** White, red, yellow, and purple/blue varieties.
- **Size.** Baby, fingerling, and petite.

### Field Preparation and Planting

Typically, the land may have been planted with another crop or left fallow the previous year as part of a two-to-three year rotation away from potatoes. Field preparation usually starts in the autumn (fall) for production in the following year. The site is irrigated and deep-ploughed to help ensure the decomposition of organic material from the previous year's crop and to produce a cold-free soil with ideal moisture for planting in early spring. A grower may choose to apply the recommended rates of phosphorous and potassium in the fall in order to encourage organic matter decomposition.

### Preparation of Potato Pieces before Planting

At about one to two weeks before planting, store the tubers in a warm and lighted area so the buds (eyes) will start to sprout. At one to two days before planting, cut the larger tubers into smaller pieces with a sharp and clean knife. Each piece should have at least one to two eyes, and each piece should not be less than 5 cm in diameter. It is recommended to leave the pieces to dry for a few hours before planting so they do not rot.

### Seed Physiological Age

Aged or older seed tubers tend to produce plants with many stems that sprout and develop rapidly, but the plants produced from older tubers die early. High stem numbers usually result in a high number of tubers per plant, which reduces the average tuber size by reducing the amount of carbohydrate available to each tuber during bulking. Early foliage death also shortens the bulking period and reduces the overall plant productivity. By comparison, plants from young potato seed tubers begin to bulk later than those from older seed tubers, which may shorten the growth period in some areas, especially in areas with a short growing season.

### Planting Recommendation

Potato plants grow larger tubers and produce higher yield when grown in rows (furrows) about 90 cm apart and 15 to 20 cm deep. If the market demands smaller size tubers then reduce the spacing accordingly.

Smaller tubers or tuber pieces are best when planted at about 30 cm apart with the cut surfaces facing downward and the buds/eyes facing upward. As plants start to grow, they are hilled to cover the roots and encourage tuber formation.

### Fertility Management

Developing healthy plants is necessary for maximum tuber growth. Nutrient deficiencies limit canopy growth and shorten the life of the plants, resulting in reduced carbohydrate production and tuber growth. Similarly, excessive use of fertilizer causes nutrient imbalances, which can delay or slow tuber growth.

### Irrigation

Plants require a constant supply of moisture. Allowing soil moisture to drop below critical levels reduces or stops canopy and tuber growth during the stress period and for several days thereafter. This effectively shortens the tuber bulking period and can also cause a variety of internal breakdown and external tuber deformities.

Also, excessive irrigation can reduce tuber growth by restricting nutrient uptake and increasing disease susceptibility.

### Weed Control

Always keep your potato patch weed-free for best results. Potatoes should be rotated in the garden, never being grown in the same spot until there has been a three to four year absence of potatoes.

### Harvesting and Storage

Reducing injury to the tubers during harvest will minimize disease infection and loss of quality in storage. It is important to know that tubers remain alive even though their vines have dried up. The two most important factors to keep tubers in fresh and firm physical condition are temperature and humidity. After being removed from the ground and placed in storage, tubers enter a period of dormancy, and under proper conditions of temperature and humidity, they remain dormant throughout the marketing season. Potatoes should be stored and handled in a cool (7 to 10°C) environment with 90 to 95 percent humidity. Every effort should also be made to minimize exposure of tubers to light throughout storage and post-harvest handling.

## POTATO DISEASES

Potatoes are subject to several serious diseases that are caused by various types of fungi, bacteria, viruses, and mycoplasmas. Diseases are generally more severe when potatoes are produced in monoculture, when they are planted near or following other solanaceous crops, when old infected seed pieces are used for planting, and when effective disease management programs are not developed and implemented. This chapter examines the main diseases and pests that affect potatoes in Georgia.

*Figure 3.1 Symptoms of late blight in potato. Author: Jean Ristaino*

### Potato Diseases Caused by Fungi

#### Late Blight

**Causal Agent – Phytophthora infestans.** Late blight is a very common disease and is the most damaging potato disease in Georgia and most other countries around the world. Losses caused by late blight are comparable only to diseases caused by viruses.

Late blight affects all types of potatoes and infects all plant parts except for flowers.

**Disease Symptoms:** Early symptoms of the disease appear on leaves as irregular dark brown spots. The spots expand slowly in dry weather and quickly in wet weather. They grow in size, often engulfing the entire leaf or a part of the leaf. Cottony, white mold growth may be seen on the lower surface and edges of the leaf when humidity is high and leaves are wet. Under warm and dry conditions, the white mold disappears, which indicates incidence of late blight. As the disease progresses, the entire plant will become covered with such spots and turn black.

Stem infection is similar to that of leaves. Its early signs include spots of different sizes. As the spots spread, the stems and branches dry out. Stems turn black and die as spots girdle them. Water is required for infection and disease development so the disease is most severe in rainy and wet weather. It occurs quite often in the highland areas of Adjara.

Tuber infection is very common. Tubers become infected by zoospores of the fungus that can swim through soil or surface water by means of flagella or by spores, which are spread to tubers from leaves. As a result, the fungus infects the tuber skin, causing it to rot.

Newly infected tubers develop spots. Tissues of infected tubers slowly turn brown, develop an unpleasant odour and rot, especially in storage.

**Control**

- Remove above-ground parts of the potato plant from the field four to five days before harvesting;
- Use effective crop rotation;
- Disinfect storage facilities and ensure optimal storage conditions;
- Grow plants on ridges rather than flat surface;
- Dispose of waste potatoes by deep burial, feeding to animals, or burning. Do not put in piles or apply to fields that will be used for another potato crop;
- Destroy volunteer potato, tomato, and solanaceous plants that may harbour this fungus;
- Seed tubers must be free of late blight lesions to prevent introduction of this disease;
- Treat seed tubers with an appropriate fungicide prior to planting;
- Timely and effective use of foliar fungicides during the growing season is very important for controlling this disease.

*Figure 3.2 Symptoms of fusarium dry rot on potatoe. Source: UNECE Organisation*

## Dry Rot of Potato Tubers- Fusarium Dry Rot

**Causal Agent – Fusarium solani.** The disease mostly occurs in storage and rarely in the field. It is favoured by temperatures of 10° to 30°C and at least 50 percent relative humidity. The disease develops rapidly in storage when temperatures are above 3°C to 4°C.

The causal fungus survives for long periods of time in the soil. It can also survive in damaged tubers and in storage facilities. The fungus penetrates the tuber only through wounds caused by mechanical injury or through tissues damaged by other diseases such as late blight and common scab. Plants emerging from infected tubers are weak and grow slowly.

**Disease Symptoms:** The disease usually develops in storage three to four months after harvest. However, tubers were probably infected long before the symptoms developed. The diseased tissues of the tuber contain whitish wart-like flakes which are actually fungus mycelia. The flesh of the infected area becomes loose and dark with time. Cavities filled with yellowish or brownish mycelia develop in the flesh of infected tubers. The tuber eventually dries out and becomes mummified.

**Control**

- Maintenance of optimal storage conditions - temperature, humidity, air-movement, etc;
- Timely removal and destruction of affected tubers;

- Seed lots with evidence of bruising and Fusarium dry rot should be treated with an effective fungicide. Tubers should only be harvested from dead vines. Remove the above-ground parts of the potato plant from the field four to five days before harvesting;
- Crop rotation can be effective; however, rotations need to be long (several years);
- Selection and use of clean (disease free) planting material. Prevent any form of mechanical damage (wounding) to the tubers during harvest and storage.

### Potato Canker, Black Scab or Wart Disease

**Causal Agent – Synchithrium endobioticum.** The disease is so serious and destructive that immediate control measures are required. Canker or black scab affects all parts of the potato, especially the tuber. It occurs less commonly on the above ground parts of the plant.

*Figure 3.3 Symptoms of potatoe canker. Source: Inspection Canada*

**Disease Symptoms**: The external symptoms of the disease are similar in most cases: The infected area forms scab-like lesions of various sizes which are initially small, approximately the size of a corn kernel. Later they grow to form gall-like growths that can become larger than the tubers. At first the young gall is white and looks like a cauliflower head but then changes its colour and turns completely black. This is an indication of the tuber tissue disintegration. The gall finally rots and the entire tuber decays.

Similar galls and scab-like lesions can form on the above ground parts of the plant. At this time, the parts of the plant above the infected area dry out and the entire plant dies.

**Control**

- Select and use resistant varieties when possible;
- Crop rotation can be effective; however, rotations must be fairly long (several years);
- Disinfection of potato tubers.

### Powdery Scab

**Causal Agent – Spongosporasub terranean.** Powdery scab is caused by a fungus-like organism that infects tubers and roots through natural openings. The source of the infection is plant debris and infected tubers where the spores causing this disease are found. Spores of this organism can survive in soil for over six years. Infection is favored in cool (15° to 20°C) and moist soils. Infection can occur over a wide range of soil pH.

*Figure 3.4 Symptoms of potato powdery scab. Source: Wikipedia*

**Disease Symptoms:** The disease affects potato tubers, but rarely roots and stems. It mostly occurs on the surface of the tuber and is not typically spread deep in the tissue.

Small pimple-like structures appear under the epidermis of young tubers. As the disease progresses, they grow larger and show up on the tuber surface. The epidermis then bursts producing sunken scab-like lesions with brown powder.

As the roots become infected, they develop small scabs with a flat part (the part attached to the root). Scabbed tubers usually rot before harvest.

*Figure 3.5 Symptoms of early blight in potato leaf. Author: Tom Leroy*

**Control**

- Treat seed pieces with an appropriate fungicide prior to planting;
- Crop rotation (avoid growing potatoes in scab-infected areas for three to four years);
- Select seed potato free of powdery scab; harvesting should be done in dry weather;
- Plant potatoes on ridges at least 30 cm high;
- Select planting sites that are well-drained and do not have a history of powdery scab. Manure from animals fed potatoes may contain powdery scab spores. Do not apply manure to fields used to grow potatoes.

## Early Blight

**Causal Agent – Alternaria solani.** The disease develops at a temperature range of 22° to24ºC but it can also develop at lower temperatures above 10ºC.

The causal fungus overwinters in plant refuse (debris) as mycelia or conidia.

Plants weakened by weather or soil conditions unfavourable to potato growth are more susceptible to early blight. The disease favours dry and hot weather, lack of moisture, lack of nitrogen and potassium in the soil, and excess amounts of phosphorus-containing fertilizers.

**Disease Symptoms:** The disease first appears during the budding period and develops throughout the entire summer. The fungus mostly affects leaves; sometimes it affects stems, and rarely affects tubers.

Dry brown spots first appear on lower leaves with concentric rings on the upper side of the spots. Leaf spotting then spreads upward. The spots also form on stems and sprouts if conditions are favourable for the disease development. As a result, the upper part of the plant may dry out and die. Dried, dead leaves remain attached to the stem.

Tubers are typically infected during harvest on the soil surface or by coming into contact with spores on the stem and leaves. Infection of tubers only occurs through wounds such as mechanical injury. Irregular lesions on tubers (up to 2cm in diameter) are sunken and slightly darker than healthy skin. A brown to black, corky dry rot may penetrate up to 1cm into tuber flesh. Infected tubers rot in storage.

**Control**

- Remove the above-ground parts of the plant four to five days before harvesting;
- Crop rotation with small grains, corn, or legumes, growing potatoes or tomatoes only every three to four years;
- Plow fields to deeply bury all plant refuse;
- Seed tubers must be free of early blight lesions;
- Remove volunteer potatoes and tomatoes from within and near the planting;
- Disinfect storage facilities and ensure optimal storage conditions;
- Timely and effective use of foliar fungicides during the growing season is very important for controlling this disease.

## Cercospora Leaf Blotch

**Causal Agent – Cercospora concors.** The causal agent overwinters in plant residue.

**Disease Symptoms:** The disease first appears on lower leaves as small (2 mm), pale yellowish spots. The spots then expand in size up to 2-3 cm and may be surrounded by a thin yellow band of tissue (halo). The infected tissue cannot initially be clearly distinguished from the healthy tissue. The infected tissue later falls into decay and the difference becomes more evident. The spots are eventually covered with thin purple flakes/specks and dry out. On the underside of spots, a violet grey layer of fungus growth may develop

### Control

- Remove the above-ground parts of the potato from the land plot four to five days before harvesting;
- Implement effective practices in potato cultivation;
- Disinfect storage facilities and ensure optimal storage conditions.
- Timely and effective use of foliar fungicides.

*Figure 3.6 Symptoms of cercospora leaf blotch. Author: Bob Souvestre*

## Rhizoctonia

**Causal Agent – Rhizoctonia solani.** This disease is most severe during rainy springs. Disease development and spread is favoured by poor cultural practices (when the tuber is planted too deep) as well as by planting in sandy and slightly acid soils. The optimal temperature for the disease is 12° to 15°C. The fungus overwinters as sclerotia on tubers or as mycelia or sclerotia in the soil where it survives for at least three to four years. Infected seed tubers are the main source of infection for emerging sprouts, while underground stems and stolons are attacked by fungal mycelia and sclerotia in the soil.

In addition to the potato, this fungus affects other vegetables (tomatoes, cucurbits, beet root) and weeds (sow thistle, horsetail, fatten, etc.).

**Disease Symptoms**: The disease is found on tubers and sprouts. Tubers form black velvety spots. The spots pose no danger to the already developed tuber but can seriously affect young tubers and sprouts. When young tubers get infected, they do not receive a sufficient amount of starch. The tuber then becomes transparent and watery and eventually dries out leaving only the skin. The same symptoms are found in late tubers. The disease can spread to stems. Greyish mycelia may girdle the stem. If the upper part of the plant is infected, stems develop slowly, weaken, turn black and then die. This can result in an uneven stand of plants. If the stem does not dry out, its growth slows down and top leaves along the mid vein become torn, inhibiting the tuber development. A black spot appears on the young stem which gradually expands and surrounds the stem. As a result, the stem breaks and may produce new sprouts below the point of the break which will also get infected and break. Mildly infected stems may still emerge from the soil but will eventually die. Such stems develop above-ground tubers.

*Figure 3.7 Symptoms of rhizoctonia on potato tuber. Source: Michigan University*

### Control

- Chitting;
- Crop rotation with corn, grasses, and cereal grains will reduce pathogen populations in soil. Do not plant potato for three to five years, if disease has been severe;

*Figure 3.8 Symptoms of potato virus X on leaves. Source: CIP potato*

*Figure 3.9 Symptoms of aucuba mosaic virus on leaves. Source: Wikipedia en France*

- Selection and use of disease-free planting material. Seed pieces must be free of black particles of *Rhizoctonia* on the skin surface;
- Treat tubers with an appropriate fungicide dust prior to planting;
- Promote rapid emergence of sprouts to suppress this disease. Avoid planting in heavy, poorly-drained soils. Plant when soil is above 15°C. Cover seed tubers with no more than 3cm of soil, then after plants emerge, build up hills during cultivation;
- Harvest tubers promptly after vines are dead to avoid development of black fungal particles on tuber skin.

## Potato Diseases Caused by Virus

There are several potato diseases that are caused by virus. The most important and common diseases include: Potato virus X (PVX); aucuba mosaic virus (PAMV); potato spindle tuber virus (PSTV); potato virus S (PVS;) and potato virus Y ( PVY).

### Potato Virus  X (PVX)

**Causal Agent – Potato virus X.** The disease reduces yield by 10 percent, and by 45 percent in the case of mosaic. The disease is spread on a land plot by contact between plants.

There are many solanaceae and leguminous crops which feed the X virus. Weeds can also be infected.

**Disease Symptoms:** Pale yellowish spots intermingled with green spots develop on the surface giving the leaf a mosaic look. Leaves are more mottled in cool weather than in warm weather. Additional symptoms include a general chlorosis and slow growth. Some varieties may develop black necrotic spots on leaves. There are also varieties where symptoms disappear as the plant grows, and the disease becomes latent.

### Potato Aucuba Mosaic Virus (PAMV)

**Causal Agent – Potato virus M.** The disease is transmitted by infected plants and the peach aphid *(Myzuspersicae)*. It causes yield losses of up to 30 to 40 percent.

**Disease Symptoms:** The type and intensity of the symptoms in potato plants depend on the strain of virus and the cultivar of potato. The two main types of symptom are: (1) bright yellow spots on the lower leaves, later coalescing to form large yellow or whitish patches; (2) necrotic spots, often leading to systemic or top necrosis. Some infected plants do not show foliage symptoms, especially during the second and subsequent years of infection and when growing under glass. During storage the tubers of many cultivars develop necrosis in the cortex and pith visible on the surface as irregularly shaped, brown patches or sunken dry brown areas.

### Potato Virus S (PVS)

**Causal Agent – Potato virus S.** This virus always occurs in combination with other viruses. It infects plants in the *Asteraceae (Compositae)* family, and the mint family.

**Disease Symptoms:** Compared to unaffected plants, leaves of infected plants are of a pale colour, with the tip of young plants bending down. The plant loses tissue tone (turgor) and begins to wilt. Certain potato varieties infected with S virus have almost the same symptoms as virus X.

*Figure 3.10 Symptoms of potato virus S on leaves. Source: AHDB*

### Leaf Drop Streak and Rugose Mosaic of Potatoes Potato virus Y (PVY)

**Causal Agent – Potato virus Y.** The disease may cause yield losses of 30 to 70 percent. The loss depends on the potato variety, the spread of the disease and growing conditions. Infected plants may die in the second half of the growing season. Several recombinant strains of PVY are reported PVY (O), PVY (NO), PVY (O), PVY (N-Wilga). Recombinant PVY (O) is the most widespread strain among the three PVY strains. The disease is transmitted by aphids and as a result of tuber cutting prior to planting.

**Disease Symptoms:** Several strains of PVY have been identified that differ by the symptoms they cause in potatoes and tobacco. $PVY^{O}$ is the common strain, and causes mosaic symptoms. $PVY^{C}$ causes stipple streak. $PVY^{N}$, the **necrotic** strain, generally causes mild foliage symptoms, but **necrosis** in the leaves of susceptible potato varieties.

*Figure 3.11 Symptoms of potato virus Y on leaves. Source: WikiGardener*

### Potato Leaf roll - Potato Virus M (PVM)

**Causal Agent – Potato virus M.** The disease causes yield losses up to 25 to 40 percent and reduces the starch content in tubers by 2 to 3 percent.

The disease is transmitted by mechanical contact, through aphids and bugs.

**Disease Symptoms:** Wrinkled upper leaves with mosaic symptoms and wavy edges. The symptoms are prominent during the budding period, but disappear slowly by the end of the growing season. In most cases, the virus is latent and occurs in combination with X, S and B viruses.

*Figure 3.12 Symptoms of potato virus M on leaves. Source: Ibric org.*

#### Control

- Test kits or lab tests are often required to identify plant viruses;
- Planting seed potatoes free of viruses is the most important management strategy;
- Clean and properly sanitize field and handling equipment and storage areas;
- Properly dispose of waste potatoes and eliminate volunteer potato plants;
- Manage insects and nematodes that may carry viruses;
- If possible, remove virus-infected plants when they are found in production fields.

Figure 3.13 Symptoms of blackleg on potato tuber. Source: University of Moscow

## Potato Diseases Caused by Bacteria

Of other bacterial diseases, blackleg causes the most serious damage to potato crops, resulting in a bacterial ring rot of potatoes, and bacterial rot of potato tubers results in a very destructive wet rot.

### Blackleg

**Causal Agent – Pectobacterium phytophthorum.** The disease affects both above-ground and underground plant parts at any stage of their development. The bacteria that cause blackleg are rod-shape. They are covered with flagella which make them mobile. They can swim in a film of water or in free water in the soil. The bacteria over winter on plant refuse (debris) in soil and on infected tubers. The bacteria can survive in soil and plant debris above ground for at least two years. The bacteria may also affect other plants, in addition to the potato, which includes many species of weed. The optimum temperature for its disease development and spread is 21° to 26ºC, but it can develop at a wide range of temperature (2º to 32ºC). The bacteria can also be spread by maggots.

**Disease Symptoms:** Symptoms develop near the root collar or directly on the root collar. At this time, the infected tissue forms small blackish spots which gradually enlarge and coalesce. The spots then cover the entire root collar, the stem turns red and the plant collapses. Before it collapses, its leaves turn yellow and the plant visibly stops growing.

Tubers are infected if the disease develops late. At this time, the centre of the tuber rots, disintegrates and turns into a cavity. These symptoms may not be visible if the tuber infection is mild. Infected tubers produce an infected plant.

**Control**

- Sanitation – Collect and use only disease free tubers for planting;
- Chitting;
- Weed control;
- Crop rotation for at least two to three years away from potatoes.

Figure 3.14 Symptoms of bacterial soft rot. Author: Don Edwards

### Bacterial Soft Rot

**Causal Agents –Erwinia, Corynebacterium, Clostridium.** The disease causes the tuber to rot. Tubers may get infected during the period prior to harvest when the bacteria gets into the tuber from stolons or from infected seed pieces (i.e. the infected tuber produces infected plants), as well as through a mechanical injury during harvest. The bacteria can also infect tuber tissues that are damaged by other diseases such as potato scab, late blight, and blackleg. They can also enter through wounds caused by certain insect pests. The disease occurs mostly in storage. Tubers with no mechanical injuries rarely get infected.

**Disease Symptoms:** The tuber becomes soft with fluid draining from the infected tissue. The tuber tissue disintegrates. The tuber skin does not disintegrate, but its content is completely decayed into a slimy mass. The rotting process releases unpleasant odours.

### Control

- Crop rotation is important. If the disease is severe, growing of potatoes should be avoided for at least after four to five years in infested fields;
- Maintenance of optimal storage conditions;
- Timely disposal and destruction of affected tubers;
- Control of pests and fungal diseases prior to harvest and in storage with appropriate insecticides and fungicides.

## Physiological Disorders

Physiological disorders are disease-like symptoms that are caused by non-biological or abiotic factors, such as nutritional deficiencies, fluctuation of soil moisture, changes in temperature, and other abiotic factors. Abiotic factors affecting potato include internal heat necrosis, tuber cracking, hollow heart, and black heart.

### Internal Heat Necrosis

Also known as internal brown spot rust spot, internal browning, and internal brown fleck. This disorder is caused by elevated soil temperatures during the latter stages of tuber growth and development. Low levels of calcium may also play an important role in the occurrence of the disorder. Several studies have found a link between reduced calcium levels in tubers and increase in the incidence of internal heat necrosis.

*Figure 3.15 Symptoms of potato heat necrosis. Source: Potato Inspection Canada*

The necrosis appears as light tan, dark yellow to reddish brown flecks or specks, these may be dark brown or black in the most severe cases. They resemble the necrosis seen with chilling injury. Flecks usually cluster near the centre toward the bud end and can appear similar to blackheart. The flecks are firm, there is no breakdown or rot. Vascular tissue is usually not affected but in some cases flecks may be confined to the vascular tissue at the bud end.

In tubers, necrotic areas are mostly found in and around the vascular bundle, usually coalescing and radiating towards the centre (pith). The symptoms are more prevalent at the bud (apical) end than at the stem end of the tuber.

The exterior of the tuber in some varieties may exhibit symptoms along with internal necrosis, but this is not always the case, and some varieties, like Atlantic, may never exhibit visible exterior symptom.

**Preventive methods**: Nutrient balance should be properly managed to reduce plant stress early in the season, particularly during rapid growth and development. This is especially true for calcium, which should be supplied at the depth at which rooting and tuber development occur. Preventing shallow tubers from being exposed also helps prevent IHN occurrence, while optimal irrigation amounts and increased soil cover can reduce exposure of shallow tubers to excess temperatures. If irrigation is being used, soil moisture should be monitored carefully so that favourable conditions are not provided for other disorders or diseases.

### Tuber Cracking

Tuber cracking can be caused by several factors including internal pressure, virus infection, and mechanical injury. Growth cracks from internal pressure occur because

*Figure 3.16 Symptoms of hollow heart in potato. Source: Gardening Know How*

of rapid tuber growth. Potato cultivars differ in their susceptibility to this type of cracking. Cracks are more severe when turgid tubers on vigorous vines are harvested from cold soil.

**Preventive methods**: Avoid over irrigation following a persistent drought. Permit soil to warm before harvesting tubers. Handle freshly harvested tubers with great care. Cure tubers at appropriate temperature and humidity (about 15°C and 95 percent relative humidity for one week) before transferring tubers in cold storage.

### Hollow Heart

Hollow heart is a condition brought about by too rapid or irregular growth. It often occurs during wet seasons in potatoes grown in very fertile or heavily irrigated soils. Hollow heart consists of more or less irregular cavities of varying sizes within the tuber and is usually lined with light-brown to brown dead tissue. This defect is usually found, but not always, in large, rough, misshapen potatoes.

Hollow heart starts as a brown centre, which is characterized as a small 0.5 to 3 centimetres in diameter, brown, circular or elliptic, opaque area with a diffuse border along the longitudinal tuber axis. In round to oval tubers, it is usually at the tubers centre; with long or oblong tubers, there may be two brown areas, one at each end. Brown areas are distinct but have a smooth, gradual change to unaffected tissue. Depending on the speed of growth resumption after stress, brown centre may or may not develop into hollow heart. Hollow heart appears as a lens or star-shaped, irregular cavity in the centre of round tubers such as Atlantic, or at either or both stem and bud ends of long tubers. The internal walls are white to tan. The cavity is larger with larger tubers and is mostly seen in very large tubers. No rot is associated with the disorder.

**Preventive methods**: Depending on local conditions, hollow heart can be difficult to prevent, but following a consistent watering schedule, applying a deep layer of mulch, and dividing fertilizer into several small applications can help protect the crop.

Planting potatoes too early may play a part in hollow heart. If hollow heart is a problem, waiting until the soil has reached 15ºC may help prevent sudden growth. A layer of black plastic can be used to warm the soil artificially if the growing season is short and potatoes must reach maturity early. Also, planting larger seed pieces that haven't been significantly aged seems to be protective against hollow heart due to an increased number of stems per seed piece.

**Preventive methods:**

- Plant closer;
- Use larger, less aged, large seed pieces;
- Establish good plant stands;
- Avoid plant skips;
- Apply potassium;
- Schedule irrigation for constant and uniform tuber growth.

*Figure 3.17 Symptoms of potato black heart. Source: Northern Dacota State University*

### Black Heart

Blackheart appears as an internal browning to blacking of the centre tissue of the tuber. Usually, there is no cavity. Pattern is irregular but margins are well defined.

Affected tissue is firm, not soft as with leak, but, when temperature is greater than 18ºC, it may turn soft and inky. It is caused by an oxygen deficiency at the centre of the tuber. Oxygen deprivation results in asphyxiation, loss of respiration, and death of cells. The disorder can develop around harvest, in storage and in transit.

**Preventive methods**: Avoid any pre-harvest, storage, and transit condition that prevents oxygen from reaching the tuber centre. Also avoid poor ventilation, water-logging, long exposure to high field temperatures (higher than 35ºC) before harvest, and prolonged storage at low temperatures (lower than 2ºC). Tubers used as seed can have lower vigour and stand because of low tuber starch that may not be sufficient to support plant emergence.

### Misshapen tubers

Misshapen tubers (called second growth) result from uneven growing conditions, including sporadic watering and high temperatures. A consistently large number of misshapen tubers over several seasons indicate the variety is probably not suited to that environment

**Preventive methods**: Avoid irregular irrigation. Avoid over fertilizing, especially during the bulking period or when the plants are in bloom. Use varieties less susceptible to misshaping. Use ridges for planting instead of flat surfaces. Avoid soil compaction

*Figure 3.18 Symptoms of misshapen potato tubers. Source: Fried to Fublog*

### Physiological leaf rolls of potato and tomato

Physiological leaf roll starts with upward cupping at the leaf margins followed by inward rolling of the leaves. Lower leaves are affected first, and can sometimes recover if environmental conditions and cultural factors are adjusted to reduce stress. If the conditions favoring leaf roll are prolonged, affected leaves may not recover. In severe cases, whole plants can be affected. If environmental conditions and cultural factors are adjusted after prolonged leaf rolling, new growth that develops may not exhibit leaf roll symptoms.

The severity of leaf roll appears to be cultivar dependent. High production-potential cultivars tend to be most susceptible. Highly vigorous cultivars of potato and indeterminate cultivars of tomato were reported to be more sensitive to this disorder than less vigorous and determinate cultivars. In some cases, the condition is believed to occur most commonly when plants are staked and pruned during dry soil conditions. In other cases, causes listed include growing high-producing cultivars under high nitrogen fertility programs, phosphate deficiency, or extended dry periods. Also, the disorder has been attributed in some areas to excess soil moisture coupled with prolonged high temperatures.

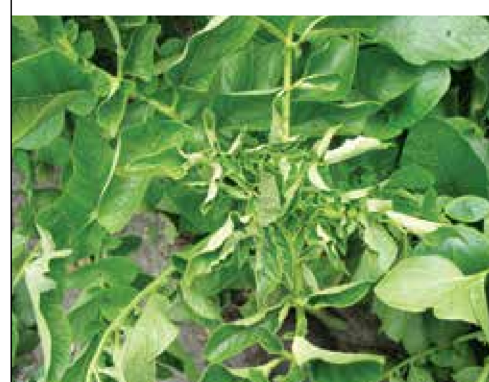


*Figure 3.19 Symptoms of physiological leafroll of potato. Source: Potato Inspection Canada*

**Preventive methods**: Some management strategies recommended for physiological leaf roll include planting low vigor and determinate cultivars. Plant in well-drained so and maintain uniform, adequate soil moisture (~2.5 cm per week during the growing season, depending on the area of production). Be careful not to over-fertilize, especially with nitrogen fertilizers providing adequate phosphorus fertilizer. Avoiding severe pruning, and if possible, maintain temperatures below 35ºC by using shading or evaporative cooling.

# CUCUMBER

Cucumber is a member of the *cucurbitaceae* family. This family includes many important vegetables like watermelon, muskmelon, pumpkin and gourd. They are all warm-season annual crops. Cucumber has a long history of cultivation for human consumption and it is a popular vegetable throughout the world. Fruits are either eaten fresh in salads or processed into relish, pickled whole, or sliced.

The crop is very susceptible to serious losses from soil-borne and foliar diseases. Production volumes are usually 40 to 50 percent lower during the hot summer months when diseases are more prevalent than in milder and drier summers.

## Plant Growth and Fruit Set

Cucumber is an annual deep-rooted (about 1 meter deep) plan with tendrils and hairy leaves. The plants may have indeterminate or determinate compact plant habits. The compact growth habit cultivars consist of plants with shorter internode length than plants that are indeterminate. Determinate cultivars are more suitable for field production, while indeterminate cultivars are more suitable for greenhouse and high tunnel production. Optimum growth occurs between 20° to 25°, with significant growth reduction occurring below16°C and above 30°C.

Three major flowering habits exist among available cucumber cultivars. The most widely grown commercial cultivars are monoecious, producing separate male and female flowers on the same plant. The other two are gynoeciousor "all-female" cultivars producing only female flowers(up to a dozen times more female flowers than those obtained in monoecious cultivars) or the so-called "PF" hybrids producing predominantly female flowers and a small number of male flowers. The male flowers produced on PF hybrids are not sufficient to produce an economical crop and sopollinator plants are usually included toinsure sufficient fertilization. In the monoecious cultivars, the first flowers are mainly staminateor 'male' followed by pistillate or 'female' flowers, from which fruits are formed.

In addition to genetics, production of male and/or female flowers is affected by several other factors including plant density, plants tress, temperature, and light intensity. For example, reduced rates of female flowering ynoecious cultivars may result from exposure to stress caused by high plant population densities, insect attack, wind damage, and combinations of lowlight intensity and high ambient temperatures. Some commercial growers in the US, spray gynoecious plants, at the two to four leaf stage, with a registered growth regulator called ethephon (2-chloroethylphosphonicacid) at 125-250 ppm to increase formation of female flowers.

Many cultivars grown in high tunnels and greenhouses (like the European types) are part henocarpic (have aborted seeds). Part henocarpic varieties require no pollination to set fruits. In fact, pollination of these cultivars may cause an off-shaped fruit appearance.

Cucumbers that produce male and female flowers on the same plant (monoecious) are dependent upon honeybees for pollination. It is recommended that four to five hives should be used per hectare.

## Soil Requirement

Cucumber plants are adapted to a wide variety of soil types with good drain age and adequate water-holding capacity. Cucumbers don't perform well on acid soils but do well under slightly acidic conditions (pH 5.5 to 7.0). It is recommended that if soil pH is lower than 5.5, a grower should apply about 2.5 tons per hectare (or 22 kg per m2) of agricultural lime at about 8 to 12 weeks before planting. However, some soils may require considerably more lime. It is suggested that liming and use of nitrate-nitrogen fertilizer helps to reduce incidence of fusarium wilt in the field. However, the availability of some micronutrients may be reduced at pH above 6.5.

### Fertilizers Recommendation

Cucumber's nutrition programs hould be tuned to achieve maximum yields and optimum market quality. For example in sufficient potassium will result in misshapen fruit or "bottlenecks", and low nitrogen restricts growth, modifies the length-to-diameterratio, reduces set and color development of the fruits.

It is suggested that 50% of the recommended fertilizer rate need to be banded about 8 cm below the seeds at planting and the remaining 50% is side dressed at 30 days after planting.

### Crop Rotation

Proper crop rotation is essential in cucumbers in order to reduce potential problems from diseases, nematodes, and herbicides carry over. It is higly discouraged to grow cucumbers on lands that have been planted with any other cucurbit crops such as watermelons, cantaloupes, pumpkins, squash, etc, within the previous three years. Proper rotation with non-cucurbit crops will help prevent potential problems from carryover of diseases on plant material. Rotation with crops that discourage nematode is also beneficial. A good crop rotation program could in clude cabbage, corn, rye or other small grains. Other well-fertilized vegetable crops not in the cucurbit family, such as fresh-market tomatoes or peppers, are suggested to use in a cucumber rotation.

### Irrigation

Cucumber plants require constant supply of water to produce high-quality fruits and high yield. Periods of growth when the plants are most susceptible to irrigation deficits include seed germination, flowering, and fruit enlargement. The frequency of irrigation is largely dependent on soil type and weather conditions. In general, for sandy soils under dry weather, the fields should be irrigated at least every other day if not more often at a rate of 2.5 to 5 cm per week.

### Weed Control

Use an integrated approach to effectively manage weeds in cucumber fields. Cultural practices for weed control include shallow cultivation, plowing, disking, hoeing, croprotation, cover cropping, living mulches, organic or plastic mulches, and herbicides. A pre-emergence herbicide application and two hoeings after planting are sufficient to control weeds in plots that have low weed seed stocks. One or two cultivations while cucumber plants are still young also may provide acceptable weed control. The two hoeings could be substituted with a post-emergence herbicide to achieve similar effectiveness in weed control. Also growing cucumbers using plastic-mulch is an effective method of controlling weeds.

## CUCUMBER DISEASES

High water content in cucumber is a factor that contributes to its being infected with several important diseases caused by fungi, bacteria and viruses. Most diseases require water to infect the plant and develop; therefore, diseases are most severe when conditions are wet during periods of frequent fog, dew, rainfall and high relative humidity. The main diseases of cucumber that are caused by fungi include: powdery mildew; Sclerotinia rot; anthracnose; gummy stem blight; Cladosporium fruit and leaf spot; downy mildew; Alternariosis (Alternaria leaf spot);target spot; Fusarium wilt; black root rot; and gray mold.

The most serious diseases caused by viruses include cucumber mosaic virus andcucumber green mottle mosaic virus. Important diseases caused by bacteria include bacterial soft rot and wilt and bacterial wilt.

*Figure 4.1 Symptoms of powdery mildew in cucumber. Source: Vegalab*

### Cucumber Diseases Caused by Fungi

#### Powdery Mildew

**Causal agents – Erysiphecichoracearumf. cucurbitacearum, Sphaerotheca fuliginea. f. cucumis.** The fungus can overwinter in plant debris from infected plants and can infect several other plants in the cucurbitaceae family including pumpkin, squash, cantaloupe and watermelon. The fungus can also infect certain weeds such as L Sonchus and plant ago. Disease severity increases during dry and hot weather conditions with high relative humidity. The fungus does not require free water to infect the plant, instead the fungus requires high relative humidity to infect. Rapid changes of temperature and relative humidity also contribute to disease development. The disease progresses rapidly when there is no rainfall but dew and high relative humidity exists. Unlike most other diseases caused by fungi, rain fall can actually inhibit the development of powdery mildew. The incubation period from infection to symptom development is four to five days; therefore, the disease can develop very rapidly. Especially when ventilation and lighting is poor, powdery mildew can be very serious in the greenhouse.

**Disease Symptoms:** Thefungi causing powdery mildew are obligate parasites and can only develop on living plants. *Erysipheci choracearum* creates a white powdery growth of fungus mycelium on infected leaves, while the powdery growth created by *Sphaerotheca fuliginea* is pink. The disease can damage the crop at any stage of its development, both in the field and in greenhouses. Disease symptoms first appear on the upper side of the leaf. At this time, singular spots appear on the leaf, as white mildew (fungus growth). Later, similar spots appear on the bottom side of the leaf. In the case of severe infection, spots grow in size, merge and cover the entire leaf. White powdery growth may also develop on the stems and fruit stalks (petioles). Damaged leaves yellow dry and eventually die. Plant development decreases and productivity diminishes. Diseased plants form small and dry fruit.

#### Control

- Use cultural practices that avoid excessive succulence and plant growth, over-crowding of plants, shading, overwatering, or excel fertilization, especially with nitrogen.
- Avoid making new planting of vine crops in the vicinity of older plantings, especially if mildew is already present.

- Destroy weeds near or in the field planting and near greenhouse.
- Sanitation – Remove and destroy plant debris from the field or greenhouse.
- Observe optimal time periods for growing and transplanting seedlings. In the greenhouse, it is necessary to observe an interval of no less than three weeks between fall and winter-spring plantings.
- Properly time application of effective fungicides are important for controlling this disease.

### SclerotiniaRot (white rot)

**Causal agent – Sclerotinialibertiana.** The pathogen has a very wide host range infecting over 300 species of plants. Plants can be damaged at any stage of their development. All parts of the plant are susceptible. This disease can kill newly emerged plants, cause wilt on mature plants and rot the fruit. The fungus produces survival structures called sclerotic at that can survive for long periods of time in the soil. Wet conditions with high humidity and relatively low temperatures favor disease development and spread. The disease can be a serious problem in greenhouses as well as in the field.

*Figure 4.2 Symptoms of sclerotinia rot. Source: Sclerotinia Organisation*

**Disease Symptoms:** Disease symptoms are often observed on the part of the plant located near the stem root.Small wet (water soaked) spots initially appear, on which white mycelia later develop. The disease gradually spreads to upper tiers of the plant. Damage caused by this pathogen to the stem, branching points and leaves is especially severe. Under conditions of high relative humidity, the white mycelia develops quickly.

As a result of development of white rot on the plant, affected parts die slowly, which finally causes complete death of the plant. First symptoms of the disease appear on fruit sets. Later, symptoms can be observed at all stages of fruit development. It should be noted that the pathogen penetrates fruit most frequently through mechanical damage. During the first stages of disease development, damaged areas of the plant develop a dirty green color, become wet (water soaked) and soft. As the disease spreads, infected fruits become covered with a dense layer of white mycelia. Eventually, black bodies (sclerotia), develop among the mycelia. These are the long-term survival structures of the fungus. Under humid weather conditions, diseased fruits rot and collapse. Under conditions of low relative humidity, diseased fruit mummify and can become completely covered with sclerotia. Mummified fruits canremain on the plant for a long time. Plant leaves become diseased as a result of contact with diseased plant remains or diseased parts of the plant. Infected leaves initially develop wet spots. Under climatic conditions favorable for disease development, fungus mycelia spreads quickly to all parts of the leaf, which then tears, deforms, dries up, and dies.

#### Control

- Because of the long term survival structures of the fungus (sclerotia), crop rotation is general not considered to be effective.
- Good agricultural practices and sanitary-hygienic measures, including cleaning agricultural equipment before entering new fields, are recommended.
- Sanitation- Remove and destroy infected plantsand plant remains
- Disinfect seed materials

- Timely applications of effective fungicides can be beneficial for control
- Deep plowing of plant debris may be helpful

*Figure 4.3 Symptoms of black root rot. Author: Jason Brock*

### Black Root Rot

**Causal agents – Pythium. sp, Thiela viopsis basicola.** Low temperature and high moisture content of the soil are required for infection and disease development. High soil moisture (soil saturated with water) is probably the major environmental factor affecting disease development. The pathogens overwinter in the soil and in infested plant debris in and on top of the soil, in certain organic fertilizers, peat, and in or on seeds and transplanting material.

The disease is most severe when cucumber is produced on the same field for several years in succession.High planting density that results in poor air circulation and slower drying time of plant tissues also contributes to disease development, especially of seedlings. The pathogens penetrate the plant through the root system, through wounds or other types of damage existing on roots and root hairs.

**Disease Symptoms:** The diseaseaffects both newly emerged seedlings and mature plants. In the case of newly emerged seedlings, the disease can cause massive destruction of the crop, especially on wet (saturated) soils. Leaves on diseased plant lose turgor and wilt, but retaintheir green color and do not fall down. Base of the stem becomes thickened. The vascular tissue (water conduction tissues of the plant) becomes discolored. After making cuts through the lower part of the stem and upper part of the root, a change in color of the inner tissues is clearly visible.Infected tissues develop a dark raspberry (purplish) colored. The disease is worse in wet areas of the field, especially where flooding has occurred.

#### Control

- Use crop rotation.
- Use cultural practices that avoid excessive succulence and plant growth ,over time.
- Sanitation- Remove and destroy infected plants and plant debris.
- Good agricultural practices and sanitary-hygienic measures, including cleaning agricultural equipment before entering new fields are recommended.
- Avoid planting in fields or areas with poor soil drainage (soils saturated with water).
- Timely applications of effective fungicides can be important for controlling the disease.

*Figure 4.4 Symptoms of anthracnose on cucumber. Source: GrowLust - Growing An Edible Garden*

### Anthracnose

**Causal agent – Colletotrichum lagenarium.** Anthracnose is a serious disease of cucumber that can result in significant yield losses under favorable conditions for disease development. The disease affects the leaves, stems, stalks and fruit. The fungus overwinters in infested plant debris in and on top of the soil. The fungus can also be carried on seed harvested from infected fruit. Free water on plant surfaces are required for infection and disease development. Free water from rain fall and overhead irrigation and high humidity are necessary for the germination of fungal spores, and their spread. Spores are spread mainly by splashing water, but can also be spread by insects, wind, people and machinery.

The optimal temperature for spore germination and growth is 22° to 27°C, with relative humidity of 100 percent for 24 hours. Visible symptoms of the disease can appear at 96 hours after infection.

**Disease Symptoms:** All parts of leaves, stems and fruits can be infected. The first symptoms appear as roughly circular light brown to reddish spots on leaves, stems or fruits. Leaves become infected at early stages of plant development. Leaves develop the distinct spots, the number and size of which depends on climatic conditions that are favorable for disease development. Spots gradually increase in size and number, causing leaves to dry and become distorted. The centers of the spots may fall out causing a shot hole effect. On stems and fruit stalks (petioles), spots are shallow, elongated, and tan in color. When stems become diseased, it is important where the infection occurs. If infections occur near the base of the stem, they may girdle the stem and the entire plant can dry up and die. If infections occur on higher parts of the plant, new shoots may develop on the lower part of the plant.

On fruit, spots are circular, sunken, and water-soaked. Spots on fruit usually develop as the fruit begins to ripen (mature) near harvest. Fruit infection often occur first on the skin of the fruit that is in contact with the ground. The number and size of spots increases with time, they merge and occupy large areas of fruit surface and may also cover it completely. If diseased fruits survive, they often have a bitter taste.

### Control

- Use crop rotation with a minimum of three years without replanting cucumber or other susceptible crops in the cucurbitaceae family such as melons.
- Select and use varieties and hybrids, which are comparatively resistant to the disease.
- Sanitation-Remove and destroy infected plant debris from the field or greenhouse.
- Timely applications of effective fungicides are important for controlling this disease.

### Gummy Stem Blight

**Causal agent – Didymella bryoniae.** Gummy stem blight is a serious disease of cucumber in the field and greenhouse. The disease can cause extensive damage on all above ground parts of field and greenhouse grown cucumbers. The disease on fruits in the field and in storage is called black rot. The fungus overwinters in debris from old infected plants in or on the surface of the soil and can be carried on infected seed. Fluctuating temperatures, excessive irrigation or rain fall, incorrect placement of plants (excess of plants per unit area) that reduces air circulation, and damage caused by nematodes contribute to development of this disease.

**Disease Symptoms**: On leaves, symptoms visually resemble sunburn. With careful inspection, thickened areas on infected leaves can be observed. Large leaves develop yellow or reddish–brown spots with various shapes. The spots grow in size, lose color and assume a quasi-circular shape. Often, spots occupy over half of the leaf area.

*Figure 4.5 Symptoms of gummy stem blight. Author: Don Ferrinine*

Diseased areas develop small black dots which are fungal fruiting structures that produce spores that can spread the disease. Stalk and stem infections usually develop at the beginning of the stalk and where it branches. Moisture usually accumulates easily at this location on the stem. Infected areas develop wet spots, which dry, develop a grayish color and become covered with black dots (fungal fruiting structures).Infected fruit soften, look like they have been boiled, blacken and then dry up.

**Control**

- Use crop rotation with a minimum of three years without replanting cucumber or other susceptible crops in the cucurbitaceae family.
- Disinfect seed material. Always start the planting with high quality disease free seed and transplanting material.
- Observing an optimal irrigation regime. Avoid over watering plants and water them at the time of day when the plants will dry the fastest. In the greenhouse, any watering method that prevents above ground plant parts from getting wet will greatly aid in disease control.
- Sanitation- Remove and destroy infected plants and plant debris from the field and greenhouse.
- Timely applications of effective fungicides are important for controlling this disease.

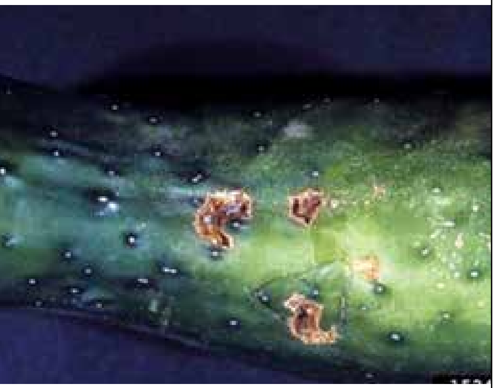


*Figure 4.6 Symptoms of cladosporium. Source: Forestry Images*

## Cladosporium (Scab)

**Causal agent – Cladosporium cucumerinum.** Cladosporiumis a widespread disease of cucumber worldwide. It mostly affects fruit, but under conditions of high relative humidity it may also infect stems, leaves, and seedlings. The greatest economic losses from scab come from fruit infections.The disease is most severe during rainy and cool summer periods, with rapid changes in temperature. Under hot summer conditions disease severity is reduced.Disease severity increases late in the growing season during the final period of cucumber vegetation, when relatively cool nightswith dew appear.

In greenhouses, this disease is most severe under conditions of rapid temperature changes and high relative humidity. Increased temperature significantly reduces disease development. The causal agent spreads by means of splashing water from rain or overhead irrigation and wind. It overwinters in and on top of the soil in infected plant debris.

**Disease Symptoms:** Fruit infections cause the most economic damage. Fruit infections begin as small (2-4 mm), greasylooking sunken specks on the fruit surface. These specks enlarge, become circular to oval in shape, gray in color, and remain sunken. A velvety layer of dark green fungal growth may develop on the surface of the lesion. Lesions often ooze a sticky exudate that dries to look like drops of hardened jelly. Spots may coalesce to form large sunken craters and cavities. The fruit skin often cracks and secondary decay organisms colonize infected tissues andcause additional fruit rot. Infected fruitsoften becomecrooked.On leaves, water-soaked, pale green, irregularly shaped spots develop. The spots enlarge and turn gray to brown in color. Eventually the inner tissue of the spot breaks and falls out, leaving irregular shaped holes and tears in the leaf. Infected leaves may become deformed. Under humid conditions, spots on the leaf and stemscan become covered with the powdery dark green growth of the fungus.

### Control

- Use crop rotation with a minimum of three years without replanting cucumber.
- Sanitation- Remove and destroy infected plants and plant debris from the field and greenhouse.
- Maintain an optimal ventilation regime in greenhouses to promote faster drying of all plant parts.
- The temperature in greenhousesafter transplanting of seedlings must be no lower than 17° to 18°C. Immediately upon discovery of the first symptoms of the disease, it is necessary to regulate relative air humidity at 70 to 75 percent.
- When watering plants in the greenhouse try to avoid getting plants (leaves and fruits) wet. Irrigate plants in the field at a time of day or under conditions that will allow the plants to dry quickly.
- Timely applications of effective fungicides are important for controlling this disease.

## Downy Mildew

**Causal agent – Pseudoperonospora cubensis.** Downy mildew is a very common and serious disease. Under environmental conditions that favor disease development (cool, wet weather and high relative humidity) downy mildew can destroy the entire crop if it is not controlled. It affects most crops in the cucurbitaceae family. The disease affects cucumber in the field and in greenhouses. The pathogen is an obligate parasite so it can only infect living plants. The oomycete pathogen requires free water in order to infect and produce spore to spread the disease. When weather is dry or if cucumber is planted in a dry location or region, downy mildew should not be a problem.The fungus overwinters as thick walled resting spores (oospores) in the soil or infected plant debris on top of or in the soil. The thick walled oospores can survive for long periods of time.

*Figure 4.7 Symptoms of downey mildew on cucumber. Source: State University Cooperative Extension*

**Disease Symptoms:** In Georgia, the disease usually starts to develop when young plants have three to five leaves. The first symptoms are pale green areas on the upper leaf surface. These areas soon become yellow in color and angular to irregular in shape and are bordered by the leaf veins. As the disease progresses, the leaf spots may remain yellow or become brown and necrotic. During moist, wet weather, the area under the leaf spot on the bottom side of the leaf becomes covered with a whitish to pale gray fuzzy growth of the pathogen (the downy mildew). Severely affected leaves may dry up and die resulting in defoliation of the plants. Disease development is favored by day and night temperaturesof 18° to22°C and the presence of water drops or dew on the plant's surface for a period of at leasteight to nine hours. Under such conditions, the pathogen forms maximal numbers of spores and the disease can spread very quickly. Once infection has occurred, the pathogen can produce spores on infected tissues in about fourdays. These spores start another infection cycle. Relatively seldom does the disease affect cucumber fruits and steam. When it does, dark spots appear on the fruits, while on the steam the disease rots the stalk and dries the plant from the diseased area towards the top.

#### Control

- Observe optimal humidity and aeration regimesin the greenhouse.
- Sanitation- Remove and destroy diseased plants and old infectedplant debris from the field or greenhouse.
- Select and use cucumber varieties and hybrids that are resistant to the pathogen.
- Under conditions favorable for disease development, the timely application of effective fungicides is very important for controlling this disease on susceptible varieties.

*Figure 4.8 Symptoms of alternaria leaf spot. Author: Howard F. Schwarts*

### Alternaria Leaf Spot

**Causal agent – Alternaria cucumerina.** Alternaria leaf spot can infect several crops in the cucurbitaceae family. The pathogen can survive (over winter) as fungal mycelium in infested plant debris on top of or in the soil for one to two years. The source of inoculum thatfirst introduces the disease are spores (conidia) that are produced by dormant mycelium in fields where the disease was present. The conidia can be carried for long distances by wind.

High temperatures and the presence of free water from rain, irrigation or dew on leaf surfaces are required for infection and disease development. The disease can be a serious problem in greenhouses with poor ventilation and high relative humidity.Rapid changes in temperature and failure to remove infected leaves and other plant parts from the planting also contribute to disease development and spread.

**Disease Symptoms**: The first symptom of the disease is the formation of small yellow brown spots with a light green or yellow halo. Spots first appear on older leaves near the top of the plant then spread to other parts of the plant. Spots quickly grow in size and their diameter often exceeds 1 cm. Spots are frequently a little sunken. When the disease is severe, spots merge and create necrotic concentric rings or zones. Severely infected leaves may become cup-shaped, dry up and die.

#### Control

- Use crop rotation with a minimum of three years without replanting cucumber.
- Sanitation-Remove and destroy infected plants and plant debris from the field and greenhouse.
- Maintain an optimal ventilation regime in greenhouses to promote faster drying of all plant parts.
- Timely applications of effective fungicides are important for controlling this disease.

*Figure 4.9 Symptoms of cucumber target spot. Source: Forestry Images*

### Target Spot

**Causal agent – Corynespora Cassiicola.** The fungus can survive (over winter) in infested plant debris in or on top of the soil for at least two years. The fungus produces spores (conidia) that are spread by wind. Rapid changes of temperature, wet conditions from rain, irrigation, dew and high relative humidity, combined with high temperatures are climatic conditions favorable for infection and disease development

**Disease Symptoms:** The first symptoms appear on older leaves, as spots of various shapes that are grayish-yellowish in color, dry and slightly protruding on the leaf's surface. Under wet, humid conditions, a dark powder develops on the bottom side of the spots. In greenhouses, spot centers are of comparatively lighter color than in the field. In cases of severe disease, infected leaves become necrotic, dry up and die resulting in defoliation of the plant.

**Control**

- Sanitation- Remove and destroy infected plants and plant debris from the field and greenhouse.
- Maintain an optimal ventilation regime in greenhouses to promote faster drying of all plant parts.
- Observing sanitary-hygienic rules in greenhouses and their adjacent territories.
- Timely applications of effective fungicides are important for controlling this disease.

### Fusarium Stem and Root Rot

**Causal agent – Fusarium oxysporum.** The pathogen is soil borne and can survive in the soil for 15-16 years or longer.The fungus penetrates the plant through root hairs, and through wounds caused by mechanical damage,insect pests and other forms of root injury. The disease is most severe when cucumber and other crops in the cucurbitaceae family are grown inmonoculture without adequate crop rotation to help reduce pathogen populations in the soil.Environmental conditions that favor disease development are high temperatures combined with low relative humidity.

*Figure 4.10 Symptoms of Fusarium stem and root rot. Source: Applied and Environmental Microbilogy*

**Disease Symptoms:** Plants may become diseased at any stage of their development. Seedlings germinating from seeds can become infected and die before they emerge from the soil. After emergence, seedlings that are infected are often stunted and may die. On older plants, symptoms of wilting are moreobvious during bloom and fruit set. Initially, the upper part of the plant begins to turn yellow and wilt during the hottest part of the day.Wilted plants may appear to recover at night as temperatures cool down and plant transpiration decreases. Leaves on infected plants often have dead areas that can look like symptoms of nutrient deficiency. When stems of wilted plants are cut lengthwise at the soil line, they often have a brown discoloration in the woody tissue immediately under the bark. Vines killed by Fusarium can become covered with a pinkish –white fungal growth in wet weather. Fruits from diseased plants are extremely bitter.

**Control**

- Because the fungus can survive in soil for up to 16 years, crop rotation is not considered to be effective for controlling this disease. If cucumber must be replanted in infested fields, crop rotations of three to four years may be helpful lowering the amount of Fusarium in the soil.Disinfect soil in the greenhouse through heat treatment or fumigation. Soil fumigation in the field can be effective, but is very expensive.
- Select and use of cucumber varieties and hybrids that are resistant to Fusarium wilt whenever possible.

*Figure 4.11 Symptoms of cucumber grey mold. Source: American Phytophatology Society*

- Avoid introducing the fungus into new fields and greenhouses. The fungus can be spread on infected planting material, equipment, tools, feet and surface water that is contaminated with infested soil.

### Gray Mold

**Causal agent – Botrytis cinerea.** This disease is most severe onnon-self-pollinated varieties.The fungus penetrates the plant mostly through wounds or old dying flower parts. The fungus can survive in soil or plant debris in or on top of the soil as sclerotia. Sclerotia are long term survival structures of the fungus. It canalso survive as mycelium in infested plant debris.Fungal conidia develop in spring on sclerotia or from mycelium in plant debris and are the source of inoculum for new infections. Low soil temperature, irrigating with cold water, improper planting density that reduces air circulation and increases drying time of plant parts and bad ventilation in greenhouses areallfactors that favor disease development. Under the proper conditions, the disease can cause serious losses in the field and in greenhouses.

**Disease Symptoms:** Thedisease canaffect leaves, stems and stalks (petioles) of cucumber. Symptoms first appear as small wet (water-soaked) spots. In time and under wet or moist conditions, the surface of diseased tissues becomes covered with a gray powdery growth of the fungus. This is where the disease gets its name (gray mold). The gray powdery fungus growth consists of mycelium and conidia of the fungus which can serve as inoculum to spread the disease. Infected fruit can become completely covered with the gray mold.Fruit may rot and collapse.

#### Control

- Sanitation- Remove and destroy infected plants and plant debris from the field and greenhouse.
- Maintain an optimal ventilation regime in greenhouses to promote faster drying of all plant parts.
- Observe sanitary-hygienic rules in greenhouses and their adjacent territories.
- Timely applications of effective fungicides are important for controlling this disease.

*Figure 4.12 Symptoms of cucumber mosaic virus. Author: William M. Brown*

## Cucumber Diseases Caused by Viruses

### Cucumber Mosaic Virus (CMV)

**Causal agent – Cucumber mosaic virus.** Cucumber mosaic is a serious disease of cucumber. The virus is spread or vectored by insects, primarily aphids and especially the peach aphid.The virus becomes deactivated easilyunder natural conditions and cannot overwinter in plant remains. It overwinters in aphid reservation areas, weeds and in the aphids themselves.

**Disease Symptoms:** Disease symptoms of most diseases caused by viruses are highly variable depending upon many factors. Often, the first symptoms of the disease appear on young leaves. At this time, leaves develop light gray or yellowish spots. With time, the number of spots increase and they frequently cover the entire leaf. Green wart-like structures often develop at the same time. Leaves eventually become deformed, develop chlorosis, necrotic spots and dry up and die. Diseasedplants are usually stunted with the distance between plantnodes (internodes)shortened.Infected fruit are light green at first, thenturn yellow.Fruit are usually deformed, with wart-like structures on their surface and are greatly reduced in size. If plants become diseased during the second half of the growing season, reduced growth (stunting) may not be observed at this time, but fruit may still be deformed.

**Control**

- Sanitation- Remove and destroy infected plants and plant debris from the field and greenhouse.
- Select and use of cucumber varieties and hybrids that are resistant to cucumber mosaic whenever possible.
- Control insects that spread (vector) the disease, especially the peach aphid.

### Cucumber Green Mottle Mosaic

**Causal agent – Cucumber green mottle mosaic virus.** This disease is most common in greenhouses. It often causes stunting of plant growth. Cucumber green mottle mosaic viruscan remain active in diseased plant remains, existing in the soil. In certain cases, virus may also spread through infected seed material. The disease has not been reported to be transmitted by insects.

*Figure 4.13 Symptoms of cucumber green mottle mosaic virus. Source:Snipview*

**Disease Symptoms:** Green wart-like structures develop on young leaves and fruit. Leaves are often deformed. In some cases, necrotic areas develop on leaves and may turn white.

**Control**

- Use crop rotation.Cucumber crops should be rotated with tomato or pepper, since these crops are not considered host plants of this particular virus.
- Use only virus free seeds and planting material.
- It is necessary to avoid rapid changes in temperature in the greenhouse. It should also be notedthat chances of spreading of this disease diminish when soil temperature exceeds 16°C.
- Sanitation- Remove and destroy virus infected plants and plant debris from the fieldand greenhouse.
- Observe sanitary-hygienic rules in greenhouses and their adjacent territories.

## Cucumber Diseases Caused by Bacteria

### Bacterial Soft Rot and Wilt

**Causal agent – Pseudomonas burgeri**: Bacterial soft rot and wilt is a serious disease of cucumber in Georgia. If the disease becomes severe, crop losses of 40 percentor higher can occur. The disease may appear at any stage of plant development. The bacteria survive and over winter in infected seed andinfected plant remains on top of or in the soil.

*Figure 4.14 Bacterial Soft rot and wilt of cucumber. Source: Snipview*

**Disease Symptoms:** Initial symptoms are wet (water-soaked), dark green spots that develop along the central vein of the leaf.The spots darken with time. Spots later merge and develop into large necrotic areas of 2-3 cm.If the plants become infected at the two to sixleaf stage, they lose turgor pressure and can wilt in the hottest part of the day. When temperatures become cooler at night, wilted plants may recover and appear normal. This phenomenon may continue for several days. Finally, the wilting becomes irreversible and the plant becomes severely wilted. Infected stalks become very soft and when cut length wise, darkened vessels and tissue inside the stalk are easily noticeable. Sometimes thisdisease doesnot produce a typical rot.In such cases, the plant's growth is stunted, lower leaves dry,and the fruit, if it develops, is not marketable. Wet (water-soaked)spots with a diameter of 0.1-0.2 cm develop on fruits that have soft rot. The central part of these spots later darkens, as a result of death of the cellson the fruits surface. In later stages of soft rot, fruit contents become brown and rotted. The bacteria spread through the plant by means of vessels.

**Control**

- Sanitation- Remove and destroy infected plants and plant debris from the field and greenhouse.
- Observe sanitary-hygienic rules in greenhouses and their adjacent territories.
- Prevent movement of bacteria from plant to plant and from location to location on hands, tools and other equipment.
- Ensure optimal plant nutrition regime. Do not over fertilize, especially with nitrogen.
- Disinfest seed and always start the planting with high quality, disease-free seeds.
- Disinfest soil with heat treatment (in the greenhouse) or soil fumigation.

*Figure 4.15 Symptoms of bacterial wilt of eggplant. Source: Missouri Botanical Garden*

### Bacterial Wilt (Bacteriosis)

**Causal agents – Erwinia tracheiphila:** Causal bacteria can overwinter on and in infected seeds.The incubation period(the time from infection until visible symptoms develop) for the disease is five to ten days.When the disease is severe, crop lossesof 40 percentand more can occur. Optimal environmental conditions for disease development aretemperatures of 26° to 28°C and relative humidity of 95-100 percent.

**Disease Symptoms:** Infected plants wilt and usually die within two weeks. Infected stems develop yellowish stripes on their surface. These stripes later darken and burst. When infected stems are cut, reddish-brown tracheae (vascular tissue) can be observed inside the stem. On leaves, small, wet (water-soaked), chlorotic (yellowish) spots are the first symptoms to develop. These spots later increase in size and their diameter reaches approximately 0.8-1 cm. In time, spots change their color and become dark red or dark brown. Fruitsfrom diseased plantshave chlorosis (yellowing), become hardened and may develop wet (water-soaked)or oily light brown spots on their surface, which are 0.3-0.5 cm in diameter. Infected fruits are not marketable.

**Control**

- Sanitation-Remove and destroy infected plants and plant debris from the field and greenhouse.
- Observe sanitary-hygienic rules in greenhouses and their adjacent territories.
- Prevent movement of bacteria from plant to plant and from location to location on hands, tools and other equipment.
- Ensure optimal plant nutrition regime. Do not over fertilize, especially with nitrogen.

- Disinfest seed and always start the planting with high quality, disease-free seeds. Disinfest soil with heat treatment (in the greenhouse) or soil fumigation.

## Physiolgial Disorders

Very few abiotic disorder are associated with cucumber fruits. Only two major abiotic disorders are known to affect fruit quality. These are fruit bitterness and chilling injury.

### Fruit bitterness

The bitterness in cucumber is linked to a group of chemicals called cucurbitacin. These chemicals are found in higher concentration in the leaves and stems, but at a very low concentration in the fruit, except in wild cucumbers where they are present at a very high concentration. These chemicals are toxic to human when consumed inlarge quantities. Several explanations have been suggested as to why some cucumber fruits become bitter. Some varieties have been reported to be prone to produce fruits with higher concentration of cucurbitacin than others and in some cases plants within a certain variety may produce more of the chemicals than others. Non-genetic factors that can increase cucurbitacin include vines grown under certain stresses (such as sever moisture fluctuation), and low temperatures often produce bitter fruits. Also, misshapen fruits are more likely to be bitter than well-shaped fruits. Improper fertilizer rates and spacing were also suggested to increase bitterness in cucumber.

*Figure 4.16 Symptoms of chillinginjury in cucumber. Source: North Carolina Cooperative*

#### Control

- Plant varieties that produce low bitter fruits.
- Transplant cucumbers into the field after the last day of frost.
- Ensure that plants receive maximum sunlight, especially late in the afternoon.
- Avoid fluctuation in soil moisture.
- Avoid planting very close to one another.
- Ensure that the plants receive adequate and balanced fertilizers.

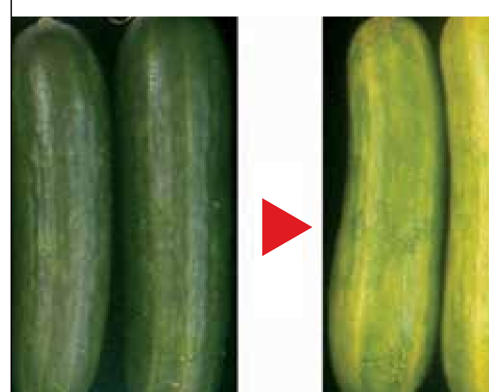


*Figure 4.17 Symptoms of cucumber, when it is stored with ethylene producing fruits like tomato and pepper. Source: North Carolina Cooperative*

### Chilling injury

Cucumbers and other warm season crops like tomatoes, peppers, eggplants, and melons are chilling sensitive at temperatures below 10°C if held for more than one to three days, depending on temperature and cultivar. Symptoms of chilling injury are water-soakedspots, pitting and decay. Chilling injury is cumulative and may start in the field before harvest. Also, cucumber varieties are different in susceptibility to chilling injury.

#### Control

- Harvest the crop early in the morning when fruits are at their coolest temperature. If the ambient temperature is lower than 12ºC, then delay harvest until the fruit temperature rises to about 15° to 18ºC.
- Store fruits between 10° to 13°C. An averagestoragelifeof cucumber fruits stored at 13ºC is between 10 and 14 days.
- If a cooler is not available, then keep fruits moist and cover with a wet burlap cloth to serves as an evaporativecooler.

# CABBAGE

Cabbage belongs to the genus *Brassica,* species *oleraceae*, variety *Brassicaceae* and cultivar group capitata. Members of this family include cabbage, cauliflower, broccoli, Brussels sprout, kale, radish, mustard, and many others.

## Cabbage varieties

Cabbage types exist in several shapes, sizes and colors. The most common types are green, savoy, red, Napa, bokchoy, and Brussels sprouts. Most form tight heads, except bokchoy. In general, head cabbage requires between 60 to 100 days from sowing to reach market maturity, depending on the variety.

## Climatic requirements

Cabbage is a cool-season crop, which can generally tolerate light freeze (0° to -1°C). Cabbage can be grown as a spring crop or a fall crop in many moderate climate areas of Georgia. Plants can tolerate a hard frost (-2°C for a few hours), however exposure to-2°C or lower for many hours can cause severe damage or death of the plants.

Ideal monthly temperatures for optimal growth and development range from 16°C to 18°C. However, cabbage and other brassica crops may become subject to bolting (premature appearance of a flower or seed stalk) when exposed to certain temperatures. Flowering usually occurs after an extended period of exposure to low temperatures (below 10°C) followed by a period of warmer temperatures. Usually, exposure to above 24°C after exposure to low temperature may cause rapid bolting, but varieties differ in their susceptibility to this disorder. Bolting is the process in which the plant switches from vegetative growth (heading) to reproductive growth (formation of flowers and seeds). This switch becomes evident when seed stalks appear, making the heads unmarketable. The presence of a seeds talk is not always visible from the exterior of the head. The head may have to be split to observe the seed stalk forming from the base of the plant. Varieties differ in their tolerance to temperatures that induce bolting. Losses to bolting in cabbage occur almost annually, particularly in overwintered crops that are exposed to severe temperatures.

## Nutritional requirement

Soil pH influences plant growth, availability of nutrients and activities of microorganisms in the soil. Keeping soil pH in the proper range is important for production of the best yields of high quality cabbage. The optimum pH for cabbage production is between 6.0 to 6.5. Calcium (Ca) has limited mobility in soil, therefore, lime should be broadcast and thoroughly incorporated to a depth of 15 to 20 cm to neutralize the soil acidity in the root zone. To allow adequate time for neutralization of soil acidity (raising the pH), lime should be applied and thoroughly incorporated two to three months before seeding or transplanting. However, if application cannot be made this early, liming will still be beneficial if applied and incorporated at least one month prior to seeding or transplanting. Generally, maintaining a soil pH of 6.0 to 6.5 will provide adequate soil Ca levels. When soil Ca falls below 400 to 450 kg per hectare, calcium deficiency problems may develop.

Because calcium levels can vary considerably in a field, soil calcium should be maintained at 550 kg per hectare or slightly higher. If the soil pH is in the optimum range of 6.0 and 6.5 and the soil Ca level is below 560 kg, then apply 900 to 1100 kg of calcium sulfate (gypsum) per hectare. The general fertility recommendation for cabbage is to apply enough fertilizer to provide about 150 kg each of nitrogen (N), phosphorus (P2O5), and potassium (K2O) per hectare. This can be done by applying 900 kg of 10-10-10 per hectare by broadcast or band placement methods before planting. Also apply 4.0 to 8 kg of Borax per ton of fertilizer. If boron is not applied with pre-plant fertilizer, spray 12 Kg of Solubor per hectare directly to the base of young plants. Cabbage has a higher demand for boron than many other vegetable crops. A boron deficiency can induce a physiological a disorder called "hollow heart." Hollow heart causes the pith of the head (center) to crack and turn brown as the head reaches maturity.

Side dress with 15 to 30 kg of nitrogen per hectare at two weeks after transplanting or about five weeks after direct-seeding. Side dress again with the same rate three weeks later.

### Planting methods

Although cabbage can be direct seeded, most producers use transplants. Direct-seeding of cabbage requires using a precision seeder to place a single seed at desired distances from one another. For optimum seed germination and stand establishment, soil temperatures must be above 5°C, otherwise seeds will be lost to damping-off and rotting, causing poor or uneven stand. Some growers choose to produce their own transplants in nurseries with transplants being dug five to seven weeks later. It is estimated that 20 grams of cabbage seeds produce about 3,500 transplants.

For a spring crop, set transplants in the field in late February or early March. For a fall crop, field-seeding should start during the first half of August or during the last half of July in northern areas. If using transplants in the fall, plant about one month later than if field-seeding. Prepare the land early by turning the soil so that any crop residue is fully decomposed before transplanting or direct-seeding is done. Space transplants at 30to 40 cm apart in the row and 90 to 100 cm between rows. This spacing will produce heads of about 1.0 to 1.5 kg.

### Irrigation

Cabbage is a fast-growing plant with shallow roots penetrating only 30 to 40cm into the soil. Although cabbage is relatively drought tolerant, adequate soil moisture should be maintained in order to maximize yields. The most critical time for irrigation is following direct seeding or transplanting and during head development. Any water stress during these periods can lead to small head size, cracking of the head, or tip burn.

### Use of plastic mulch

Plastic (Polyethylene) mulch offers several advantages in growing many horticultural crops. Plastic mulch increases soil temperature, which can accelerate plant growth and development, it conserves soil moisture, reduces soil compaction, leaching of fertilizer, soil moisture evaporation, and competition from weeds. Most growers use double rows spaced 25 to 30 cm apart between rows within the row, and 80 to 90 cm between rows. Using plastic mulch adds to the production costs; however, the cost can be offset by earlier and larger yield of high-quality heads. In order to spread the increased cost over two seasons, growers can plant another crop (double cropping) before or after cabbage harvest. Care must be taken throughout the growing season not to tear or damage the mulch. Double-cropping with tomatoes, peppers, or melons will spread production cost over two crops.

### Controlling Weeds

Planting related crops year after year in the same field will increase pest pressure in that field causing an unlikely chance to produce a marketable crop of cabbage. The use of cover crops can also be used in a rotation. Crop rotation is one of the most effective pest management strategies that a grower can use to reduce pest pressure. Avoid producing cabbage in areas where any related crops were grown the previous season. The longer the rotation, the more effective the pest control will be (three to four years is ideal). An ideal four-year crop rotation for cabbage includes one of the following families: the cucurbitaceae family cucumbers, watermelons), followed by the Solanaceae family (tomatoes, bell peppers, eggplant), and the leguminaceae family (beans and peas).

## CABBAGE DISEASES

Cabbage has several diseases that can be very serious under environmental conditions that are conducive to disease development. Diseases of cabbage are caused by fungi, viruses and bacteria. Most cabbage diseases are caused by fungi. The main diseases that are caused by fungi include: Clubroot, Downy Mildew (perenosporosis), AlternariaLeaf Spot (alternariosis), Black Leg, Fusarium Wilt, Gray Mold, White Rust, Rhizoctonia (rhizoctoniosis) and Sclerotinia White Rot. The most important disease caused by a virus is cauliflower mosaic.

Important diseases caused by bacteria include bacterial soft rot and black rot of cabbage.

### Cabbage Disease Caused by Fungi

#### Clubroot of Cabbage

*Figure 5.1 Symptoms of clubroot in cabbage. Source: The Biking Gardener: New Plants*

**Causal Agent – Plasmodiospora brassicae.** Clubroot is a world-wide problem in temperate climates on several important crops in the family brasicaceae including, cabbage, broccoli, cauliflower, radishes and turnips. It is caused by a soil-borne fungus that only infects plants in the family cruciferae. It infects through root hairs. Once inside the plant, it stimulates abnormal growth of infected tissues resulting in swollen club-shaped galls. Infection is favored by excess soil moisture (saturated soils), low pH (5.6 to 6.5) and temperatures of 18°to25°C. However, the disease can occur over a wide range of conditions. Once a plant is infected, many spores of the fungus are produced inside of infected tissues within the "club-shaped" galls. These spores can survive in the soil for at least 10 years where they can cause new infections. The spores can be moved by wind, water, machinery, people and anything else that can move infested soil to nearby fields where they can cause new infections and continue to spread the disease.

**Diseases Symptoms:** The roots of plants affected by this disease develop club-shaped galls. The fungus induces hypertrophy (an increase in cell size) and hyperplasia (an increase in cell number) much like cancer in mammals. The distorted tissue blocks the process of absorption of water and mineral substances by the roots. When infection is severe and occurs early, this can result in a stunting of plant growth, yellowing of the foliage due to reduced mineral uptake, and wilting of the plant, especially in hot weather.

On plants that are not severely infected, the disease may go unnoticed.

Below ground galls are not visible and appearance of the plant above the earth's surface may not change greatly as a result of the disease. It is often possible to discover this disease only as a result of inspection of the root system for the presence of galls.

Diseased seedlings are completely useless for further production, since they cannot form roots and develop adequately.

**Control**

- Club root is a very difficult disease to control;
- Since club root is favored by low soil pH, adding lime to the soil to increase soil pH to 7.2or above may be helpful. However, raising pH too high may be harmful to other crops;
- Observing the root system while transplanting seedlings and removing diseased plants is important. The use of pathogen-free seedbeds and uninfected plants is essential to prevent introduction of the disease;
- Crop rotation –Growing cabbage on the same soil no more than every five to seven years is important to prevent the development of large populations of fungal spores on land that is not already heavily infested. Heavily infested areas may have to be abandoned from production of cabbage and other plants in the family Cruciferae;
- Control weeds in and near the planting, especially plants in the family Cruciferae;
- Clean and disinfest all machinery and other equipment before moving it from infested to non-infested "clean" fields;
- The use of fungicides in transplant water or applied to the soil at or before planting, may be helpful in controlling this disease.

### Downy Mildew (Perenosporosis)

**Causal Agent – Peronospora brassicae gaum**. Downy mildew affects all cultivated plants in the cruciferae family. It can be a very serious disease on cabbage, broccoli, cauliflower, radish and turnip. Under favorable conditions for disease development, it may cause serious losses in the field and can develop after harvest in storage, causing a rot that can reduce the quality of the product in packing and shipping.

The oomycete pathogen overwinters in roots or in decaying portions of diseased plants. The pathogen produces thick-walled resting spores called oospores in stems, cotyledons, and other fleshy parts of infected plants. The oospores can survive for long periods of time. On growing plants, the pathogen produces large numbers of another type of spore that are blown by wind or splashed by rain to cause new infections in the field. Moisture and temperature are important in the spread and reproduction of the pathogen. High relative humidity during cool or warm conditions promotes the growth and spread of the pathogen. Disease developments lows down or stops under hot and dry conditions. Free water on the surface of the plant from fog, rain, dew or irrigation is

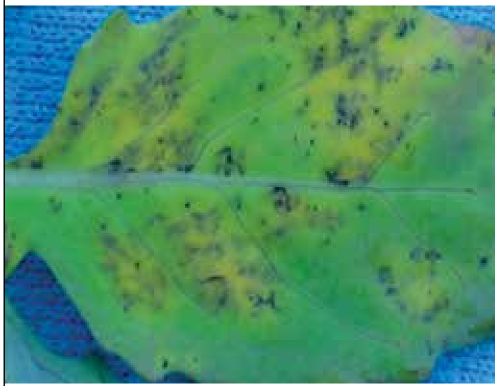


*Figure 5.2 Symptoms of downey mildew on cabbage. Source: Vegetable Pathology – Long Island Horticultural Research & Extension Center*

required for the pathogen to germinate, infect the plant and produce additional spores to spread the disease. Spores can be produced on newly infected plant parts in as little as four days.

**Diseases Symptoms:** Plants can be infected at any stage of development. In seed beds, cotyledons and young leaves may develop a fungal growth on the underside of the diseased leaf. Later, a slight yellowing develops opposite the fungal growth on the upper side of the leaf. On older leaves infected areas gradually enlarge, turn bright yellow then become tan and like paper. Under cool, moist conditions, a white mildew growth can be seen on the underside of infected leaf spots. Severely infected plants may rot and die in the field.

The disease also spreads to cabbage heads during their winter storage. Grayish spots develop on outer leaves, which then darken and cause cabbage to rot. The disease may also appear on second-year plantings and seed land plots.

**Control**

- Crop rotation- Use a rotation that excludes the production of crops in the cruciferae family for at least two out of every three years;
- Sanitation- Yes sanitary measures such as the use of clean seed beds away from the production of crops in the cruciferae family. Remove and destroy infected plant parts in the field and in storage;
- Control weeds, especially plants in the family cruciferae, in and near the planting;
- If severe disease is expected, applications of an effecting fungicide is very important for controlling this disease. Weekly applications may be required starting soon after plant emerge.

*Figure 5.3 Symptoms of alternaria leaf spot. Source: Wikimedia Commons*

## Alternaria Leaf Spot

**Causal Agent – Alternaria brassicae.** The fungus can infect most of the major crops in the family cruciferae. The disease damages cabbage during the first and second year of production and in storage.

When the disease is severe, seed losses may constitute up to 60 percent. During the first year, damage caused by the disease to the plant may be insignificant, but disease development during the second year can result in significant losses. The disease can also cause significant damage and losses in storage and on young plants after planting. Damage during these periods is more extensive, compared to the first year.

The pathogen can survive on infected plants and in infested crop residues. Free water is required for infection. A minimum of six to eight hours of leaf wetness is required for infection, and severe disease can develop under conditions of long periods of warm and wet weather. At least 12 hours of 90 percent relative humidity is required for the pathogen to produce spores on the surface of infected tissues. The optimum temperature for spore production is 18° to 24°C. These spores are spread by splashing water from rain or irrigation and by wind. They spread the disease by infecting other plants.

**Diseases Symptoms:** On white-headed cabbage, during the first year, symptoms are observed as small, black spots measuring 1to 2 mm in diameter on lower leaves and cabbage fruit walls. Later the spots enlarge into circular, tan to brown spots that are visible on both sides of the leaf. These spots can enlarge to 5 to 25 mm in diameter and usually contain concentric rings, giving the spots a target-like appearance. Spots sometimes have a yellow margin or halo. If conditions are favorable, the fungus produces spores and the spots become covered with a velvety green growth of the fungus. Old leaf spots develop a texture like paper and may tear. In second-year plants, the disease often develops on cabbage fruit or rather bags of the walls, on the whole length. Such fruit is covered with black spots. Spots which develop at the ends, open the shoots at the ends, so their ends resemble scissors.

**Control**

- Always use pathogen or disease-free seed. If seed is infected, apply fungicide seed treatments. Seed can also be treated using hot water soaks. Water is warmed to a temperature of 50°C and seeds are soaked at this temperature for 20 minutes. Seeds are then removed from the water and chilled in cold water and allowed to dry;
- Sanitation-remove and destroy diseased crop residues from the planting after harvest;
- Timely applications of effective fungicides can provide good control of this disease.

### Black Leg (Phoma Leaf Spot and Canker)

**Causal Agent – Phoma lingam:** Black leg is caused by the fungus *Leptospharia maculans*. The imperfect or asexual state of the fungus is *Phomalingam*. The asexual state of the fungus (*Phoma lingam*) produces tiny black dot-like fungal fruiting structures (pycnidia) on the surface of infected tissues. These structures are useful in diagnosing the disease. The fungus can affect all parts of the plant (leaves, stem, root, and bags). The disease may occur during any period of plant development. The fungus overwinters in infected seeds and infested plant debris in and on top of the soil. It can also overwinter on several weeds species in the family cruciferae and other cultivated crops in the cruciferae, especially rape. Free water on the surface of the plant from rain, dew or irrigation is required for the fungus to infect. Optimal conditions for disease development include temperatures of 21° to 25°C, relative humidity of 60 to 80 percent and free water on the plant surface for a period of 24 hours.

*Figure 5.4 Symptoms of cabbage black leg. Source: OSU Extension Plant Pathology*

**Diseases Symptoms**: On the leaves and stems of young plants, brown spots of various sizes develop. The growth of diseased plants is stunted and severely diseased plants may die. Spots gradually darken, dry, and contain many dark, tiny fungal fruiting bodies called pycnidia.

When mature plants become diseased, yellowish to grayish sunken spots develop on the main stem at their root necks or foundations of side roots. These spots also develop the black tiny fungal fruiting bodies at their centers. The root neck and main branches of the diseased plant develop an internal dry rot. They become hollow, dry up and disintegrate. These plants eventually die as a result of the disease.

**Control**

- Always use pathogen or disease-free seed. If seed is infected, apply fungicide seed treatments. Seed can also be treated using hot water soaks. Water is warmed to a temperature of 50°C and seeds are soaked at this temperature for 20 minutes. Seeds are then removed from the water and chilled in cold water and allowed to dry;

- Crop rotation-Use a rotation that excludes the production of crops in the cruciferae family for at least two out of every three years;
- Sanitation- Remove and destroy diseased crop residues from the planting after harvest;
- Avoid planting cabbage next to fields of oil seed rape;
- Timely applications of effective fungicides can provide good control of this disease.

*Figure 5.5 Symptoms of fusarium wilt in cabbage. Source: Ontario crop IPM*

### Fusarium Wilt

**Causal Agent – Fusarium oxysporum.** Fusarium wilt is a serious disease of cabbage and can result in significant losses, especially on early varieties. The fungus is soil-borne and produces a type of spore (chlamydospore) that allows it survive in soil for many years.

It mainly affects seedlings, both in the trays and after they are transplanted into the field. Under conditions that are favorable for disease development, the death of young seedlings may reach 20 to 25 percent.

The fungus penetrates the plant through wounds that are usually created by mechanical damage. The fungus moves through the above ground part of the plant by colonizing the vascular system. Growth of the fungus and the production of spores inside the plant plugs up the water and food conduction vessels of the plant. This severely limits the uptake of water and nutrients. This results in a yellowing and wilting of the plant, especially in hot weather. The optimal condition for disease development is a soil temperature of 15° to 17°C. Air temperature and relative humidity have little effect on disease development.

**Diseases Symptoms:** The main symptom of this disease is yellow greenish coloring of the leaves, often on one side of the plant. Infected plants loose turgor pressure and wilt, especially in hot weather or during the hottest part of the day. Leaves develop unevenly. They develop more strongly where green color predominates.

When stalks and leaf stems from diseased plants are cut in cross section with a knife, a light or dark brown circle of discolored tissue is visible in the vascular tissue. Diseased leaves fall down, the head is distorted. In case of severe damage, only naked head remains.

#### Control

- Prevent the movement of infested soil into clean, uninfected fields on machinery, other equipment and anything else that can move soil;
- Maintain a good fertility program for cabbage. There are some reports that say potassium deficiency can increase disease severity;
- Sanitation-remove and destroy infected plant remains;
- Select and use resistant plant varieties if available.

*Figure 5.6 Symptoms of gray mold in cabbage. Author: Geoff Dixon*

### Gray Mold

**Causal Agent – Botrytis cinerea.** Gray mold is one of the most widespread and serious diseases of cabbage and other plants of the cruciferae family. On cabbage, it is especially severe and causes the greatest losses during storage. Most often, plants become infected near the end of summer, during rainy weather, or when there is due on the cabbage for long periods of time.

Various types of mechanical damage also contribute to infection and disease development.

The fungus survives and overwinters as conidia and sclerotia on plant remains in and on top of the soil as well as in plants in storage. The disease is spread by means of fungal spores (conidia) that often come from storage areas.

**Diseases Symptoms:** During storage, under conditions of high temperature and relative humidity, the surface of cabbage heads becomes covered with a gray mass of fungal growth (mold), which consists of fungal spores (conidia) and mycelium. Leaves rot and become mucous.

In diseased tissues, after a certain period of time, there can be observed black fungal structures called sclerotia. These are survival structures of the fungus that can remain viable for long periods of time. The disease spreads easily to healthy plants by windblown or water- splashed conidia. The fungus sometimes infects newly emerged plants resulting in death of the seedlings.

**Control**

- Use proper agricultural production technique that minimize damage to the plant and results in healthy vigorous plants;
- Sanitation- Remove and destroy infected plant remains in the field and especially in storage;
- Careful and thorough cleaning and disinfesting of storage areas is necessary;
- Provide optimal storage conditions (temperature and relative humidity) throughout storage;
- The timely applications of effective fungicides and post-harvest dips of fungicides can be helpful in controlling the disease.

### White Rust

**Causal Agent – Albugo candida.** Apart from cabbage, the causal agent also affects many other crop plants and weeds in the cruciferae family. The disease can affect leaves, blossom clusters and stems. The pathogen is soil borne and survives in plant remains in and on top of the soil and in the soil alone. It produces thick-walled oospores that allow it to survive in the soil for long periods of time. Oospores germinate in plant remains or in the soil and produce swimming zoospores. Zoospores swim or are splashed onto the plant where they cause infections that result in raised pustules. Free water on the surface of the plant from rain, dew or irrigation is required for infection. Another type of spore (sporangia) is produced on the pustules and these sporangia spread the disease within the crop primarily in splashing water. Infections can occur within four to six hours under optimal conditions. The optimum temperature for infection is 20°C.

**Diseases Symptoms:** Early symptoms are small, raised, white- or cream-colored blisters that measure2 to 3 mm in diameter that form under the epidermis on leaves, stems and flowers talks. The epidermis covering the blisters soon ruptures releasing powdery white fungal structures (sporangia). In time, larger blisters ranging from 2 to 3 cm in diameter may develop.

*Figure 5.7 Symptoms of white rust in cabbage. Source: Flicker*

Distortion of leaves is common and leaves may develop a yellow or red discoloration. Severely infected leaves wither and die. In time, older pustules can become rotten and brown. Infected blossom clusters become distorted. Blossom cluster stems thicken and their ends become twisted.

**Control**

- Crop rotation - Use a rotation that excludes the production of crops in the cruciferae family for at least two out of every three years;
- Sanitation - Remove and destroy diseased crop residues from the planting after harvest. Deep plowing to bury infected plant remains is beneficial in reducing the spread of spores to nearby crops;
- Select and use resistant varieties if available;
- Timely applications of effective fungicides can provide good control of this disease.

## Rhizoctonia

*Figure 5.8 Symtoms of rhizoctonia in cabbage.Source: Departments of Agriculture and Food Australia*

**Causal Agent – Rhizoctonia solani.** Rhizoctonia survives and overwinters in plant residues in and on top of the soil and in soil alone as mycelium of sclerotia. Sclerotia are specialized structures that allow the fungus to survive for long periods of time in the soil. Mycelium and sclerotia cause the first infections on seedlings and older plants. The disease is favored by warm soil temperatures (25° to 30°C), but is capable of causing problems at much lower temperatures. In Georgia the disease mostly affects late head cabbage in rainy fall conditions.

This disease is especially dangerous for specialized farms and mono crop production.

The disease can be very damaging in storage, especially under poor storage conditions with high temperatures. The higher the temperature in the storehouse, during storage periods, the quicker the disease spreads. The fungus spreads from diseased to healthy cabbage heads through direct contact.

**Diseases Symptoms:** The main symptom characteristic of Rhizoctonia is cabbage leaf rot. Diseased leaves develop wet, light brown color spots with an irregular shape. In time, a whitish growth of fungus mycelium can be observed on their surface. Later on, both spots and mycelium develop a darker color. A dark-brown web of mycelia and sclerotia develop along the central vein of the leaf. Outer leaves gradually yellow and dry up and may die.

**Control**

- Use proper agricultural production technique that minimize damage to the plant and results in healthy vigorous plants;
- Sanitation- Remove and destroy infected plant remains in the field and especially in storage;
- Do not plant in fields that have under composed residues from crops in the cruciferae;
- Careful and thorough cleaning and disinfesting of storage areas is necessary;
- Provide optimal storage conditions (temperature and relative humidity) throughout storage;
- Fungicide treatments in the field have had limited effectiveness.

### Sclerotinia Rot (White Mold)

**Causal Agent – Sclerotinia sclerotiorum.** The fungus causes disease on many species of plants. The disease is more common on heavy, clay soils. Poor storage conditions (high temperatures and relative humidity) and warm wet conditions in the field contribute to disease spread and severity.

**Diseases Symptoms:** When the disease appears in the field, root neck and lower leaves are damaged. Diseased tissue loses color, becomes wet (water-soaked) and velvety white growth of fungal mycelium develops on the surface. In autumn, the mycelium thickens and transforms into black, variously-shaped sclerotia, the diameter of which fluctuates between 1 mm to 3 cm.

White mold is especially serious during storage. Damage starts on cabbage head outer leaves in the field before harvest, especially during rainy weather.

Under poor storage conditions (high temperature and relative humidity), cabbage head leaves begin to rot, become slimy and fungal mycelium develops on their surface. In time, sclerotia develop among the mycelia. The fungus spreads easily from diseased to healthy cabbage heads, as a result of direct contact.

*Figure 5.9 Symptoms of sclerotinia white rot in cabbage. Source: Departments of Agriculture and Food Australia*

**Control**

- Careful and thorough cleaning and disinfesting of storage areas;
- Provide optimal storage conditions (temperature and relative humidity) throughout storage;
- Use proper agricultural production technique that minimize damage to the plant and results in healthy vigorous plants;
- Sanitation - Remove and destroy infected plant remains in the field and especially in storage.

## Cabbage Diseases Caused by Viruses

### Cauliflower Mosaic

**Causal Agent – Cauliflower mosaic virus.** Cauliflower mosaic virus infects white-headed cabbage, leaf cabbage, kohlrabi and cauliflower. The causal virus spreads by means of plant juice, as well as cabbage and peach aphids and members of super family *Aphidoidea*. Sources of the virus are other infected crop plants and susceptible weed in the cruciferae family. Optimal temperature for spread of cauliflower mosaic virus is $16^{0}$to$18^{0}$C.

*Figure 5.10 Symptoms of cauliflower mosaci virus. Source: Departments of Agriculture and Food Australia*

**Diseases Symptoms:** Disease symptoms appear four to five weeks after transplanting. Veins of diseased plants become chlorotic and assume a lighter color, then develop dark green spots. Leaves become deformed because veins stop growing. Sometimes small necrotic spots can be observed on diseased leaves. In case of severe damage, necrotic spots may develop and leaves may drop prematurely. Under conditions of high temperatures, disease symptoms may disappear. As temperatures become lower, the symptoms may reappear.

**Control**

- Always start the planting with pathogen (disease) free seeds or transplants;
- Remove and destroy infected plants from the field and control weed species in

*Figure 5.11 Symptoms of bacterial soft rot. Source: Plant Disease and Insect Clinic*

the cruciferae family in and near the planting that can serve as a source of the virus;

- Control aphids and other insect pests which can transmit the virus.

## Cabbage Disease Caused by Bacteria

### Bacterial Soft Rot

**Causal Agent – Erwvinia carotovora, Erwvinia aroideae, and Pseudomonas Spp.** Conditions favorable for spreading of soft rot include warm weather ($20^0$ to $25^0$C) and relative air humidity within 50 percent. The bacteria generally penetrate the plant through wounds caused by mechanical damage, various insect pests (cabbage fly and cabbage bugs), and other plant diseases. Sources of infection are mostly infected plant remains on top of or in the soil and contaminated equipment or storage facilities.

**Diseases Symptoms:** First symptoms of the disease may be observed at the early leaf stage. At this time, leaves develop oily spots, as a result of which infected plants stop growing and may die. Disease development and spread becomes massive (extensive or widespread) during the second vegetation stage. At this point, outer leaves of diseased cabbage heads darken, become slimy and rot. The disease is most severe under conditions of warm temperatures and high relative humidity or wetness. The disease gradually spreads to the whole cabbage head, which rots completely and becomes separated from the stem. This process is accompanied with an unpleasant smell. It should be noted that if top leaves of the cabbage are damaged by disease and this period coincides with dry weather, the damaged areas may become dry, thin and transparent. In such cases, it is possible to localize spread of this disease on the cabbage head. Disease development sometimes begins from the crown of the cabbage, in which case it softens, development stops, and the heads fall off.

The disease can also cause serious losses in storage. Cabbage, which is diseased but no symptoms are visible during its inspection, begins to rot in storage if temperatures exceeds $3^0$ to$4^0$C and relative humidity is high. The bacteria move easily from diseased to healthy cabbage, which spreads the disease.

**Control**

- Use proper agricultural production technique that minimizes damage to the plant and results in healthy vigorous plants. Maintaining proper plant nutrition to prevent nutrient deficiencies is important;
- Sanitation - Remove and destroy infected plant remains in the field and especially in storage;
- Careful and thorough cleaning and disinfesting of storage areas is necessary;
- Provide optimal storage conditions (temperature and relative humidity) throughout storage. Storage temperature should be close to $0^0$C and never exceed $4^0$C;
- Observe crop rotation: the optimal option is growing cabbage after beet and legumes;
- Prevent damage to heads through timely and high-quality chemical treatment against pests (cabbage fly control is especially important) and other diseases.

### Black Rot of Cabbage

**Causal Agent – Xanthomonas campestris.** Black rot is a very important disease of many crops in the cruciferae family. The causal bacteria can survive and over winter in infected seed, diseased weeds and in infested crop remains that are not decomposed. The main source of infection is infected seed material Bacteria which penetrate the seeds can invade the seed root and then spread into the plant. Water is required for infection and the disease is spread within the field mainly by splashing water. During quick changes between day and night temperatures, dew appears on leaf edges, which allows the bacteria to easily penetrate the plant through natural openings. The disease reduces the market quality and value of cabbage.

*Figure 5.12 Symptom of black rot on cabbage. Source:Cornell University College of Agriculture and Life Sciences*

**Diseases Symptoms:** The first symptoms of the disease appear three to four weeks after planting of cabbage seedlings. At the first stage of cabbage rosette development, the edges of lower leaves develop localized black spots, on which blackened vessel nets are easily visible. It is possible to see blackened vessels on stems cut in cross section with a knife with the unaided eye. Leaf veins blacken, while tissue between them yellows. Damaged tissues dry and thin. Disease symptoms may also be manifested as yellowing of leaf edges. When the stem is diseased, the vascular system becomes damaged. The stem becomes plugged with bacterial ooze, which is produced by the bacteria reproducing inside it. Vessels blacken, dry and fail to perform their necessary functions. Diseased plants often cannot form heads, while if the heads still appear, they are underdeveloped and of poor quality.

#### Control

- Always use pathogen or disease-free seed or planting material. Seed can be treated using hot water soaks. Water is warmed to a temperature of 50°C and seeds are soaked at this temperature for 20 minutes. Seeds are then removed from the water and chilled in cold water and allowed to dry;
- Crop rotation- Use a rotation that excludes the production of crops in the cruciferae family for at least two out of every three years;
- Use proper agricultural production techniques that minimize damage to the plant and results in healthy vigorous plants;
- Sanitation- remove and destroy diseased crop residues from the planting after harvest;
- Systematic replacement of infested soil in green houses, or steam treatment and fumigation of infected soils;
- Timely and high-quality chemical treatment against harmful insect pests which transfer the disease.

## Physiological Disorders

### Leaf tip burn

Tip burn is the death of the margins of expanding young leaves within the cabbage head. The outside leaves are usually not affected by tip burn. However when an affected head is cut open tip burn will be visible as dark areas at the margins of young leaves. Tip burn is often associated with periods of rapid growth. The resulting tissues are often weak and susceptible to deterioration. The defect is possibly caused by a shortage of calcium associated with rapid growth and water stress. Varieties differ in susceptibility to this disorder, and using a non-susceptible variety is the best practices to avoid the problem. Additionally, avoid over fertilizing the plants, especially at young age. Adjusting soil pH to 6 to 6.5 and keeping adequate soil moisture will also reduce tip burn.

### Head splitting

Mature cabbage heads may split if not harvested in a timely manner. Splitting occurs when the stem and internal leaves grow after the head is mature, putting too much stress on the outer leaves forming the head. It occurs more frequently after a rain storm or over irrigation. Early maturing varieties tend to split more easily, they should be harvested soon after the head reaches the marketable stage to avoid the problem.

### Hollow Heart

Cabbage and other brassica crops have a higher demand for boron than many other vegetables. A boron deficiency results in the development of a condition called "hollow heart." With hollow heart, the pith of the head (center) becomes cracked and brown as the cabbage reaches maturity. To avoid hollow heart development, apply 5 to 10 kg of Borax per ton of fertilizer. If boron is not applied with pre-plant fertilizer, spray 10 kg of Solubor per hectare or 2 liters of N-Boron per hectare directly to the base of young plants.

### Post harvest handling

Winter produced head cabbage can be stored for up to one year under ideal storage temperature of -1$^0$ to 1$^0$C and relative of 96 to 98 percent. However, if no cold storage is available, cabbage, unlike broccoli or cauliflower, can tolerate storage outdoors and in cellars provided that the temperature does not drop below 12$^0$C. If stored outdoors during the fall and winter, cabbage heads should be kept moist and in shaded areas.

# TOMATO

# CHAPTER 6

Tomato (*Lycopersiconesculentum* Mill.) is one of the most widely grown vegetables in the world, planted in more than 160 countries. According to the United Nations Food and Agricultural Organization (FAO), world production of tomato in 2014 was estimated at about 120 million tons with an increase of more than 35 percent in the last ten years. About 75 percent of the production is sold for fresh market and the remaining 25 percent is processed into juice, paste, and sun dried. Tomato fruits are rich in the carotinoid lycopene, which is related to vitamin A and beta carotene. Carotenoids are very powerful antioxidants and have been reported to have anti-cancer properties.

## Environmental Requirements

Tomato is a warm season crop requiring air temperature in the range of 20°to 32°C. However, for optimum plant growth, soil temperature is more important than air temperature. Tomatoes should be planted when daytime soil temperature is not less than16°C. When tomatoes are seeded too early in cold soils, seedlings will not grow uniformly and/or they may not grow at all. Additionally, root development of seedlings grown in cold soils will be very slow and they will have difficulty absorbing nutrients, especially phosphorous. Black plastic mulch is often used to warm up the soil.

## Soil Requirements

Tomato plants will grow on most types of soils, however, the extent to which the root system will develop is affected by the soil profile. Root growth will be restricted if there is a hard pan, a compacted layer, or a heavy clay zone. Tomatoes are considered to be deep rooted and under favorable conditions, some roots will grow to a depth of as much as three meters. The majority of roots, however, will be in the upper 25 to 50 cm of soil.

Since root development is severely limited by soil compaction, proper land preparation should significantly reduce or eliminate soil compaction problems. Use of leguminous and non-leguminous crops like alfalfa, wheat, oat, or rye cover crops help increase organic matter in the soil and improve soil aeration. Optimum soil pH for growing tomato is about 6.8.

## Nutrients Requirement

Tomato plants demand moderate amounts of fertilizer. The greatest demand occurs in the first 8 to 14 weeks of growth, and peak absorption takes place after the first harvest. Therefore, plants require high nitrogen, phosphorous, and potassium applications early in the growing season with supplemental applications, especially nitrogen, needed after the fruit initiation stage. It is estimated that plants remove from the soil 3 to 4 kg each of nitrogen and potassium, 2 kg of calcium, 0.5 kg of phosphorous, and 0.5 kg of magnesium for every ton of tomato fruits produced. The general recommendation rates for the major nutrients include 52 kg nitrogen, 120 kg potassium, and 100 kg phosphorous per hectare. Nutrient treatments are best when based on both soil and leaf analysis. Leaf analysis is a better predictor of the nutritional status of the plant than soil analysis. For potassium and phosphorous they are applied at one time, usually a few days before transplanting, while calcium application is usually made the previous fall before transplanting. In some instances, plants grown in cold soils could show phosphorus deficiency, which results in plants being stunted with purple leaves on the underside.

## Varieties

Tomatoes are classified into several groups based on the growth habit of the plants, fruit shape, fruit color, and processing qualities.

Tomato varieties are classified into two groups based on their growth habits, determinate and indeterminate.

- Determinate tomatoes shoot growth terminates with a flower bud. Plants are usually more compact, reaching about two meters in height. Varieties in this group usually produce fewer fruits that mature early and in a short period of time. Determinate varieties are usually field gown and they do not require support.
- Indeterminate tomato varieties form flower buds along the sides of the shoots allowing the plants to continue to grow reaching many meters in height, especially when grown under controlled environment. These varieties are grown for fresh market and they are more suitable for greenhouse or high tunnel production, because they continue to produce fruits for several months as long as the growing conditions are favorable. However, indeterminate varieties require wires or twines for support in order to keep the plants from lodging. When grown outdoor, indeterminate varieties will continue to grow until the weather condition is no longer favorable. Both greenhouse and outdoor indeterminate varieties require continuous care by removing suckers and positioning the shoots to allow for air movement and light exposure.

Tomato varieties are also classified based on the shape of their fruits.

- Beef or steak tomatoes are round and vary in size from 50 grams up to several hundred grams. The biggest steak tomato grown in the US weighed almost 3.5 kg. Steak tomatoes are grown primarily for fresh market and juice production. However, they are not good for processing into paste or sun drying because of their low soluble solids.
- Roma tomatoes are oblong in shape and have high soluble solids content, which make them more suitable for processing into paste and sun drying and for long distance shipping, because of their high firmness.
- Cherry tomatoes are the smallest size tomato. They are grown primarily for fresh market.

Tomato varieties are also classified based on their fruit color into red, yellow, and purple. Most commercially grown varieties are hybrids. A few open pollinated heirloom varieties are still on the market.

## Cultural Requirements

Irrigation is essential to produce consistent yields of high quality tomatoes. Rainfall amounts are often erratic during the growing season, especially when plants are grown in sandy soils with low water holding capacity. Drip irrigation, plastic mulch, and raised beds are the preferred methods of growing tomato. Sprinkler irrigation is used in many countries but the risk of fruit cracking makes sprinkler irrigation less desirable.

Weed control is very essential for optimum tomato production. Weed control measures include hand weeding, hoeing and chemical control. Check with the local Georgia Extension Office for the latest information on chemical weed control in your area.

### Harvesting and Postharvest Handling

Tomato fruits are very perishable, they are usually harvested based on their distance to the market. Tomato fruits picked for long distance markets are usually harvest at the mature green stage, a stage when the fruit skin is dull green and the seeds are surrounded by a soft jelly-like material called the placenta. Fruits can also be picked at the breaker stage, when the fruit skin starts to turn red, or when fully ripe, when the distance to the market is very short. Tomato fruits are very sensitive to bruising. To avoid bruising, fruits should be harvested under utmost care, especially when they are at the green stage, in order to reduce the risk of failure to ripen. They should also be packaged properly in order to avoid compaction and compression bruises.

Tomato fruits are also sensitive to low temperature storage. Ripe fruits should be stored at 14° to 16°C, while mature green fruits should not be stored at less than 18°C. In some countries mature green tomato fruits are treated with an ethylene releasing compound called ethephon or ethrel in order to induce ripening.

## TOMATO DISEASES

There are several major diseases that can attack tomatoes on an annual basis. All of them have the capability of causing serious damage to the crop or even destroying it under the proper environmental condition. The plant pathogens that cause tomato diseases are fungi, bacteria and viruses.

Most tomato diseases are caused by fungi. These diseases include: Anthracnose, Early Blight (Alternariosis), Leaf Mold (Cladosporiosis), White Mold (Sclerotiniosis), Verticilium Wil,; Late Blight (Phytophthora), Fusarium Wilt, Septoria Leaf Spot, Powdery Mildew, Black Leg (Root Rot) and Rhizopus Ripe Rot (Wet Rot).

Several important diseases are caused by bacteria. These include: Bacterial Canker, Bacterial Wilt and Bacterial Spot.

Viruses can also cause some very serious diseases of tomato. Some of the most important in Georgia include: Tomato Mosaic Virus (TMV), Impatience Necrotic Spot Virus, and Stolbur Virus.

Some are caused from non parasitic organisms, such as Blossom End Rot of Tomato, Yellow Shoulder and others.

### Tomato Diseases Caused by Fungi

#### Anthracnose

**Causal Agent – Colletotrichum coccoides.** The fungus survives from crop to crop in infected plant debris in the soil. Wet and warm conditions are most conducive for disease development. Conditions that favor plant infection are temperatures from 10°to 30°C (with an optimum of 20° to 24°C). Free water on the plant surface is necessary for spore germination and infection. The spores that cause infections are spread mainly by splashing water from rain or overhead irrigation. The fungus can infect seedlings resulting in seedling blight (death). The fungus can also infect the roots of the plant. Fruit infection can be serious and result in severe disease losses. Fruit infections develop most rapidly on ripening and over ripe fruit.

*Figure 6.1 Symptoms of anthracnose on tomato. Author: Bruce Watt*

**Diseases Symptoms:** Infected roots of fully-grown plants become covered with dark spots. The bark stiffens and black microsclerotia (small fungal structures) accumulate under the bark giving the roots a black appearance.

On fruit, water-soaked circular and on cave spots first appear under the skin as fruit ripens. With time, the spots develop a dark yellow color, in later stages of development, spots become darker and become black in color. The fungus produces spores (conidia) on diseased tissues. These conidia result in further spread of the disease. The disease can develop very rapidly during storage and transportation to market, and during artificial ripening.

**Control**

- Sanitation - Remove old dead plants and debris from the field. Remove infected and over ripe fruit from the field;
- Crop rotation is an important cultural practice for control of soil borne diseases. Cucumber, onion, legumes, alfalfa, cabbage, and autumn wheat are considered to be good crops for rotating with tomato. Tomatoes should not be rotated with other solanaceous crops such as potato or peppers. For crop rotation to be successful, tomato should not be replanted in the fields for at least three years;
- Prevent mechanical damage to the fruit and other plant parts;
- Harvest fruit at the proper time before it is fully ripened. Avoid letting fruit become over ripe in the field or in storage;
- Maintain proper storage conditions. Fruit should be stored at 5°to 6°C;
- If overhead irrigation is required, apply it early in the day so that plants dry before sundown;
- Plant tomatoes in well drained fields to avoid excess soil moisture as fruit ripen;
- Select and use an effective fungicide for disease control. A good fungicide spray program is very important for controlling this disease.

## Early Blight (Alternariosis)

*Figure 6.2 Symptoms of early blight on leaf. Source: Cornell University*

**Causal Agent – Alternaria solani, Early Blight (Alternariosis).** This is a very common disease of tomato. It causes leaf spots, fruit rot and stem lesions on tomato. The disease can occur over a wide range of climatic conditions and can be very destructive if left uncontrolled, often resulting in complete defoliation of plants. In contrast to the name, it rarely develops early, but usually appears on mature foliage.

**Disease Symptoms:** On leaves the first symptoms usually appear on older leaves and consist of small, irregular, dark brown to black, dead spots ranging in size from a pinpoint to 5 to 7 mm in diameter. As the spots enlarge, concentric rings may form as a result of irregular growth patterns by the organism in the leaf tissue. This gives the lesion a characteristic "target-spot" or "bull's eye" appearance. There is often a narrow, yellow halo around each spot and lesions are usually bordered by veins. When spots are numerous, they may grow together, causing infected leaves to turn yellow and die. Usually the oldest leaves become infected first and they dry up and drop from the plant as the disease progresses up the main stem.

On tomato, stem infections can occur at any age resulting in small, dark, slightly sunken areas that enlarge to form circular or elongated spots with lighter-colored centers. Concentric markings, similar to those on leaves, often develop on stem lesions. If infested seed are used to start tomato transplants, seedlings may damp off soon after emergence. When large lesions develop at the ground line on stems of transplants or seedlings, the plants may become girdled.

**Control**

- Crop rotation is an important cultural practice for control of soil borne diseases. Cucumber, onion, legumes, alfalfa, cabbage, and autumn wheat are considered to be good crops for rotating with tomato. Tomatoes should not be rotated with other solanaceous crops such as potato or peppers. For crop rotation to be successful, tomato should not be replanted in the fields for at least three years;
- Sanitation: burn or bury all diseased plant tissue after harvest;
- Use disease resistance when possible. Select varieties that have a lower susceptibility to early blight;
- Use certified disease-free tomato seed and transplants;
- Use appropriate measures to control weeds and volunteer tomatoes in production areas;
- Maintain fertility at optimal levels - nitrogen and phosphorus deficiency can increase susceptibility to early blight;
- Time applications of overhead irrigation to allow plants to dry before nightfall;
- Although the above measures are important to minimize infection, it is usually necessary to apply a good fungicide spray program in order to achieve satisfactory control of the disease.

### Leaf Mold (Cladosporiosis)

**Causal Agent – Cladosporium fulvum.** Leaf mold (Cladosporiosis) is a common and destructive disease on tomatoes worldwide. Leaf mold is primarily a problem on tomatoes grown in greenhouses and high tunnels. It can also be a problem in fields and garden-grown tomatoes under conditions that are favorable for disease development.

When humidity is high, the fungus develops rapidly on leaves, usually starting in the lower leaves and then moving upward. If the disease is not controlled, large portions of the foliage can be killed, resulting in significant yield reductions. Early infections are the most damaging.

**Diseases Symptoms**: Symptoms usually develop only on the leaves. The first symptom is the appearance of small yellowish colored spots on the upper leaf surface. On the lower leaf surface, the fungus begins to produce vast numbers of spores (conidia) within the infected tissue of the leaf spot on the bottom of the leaf. The fungus appears as an olive green to grayish purple velvety growth consisting mainly of fungal spores. These spores are easily spread from plant to plant by air currents, splashing water, on tools, and clothing of workers, and possibly by insects. Spores germinate in water films or when humidity levels are above 85 percent, at temperatures between 4°and 34°C. The optimum temperature for germination is between 24° and 26°C. Leaves are infected through stomata when humidity levels are 85 percent or higher. Infection occurs most rapidly when humidity levels at the leaf surface fluctuate between 85 percent (day) and

*Figure 6.3 Symptoms of leaf mold. Source: Cornell University*

100 percent (night). Spore production is most abundant at relative humidity between 78 and 92 percent, but can occur at humidity as low as 58 percent.

Infected leaf tissue becomes yellowish brown, and the leaf curls, withers, and drops prematurely. The withering and defoliation progress up the plant until the entire plant may appear dry and dead.

**Control**

- Whenever possible, keep the relative humidity in the greenhouse below 85 percent, and keep free moisture from forming or persisting on leaves. This will inhibit the development and spread of the leaf mold fungus;
- Provide good ventilation and as much light as possible. Circulate air with fans to eliminate dead-air pockets;
- Keep night temperatures in the greenhouse warmer than outside air temperatures;
- Attempt to avoid wetting the leaves when watering. Water plants early in the day to allow leaves to dry by mid-afternoon;
- Maintain a temperature of at least 16° to 18°C throughout the season;
- Provide adequate plant and row spacing to avoid excessive shading;
- Leaf mold resistant varieties are available, but because the fungus mutates readily (there are at least 12 races of the pathogen) resistant varieties are of limited use. Because new virulent races can develop in onl a few years a tomato variety which is resistant one year may be very susceptible the next. If available grow varieties with more than one leaf mold resistance gene;
- Reduce primary inoculums levels through sanitation, steam treatment of greenhouses, and seed treatment;
- After harvest, carefully remove and destroy (burn) all plant debris;
- Where possible, steam entire greenhouse sections between crops, preferably on a bright, hot day when little steam will be needed. Close all ventilators, and maintain the temperature at135°F (57°C) for at least six hours;
- Where necessary, use hot water treated seed. Treat seed for 25 minutes at exactly 122°F (50°C);
- A fungicides pray program may help control the disease, but should be considered secondary to environmental (cultural) control measures. If fungicides are used, be sure to thoroughly cover all above-ground parts of every plant, especially the lower surface of the foliage, with e ach spray.

*Figure 6.4 Symptoms of blight on tomato. Source: Gardening Know How*

### Sclerotinia and Sclerotium Blight (Sclerotiniosis)

**Causal Agent – Sclerotini ali bertiana and Sclerotium bataticola.** *Scelerotinia* causes white rot and *Sclerotium* causes southern blight of tomato in the United States and throughout the world.

Both fungi penetrate the plant primarily through wounds (mechanical damage). Both diseases develop most rapidly under conditions of rapid drops in temperature, high relative humidity, dense vegetation canopy (which is characteristic of Georgia), and conditions of poor ventilation in greenhouses. Both fungi survive in the soil and plant debris for very long periods of time, as sclerotia. Sclerotia are fungal survival structures that resist adverse environmental conditions in soil. These sclerotia serve as the primary inoculum for the disease. In general, the development of both diseases is favored by soils that are poor in terms of organic matter and have low microbiological activity. The progress of disease development occurs more rapidly under conditions of rapid changes or fluctuations in humidity and in temperatures lower than 20°C. Disease development decreases, temperatures rise, and disease development ceases at temperatures above 25°C.

**Disease Symptoms**: Major symptoms include a gradual wilting of the plant and a stem rot with formation of cavities in the pith. These cavities are filled with whitish-grayish fungal mycelia and large black sclerotia. Infected fruit have very distinctive symptoms. A white fluffy layer of powdery fungal growth develops on the surface of infected fruit. In time, black sclerotia form on the surface of infected fruit. Infected plants usually die eventually.

**Control**

- Crop rotation is an important cultural practice for control of soil borne diseases. Cucumber, onion, legumes, alfalfa, cabbage, and autumn wheat are considered to be good crops for rotating with tomato. Tomatoes should not be rotated with other solanaceous crops such as potato or peppers. For crop rotation to be successful, tomato should not be replanted in the fields for at least three years;
- Sanitation: burn or bury all diseased plant tissue after harvest;
- Use disease resistance when possible, select varieties that have resistance;
- Maintain fertility at optimal levels and maintain soil moisture content at 80 to 85 percent;
- Select and use an effective fungicide for disease control, A good fungicide spray program may be helpful for controlling this disease.

### Verticilium Wilt

**Causal Agent – Verticillium dahliae.** Verticillium wilt is caused by the fungi *Verticillium dahliae*. The fungus attacks a wide range of plant species, including cultivated crops and weeds. It is soil-borne in field and greenhouse soils where it can persist for many years.

*Figure 6.5 Symptoms of verticilium wilt on tomato leaves. Source: Tatoo Pictures*

**Disease Symptoms**: Verticillium wilt symptoms on tomato are similar to those of Fusarium wilt. Often no symptoms are seen until the plant is bearing heavily or a dry period occurs. The fungus spreads through the plant within the vascular system where it can block water transport resulting in a wilt. The bottom leaves become pale, then tips and edges die and leave finally die and drop off. V-shaped lesions at leaf tips are typical of Verticillium wilt of tomato. Infected plants usually survive the season but are somewhat stunted and both yields and fruits may be small depending on severity of attack. A light tan discoloration in the stem similar to that caused by Fusarium wilt may be found but is usually confined to lower plant parts. The discoloration is typically lighter in color than with Fusarium wilt. Symptoms on one side of the plant only are sometimes seen. When infected stems are cut length wise, brown streaks in the vascular tissue can be observed well up into the plant.

Verticillium dahliae is most active between 75° and 83°F. Although disease is retarded by the higher temperatures that favor Fusarium wilt, visible symptoms may appear to be more severe when high temperatures exist, due to restricted water movement in the plant brought about by damage done to the water conducting vessels earlier in the growing season.

### Control

- Because the Verticillium fungus is widespread and persists for several years in soil, a long crop rotation (four to six years) is necessary to reduce populations of these fungi. Avoid using any solanaceous crop (potato, pepper, and eggplant) in the rotation, and if Verticillium wilt is a problem also avoid the use of strawberries and raspberries, which are highly susceptible. Rotate with cereals and grasses wherever possible;
- Keep rotational crops weed free because there are many weeds that are infected by Verticillium;
- If practical, remove and destroy infected plant material after harvest;
- Maintain a high level of plant vigor with appropriate fertilization and irrigation, but do not over- irrigate, when possible, especially early in the season;
- When possible, plant disease resistant tomato varieties. If soils are heavily infested with the Verticillium fungus, it may not be possible to grow Verticillium susceptible varieties.

*Figure 6.6 Symptoms of late blight on tomato. Author: Bob Mulrooney*

## Late Blight of Tomato

**Causal Agent – Phytophthora infestants.** Late blight is one of the most devastating diseases of tomato worldwide. If left unmanaged, this disease can result in complete destruction of the tomato crop. Late blight is caused by the fungus *Phytophthora infestans*. Unlike most pathogenic fungi, the late blight fungus cannot survive in soil or dead plant debris. For an epidemic to begin in any one area, the fungus must survive, be reintroduced on seed tomato transplants, or live spores must blow into the planting along with rainstorms. Ideal environmental conditions that favor disease development include warm days (21° to 29°C) and a relative humidity near 100 percent, followed by cool nights (7° to 15°C) with heavy dew, fog, or a light, drizzly rain that persists through the morning. Heavy overcast skies during the morning prevent temperatures from rising rapidly and the foliage remains wet. In moist weather, viable spores (sporangia) may be carried 20 miles or more by strong winds and rain. Under ideal conditions, lesions may appear on leaves within three to five days after infection, followed by the growth of a white mold (mycelium) soon after. Sporangia formed on the mycelium are spread rapidly by irrigation, rain and equipment. They are easily dislodged by wind and rain and can be blown into neighboring fields within five to ten miles or more, thus beginning another cycle of disease.

**Disease Symptoms**: Late blight appears on tomato leaves as pale green, water-soaked spots, often beginning at leaf tips or edges. The circular or irregular leaf lesions are often surrounded by a pale yellowish-green border that merges with healthy tissue. Lesions enlarge rapidly and turn dark brown to purplish-black. During periods of high humidity and leaf wetness, a cottony, white mold growth is usually visible on lower leaf surfaces at the edges of lesions. In dry weather, infected leaf tissues quickly dry up and the white mold growth disappears. Infected areas on stems appear brown to black and entire vines may be killed in a short time when moist weather persists.

Late blight can also develop on green tomato fruit, resulting in large, firm, brown, leathery-appearing lesions, often concentrated on the sides or upper fruit surfaces. If conditions remain moist, abundant white mold growth will develop on the lesions and secondary soft-rot bacteria may follow, resulting in a slimy, wet rot of the entire fruit.

**Control**

- Use only obviously healthy tomato transplants free of dark lesions on leaves or stems. When transplanting, discard and destroy all tomato seedlings with lesions on the stem and leaves;
- Volunteer tomatoes can be a significant source of spores of the late blight fungus. All volunteers should be destroyed as quickly as possible;
- Growers should look (scout) for disease symptoms in the field or greenhouse. Diseased plants should be removed from the planting and destroyed;
- Plant tomatoes as far as possible from potato plantings;
- Plant in a well-drained, porous soil and follow a three-year rotation away from tomato and exclude susceptible crops;
- A good fungicide spray program is essential for adequately controlling this disease once it appears in the planting. If conditions are highly favorable for disease development, and the disease becomes well established and widespread in the planting or greenhouse, fungicides will probably not provide adequate control.

## Tomato Fusarium Wilt

**Causal Agent – Fusarium oxysporum. f. spp. Lycopersici.** The fungus that causes Fusarium wilt is soil borne and survives in the soil for very long periods of time. The disease attacks plants at all stages of development. The disease is very destructive and occurs in all tomato-growing areas world-wide. Light soils favor disease development. Fusarium wilt is most serious during hot weather, when air and soil temperatures are 25° to32°C with an optimum at about 27°C. The first symptoms generally appear about the time of bloom or soon after the set of the crown-cluster fruit, but infections may occur at any time during the life of the plant.

*Figure 6.7 Symptoms of fusarium wilt on tomato plant.Source: Demo garden plots*

**Disease Symptoms:** The first symptom of Fusarium wilt in gardens and fields is usually the golden yellowing of a single leaflet or shoot, or a slight wilting and drooping of the lower leaves on a single stem. As the fungus develops inside the stem, plants show progressive yellowing, wilting, and withering starting generally with the lowermost foliage. Yellowed and wilted leaflets drop early. Often the symptoms appear first only on one side of the stem. Affected plants turn a bright yellow, wilt, dry up, and usually die before maturity, producing few, if any, fruit.

When the epidermis and cortical tissues (bark) on a section of the main stem close to the base of the plant is cut and peeled back, a distinct chocolate-brown discoloration of the water - and food-conducting (vascular) tissue is evident. The streaks extend from the roots up through the branches and into the petioles.

In damp weather, the pinkish-white masses of Fusarium spores may be seen on dead vines or in wounds and leaf scars of severely infected plants. Seedbed infections commonly cause severe losses. Affected seedlings are stunted. The older leaves droop and curve inward, the veins are cleared, and the leaves commonly droop, later wilt, and die. Fruit infection may occur and can be detected by the brown discoloration of the vascular tissue within the fruit.

Symptoms of Fusarium wilt may be confused with those of Verticillium wilt, caused by a common soil fungus *Verticillium albo-atrum (V. Dahliae)*. The two tomato wilts usually cannot be distinguished except by culturing the fungus in the laboratory.

**Control**

- Plant only certified disease-free seed and transplants (if available), well-drained, wilt-free soil. Tomato seed treated properly with hot water is free of the Fusarium fungus;
- Disinfest greenhouse and seed bed soil before planting, using steam or as oil fumigant (e.g., chloropicrin, Vorlex, methylbromide, etc.) fungi. Greenhouse structures, benches, containers, used stakes, and tools should be disinfested and pathogen free;
- In infested soil, grow only tomato varieties that are highly resistant or immune to Fusarium and Verticillium wilts. For information on resistant varieties please consult the information found in the tomato disease catalog at (http://vegetablemdonline.ppath.cornell.edu. However, in order to be successful and to choose the best variety, the race of Fusarium should be known in advance;
- Use crop rotation. Grow tomatoes in the same field area no more than once in four years. Lightly infested soil may become heavily infested by too-frequent cropping of tomatoes;
- In home gardens, pull up and burn wilt-infested plants when they become severely diseased;
- Fungicides are not effective for controlling Fusarium wilt.

*Figure 6.8 Symptoms of septoria on tomato leaf.Source: Cornell University*

## Septoria Leaf Spot

**Causal Agent – Septoria lycopersici.** Septoria leaf spot is a disease of the leaves and stems of tomato. It does not affect the fruit directly. The disease can result in rapid defoliation of the plant under warm and wet conditions. The fungus requires water on the surface of the plant in order for the spores to germinate and infect. The fungus survives between tomato crops in the soil on infested debris of tomato and weeds. Spores formed on crop debris splash onto foliage and start the disease. Wind and rain spread spores produced by the fungus to adjacent uninfected leaves. In the greenhouse, spores can survive on structures such as bench tops for a limited amount of time. The fungus is most active between15 °and 27⁰C, when rainfall is abundant.

**Disease Symptoms:** Symptoms may appear on the leaves and stems at any stage of plant development; however, they usually become evident after plants have begun to set fruit. The first symptoms are small, water-soaked, roughly circular spots scattered over the leaf. These spots enlarge to become 2 to 5mm in diameter with dark margins and tan centers. Small, dark, pimple-like fruiting bodies in which spores of the fungus are produced can be seen in the center of the lesions. Older leaves near the ground usually show symptoms first. The disease moves up the plant rapidly onto younger foliage in rainy, warm weather. When leaves are heavily infected, they drop prematurely. Exposed fruits are subject to sunscald. Severely affected plants have poorly developed fruit which become red early and lack sugar content. The fungus which causes this disease can grow on several different weed species.

### Control

- Use crop rotation. Rotate out of tomatoes for four years and avoid using any solanaceous crop (potato, pepper, eggplant) in the rotation;
- Sanitation: Remove, burn or bury all plant debris;
- Grow tomato transplants in sterilized soil;
- Control weeds, especially horse nettle and nightshade;
- When conditions are favorable for disease development, an effective fungicide spray program may be necessary in order to adequately control Septoria Leaf Spot;

## Tomato Powdery Mildew

**Causal Agent – Leveillula taurica and Erysipheci choracearum.** Fungi causing this disease are an obligate parasite and cannot survive without the living host. It survives from crop to crop in living weed species or in living tomato plants between crops. It cannot survive in dead plant debris, and conidia of the fungus that spread the disease by wind do not survive for long periods of time. Unlike most other fungi that cause plant diseases, powdery mildew fungi do not require free water on the surface of the plant in order for spores to germinate and infect. Instead the fungus requires conditions of high relative humidity to infect. It requires relative humidity levels greater than 50 percent and the optimum relative humidity for infection is 90 percent and above. Infection can occur between the temperatures of 10° to 35°C with the optimum temperature below 30° C (16° to 20°C). Powdery mildew is usually most serious under greenhouse conditions; however, it can be a serious problem in the field and in gardens on highly susceptible varieties.

*Figure 6.9 Symptoms of powdery mildew on tomato.Source: Cornell University*

**Disease Symptoms:** Symptoms first appear as light green to bright yellows pots on the upper surface of the leaf. These spots usually don't have very distinct margins and gradually become more notice able as they develop the white, powdery appearance typical of powdery mildews. However, this is where this disease differs from most other powdery mildews that we encounter. The powdery mildew of tomato is apparently much more aggressive than other mildews. Once leaves are infected, they quickly brown and shrivel on the plant. This rapid death of infected leaves and defoliation of plants is not typical of most mildews. The fungus is readily spread to nearby leaves or plants since abundant spores are produced and are easily carried by air currents or production activities in the house.

### Control (Greenhouse)

- Maintain adequate row and plant spacing to allow for good air circulation through the plant canopy in order to reduce relative humidity;
- Maintain relative humidity levels below 85 percent;
- Promote good air circulation, especially in plastic houses;
- Look at the plants (scout the greenhouse) for disease symptoms and prune out and remove diseased plant tissues (do not carry them exposed through the house). This can spread the disease;
- Following harvest, all plant debris should be removed and production areas should be thoroughly cleaned and disinfested;

- Use resistant varieties;
- Effective fungicides can be very important for controlling this disease. Fungicides should be applied as soon as symptoms are first observed. Early control is critical. If the disease becomes widespread, fungicides may not be effective for control.

**Control (Field)**

- Maintain adequate row and plant spacing to allow for good air circulation through the plant canopy in order to reduce relative humidity;
- Staking up plants and pruning helps to increase air circulation in the canopy and reduce relative humidity;
- Look at the plants (scout the field) for disease symptoms and remove diseased plants as soon as they are detected;
- Use disease resistance varieties if they are available;
- Effective fungicides can be very important for controlling this disease. Fungicides should be applied as soon as symptoms are first observed. Early control is critical. If the disease becomes very widespread and severe, fungicides will probably not be able to provide effective control.

*Figure 6.10 Symptoms of seedling damping off. Source: Thoughtyomayskpictures*

## Seedling Blight and Damping-Off (Black Leg)

**Causal Agent – Pythium spp. Rhizoctonia solani, Fusarium spp.** Species of soil-borne fungi in the following genera are commonly associated with seedling blight and damping-off: Black Leg, Rhizoctonia, Pythium, Phytophthora, and Fusarium.

Black leg is a disease of tomato seedlings. The disease is favored by wet weather and high soil moisture (saturated soils) in the field and high relative humidity in the green house. Improper spacing of plants resulting in dense vegetation and inadequate ventilation are highly conducive for disease development.

**Disease Symptoms:** Dark brown to black, sunken lesions develop on the stem at the base of young tomato seedlings at or below the soil line. The lesions generally girdle the stem. Infected plants dry up and die. Even if new roots develop above the damaged area, plant development is greatly impeded.

**Control**

Select light, well-drained soils. Avoid heavy soils that can become saturated with water. Disinfest greenhouse and seedbed soil before planting, using steam or a soil fumigant (e.g., chloropicrin, Vorlex, methyl bromide, etc.) that is effective against soil-borne fungi;

- Greenhouse structures, benches, containers, used stakes, and tools should be disinfested and pathogen-free;
- Maintain adequate row and plant spacing to allow for good air circulation through the plant canopy in order to reduce relative humidity and provide adequate ventilation in the greenhouse;
- Fungicides and fungicide drenches;
- Cultural control practice.

### Rhizopus Rot (Wet Rot)

**Causal Agent – Rhizopus nigricans.** Disease damages both green and ripe tomato fruit. Optimal conditions for pathogen development are high air humidity and an optimum temperature around 15°C.

Disease development and spread greatly increases in such storage, especially where tomatoes are stored improperly in thick layers.

**Disease Symptoms:** Initially water-soaked, colorless spots develop under the skin on the fruit surface. During this early stage of development, it is difficult to differentiate damaged from healthy tissue. After two to three days, the inner tissues (flesh) of the fruit start to break down (disintegrate) and turns into a colorless, liquid mass which has an unpleasant odor. Fruit skin becomes wrinkled and cracked. This disease especially damages unripe fruit. In conditions of high temperature, damaged green fruits are completely destroyed within five to seven days.

*Figure 6.11 Symptoms of rhizopus rot. Author: R. Stolonifer*

#### Control

- Timely crop harvesting. Harvest fruit before it becomes fully ripe (red);
- Proper storage and post-harvest handling. Store tomatoes at a temperature of less than 7°C;
- Sanitation is very important. Storage areas and containers should be properly disinfested after use.

## Tomato Diseases Caused by Viruses

### Tobacco (Tomato) Mosaic Virus (To Mv)

**Causal Agent – Tomato Mosaic virus.** Is the same as tobacco mosaic virus and is extremely infectious, being spread easily by persons touching a healthy tomato plant after touching an infected plant. Plant to plant contact during pulling out of young seedlings, transplanting, cultivating, weeding, and wind-whipping of the leaves are other very common ways of spreading the virus. Hand operations, such as pruning, tying, pollinating, spraying, watering, and picking fruit are also important tent transmission, especially in greenhouse grown tomatoes. This secondary spread, very common in greenhouses about 10 weeks after planting, can occur very rapidly once inoculums is available from plants infected in the seedling stage. The time from mechanical inoculation of leaves to the development of symptoms can be as short as a week, and newly infected plants are a ready source of virus for additional spread even before symptoms are evident. In a greenhouse, earliest symptoms commonly occur near entrances, sources of water, and other service areas. The most rapid spread occurs along rows due to mechanical spread by workers.

*Figure 6.12 Symptoms of To Mv on tomato. Source: Technico Agricola*

**Disease Symptoms:** Light and dark green mottled areas, which are usually some what raised and puckered, deveop in the leaves. The young leaves at the tips of the growing shoots tend to bunch and unfold unevenly. Plants infected when young are commonly stunted and have a yellowish cast. Leaflets on young plants growing under glass or plastic are often long, pointed, and narrow. Symptoms appear about 10 days after the plants become infected.

Stem streaking can because by one or more virus strains. The streaks are dark and longitude in a land may be short or long. Affected stems are brittle, easily broken, and contain brown are as in the pith and cortex.

*Figure 6.13 Symptoms of INSV on tomato Source: Thoughtyomaysk pictures*

*Figure 6.14 Symptoms of stolbur on tomato.Source: Phytoplasmas data base*

Ordinarily the fruit does not show any marked disfiguration. Both the number and size of the fruit are reduced, however, resulting in only about half the yield of healthy plants. The earlier plants become infected, the greater the loss. Occasionally fruit mottling, bronzing, and internal browning develop. Distinct mottling is associated with severe strains of the virus. The symptoms may be masked in hot weather, but the plants remain infected. The symptoms reappear when cool, cloudy weather returns.

### Tomato Impatience Necrotic Spot Virus (INSV)

**Causal Agent – Tomato Impatience Necrotic Spot Virus.** Is transmitted from plant to plant primarily by western flower thrips (there are several other species of thrips which can also transmit these viruses). Thrips acquire the virus as larvae and only transmit during the adult stage. An adult thrips can infect a plant with the virus after feeding for only 30 minutes.

**Disease Symptoms:** INSV causes a wide variety of symptoms including wilting, stem death, stunting, yellowing, poor flowering, and sunken spots, etches, or ring spots on leaves. Symptoms are not very specific or consistent, and merely tell the grower that there is something wrong with the plant. Many other diseases and plant problems can cause symptoms that resemble INSV. Virus symptoms may depend on time of year, type of plant, age of plant, plant physiological state, growing conditions at the time of infection, and strain of virus.

Positive diagnosis is made through the use of either inoculating special indicator plants or chemical tests to determine if the virus is present.

### Tomato Stolbur

**Causal Agent –** Stolbur is caused by a phytoplasma, which essentially is a bacterium without a cell wall. The disease usually appears during periods of high soil temperature. Disease is transmitted by insects. In Georgia, the dragonfly *Hyalestes mlacosewichi* is considered to be the most important insect vector.

**Disease Symptoms:** In general, three main types of symptom are distinguished: flower changes, premature wilting, and death without obvious flower changes. however, symptoms may be absent or hardly distinguishable. Moreover, they will vary with the stolbur strain, environmental conditions and host resistance.

Leaves developed before infection become greenish-yellow, especially at the margins, which may roll up ward. Newly formed leaves become more yellow and are smaller. Stems become thin at the apexes growth is stopped, but enlarged at the infection sites as a result of abnormal phloem formation. This appears as a greenish, water-soaked band one to two mm wide, which extends towards the xylem. Lateral shoots develop, giving the plant a bushy aspect. Flower buds assume an abnormally erect position, the sepals, whose veins develop a violet color, remain completely joined and the calyx is enlarged and cyst-like ("big bud").

Flowers, if already formed when infection occurs, become similarly erect, and maybe sterile, and petals are greenish instead of yellow. Distortion is common, and petals of young flowers become totally dwarfed and green. Peduncles are thicker than normal. Fruit development is arrested following infection. Green fruits already formed become solid, dry and color very slowly. Necrosis occurs at the embryonic center in younger fruits. Pedicels of fruits are thicker than in healthy plants, in spite of the relatively small fruit size.

### Control

- Always start the planting with healthy seeds or transplants, Seeds should be treated in advance in 20 percent hydrochloric acid for 30 minutes or in the one percent solution of potassium permanganate for 20 minutes. (If tomato seed is produced by a company, in such case it will already have undergone anti-viral procedures);
- Contaminated soil in greenhouses must be replaced with uncontaminated soil, on which no tomato, pepper and other solanaceous crops have been produced. It can also be steam treated at the temperature of 90° to 100°C, for one to two hours;
- Identification and eradication of insect vectors, as well as timely identification and removal of diseased plants are of great importance. It is necessary to monitor plants in the greenhouse and field at least once a week. Immediately upon discovery of insect vectors or disease symptoms, diseased plants should be removed and healthy plants treated with an insecticide to control the insect vectors. Replacing diseased plants (after removal) with healthy plants should not be conducted earlier than two to three days. Diseased plants should be placed in special containers after they are removed. These containers should be disinfested periodically. General virus control methods also include: disinfesting work tools with a five percent solution of potassium permanganate, weed management within and near the planting, and conducting proper production practices for tomatoes such as appropriate irrigation and fertilization and optimal plant and row placement. In greenhouses, it is necessary to regulate air temperature and humidity, as well as soil moisture content. Bringing decorative houseplants into the greenhouse should never be permitted, since they may be a reservoir for the virus and become a source of infection;
- Production of varieties/hybrids resistant to viral diseases is an important factor;
- It is inadmissible to bring into greenhouses, where tomatoes are grown, the soil on which potatoes or other solanaceous crops have been produced. For seed-production purposes, it is not recommended to use the fruit which has been picked from plants with viral disease symptoms.

## Tomato Diseases Caused by Bacteria

### Bacterial Canker of Tomato

**Causal Agent – Clavibacter michiganensis.** Bacterial canker is caused by *Clavibacter michiganensis* .sub sp. speck pathogen. It has the ability to infect tomato plants systemically. It is seed borne and can survive on infested plant debris in soil. Bacterial canker is a severe disease that is wide spread and can cause localized epidemics during warm, moist conditions. Optimal conditions for bacterial spot and canker are high moisture, high relative humidity and warm temperatures (75° to 90 °F).

*Figure 6.15 Symptoms of bacterial canker on tomato. Author: T.A Zitter*

**Disease Symptoms:** Primary or systemic symptoms of bacterial canker (from infections originating in seeds or young seedlings) include stunting, wilting, vascular discoloration, development of open stem cankers, and fruit lesions. When affected stems are split open lengthwise, a thin, reddish-brown discoloration of the vascular tissue is observed, especially at the base of the plant. On young seedlings in the greenhouse, lesions may appear as raised pustule son leaves and stems. These plants rarely survive the season in the field. Secondary symptoms in the field include leaf "firing" (necrotic marginal leaf tissue adjacent to a thin band of chlorotic tissue) and fruit lesions. Spots on fruit are relatively small (3 to 6 mm) surrounded by a white halo ("bird's-eye" spots). Canker bacteria may also invade internal fruit tissues, causing a yellow to brown breakdown.

**Control**

- Rotate tomatoes with non-solanaceous crops with at least two to three years between tomato crops. Avoid rotation with peppers, which areal so susceptible to bacterial spot;
- Plant only seed from disease-free plants or seed treated to reduce any bacterial populations. Treatments include fermentation of tomato pulp and seeds at room temperature for four to five days;
- Some decrease in germination maybe expected from these treatments;
- Use only transplants free of disease symptoms;
- Carry out proper sanitation of transplant production green-houses. Remove all weeds and plant debris, clean all tools with disinfectant solution, and wash hands thoroughly before and after handling plants. Water plants early in the day to reduce the amount of time foliage is wet. Do not handle plants when they are wet. After each crop, clean greenhouse walls ,benches, etc., with hot soapy water, followed by thorough rinsing and treatment with a disinfectant. If possible, close up greenhouse after transplant production is completed to allow natural heating during the summer. Use only new plug tray sand pathogen-free planting mixes. Avoid growing peppers and tomatoes in the same greenhouse unless pepper seed has also been treated as in step 2;
- In the field, control irrigation to minimize the time foliage is wet and avoid working among wet plants to minimize spread of disease.

*Figure 6.16 Symptoms of bacterial wilt in tomato plant. Source: Invasive Organisation*

**Tomato Bacterial Wilt**

**Causal Agent – Ralstonias olanacearum**. The bacteria can overwinter in soil. The pathogen can occur in newly-cleared land as well as in areas where susceptible crops have not been grown. The bacteria often enter a field on infested transplants or equipment or through drainage water. Bacteria infect plants through the roots or stems, most often where tissue has been injured by cultivating or by some other physical means such as nematodes. The disease is most commonly found in low, wet areas of fields and is most active at temperatures above 25°C.

**Disease Symptoms:** A characteristic of this disease, which sets it apart from other wilt diseases, is that plants wilt and die rapidly without yellowing or spotting of the foliage. Bacteria cause wilt by invading and gradually blocking the vascular tissue (the food- and water-conducting vessels just beneath the epidermis).

To identify bacterial wilt, cut and peel back a section of the epidermis and cortical tissue (bark) just above the soil line. In the early stages of bacterial wilt, the pith (center of the stem) will appear water soaked; later, the pith will turn brown and sometimes become hollow. The discoloration of the pith distinguishes this disease from Fusarium and Verticillium wilt.

Another relatively easy diagnostic technique is to cut a portion of the affected stem and place it in a clear-sided glass container filled with water. Watch for a white, milky ooze streaming out of the cut end of the discolored vascular tissue. The white, milky ooze is diagnostic for this disease.

**Control**

- Use crop rotation. Grow susceptible crops (peppers, potatoes, and eggplant) in the same area no more than once every four years to reduce inoculum in the soil;
- Use soil fumigation in heavily infested fields;
- In the home garden, rogue (weed out) wilted plants and remove the soil surrounding their roots to reduce spread of the disease;
- Disinfect infested soil with soil solarization;
- Control humidity, moisture and temperature in the green house;
- Sanitation; remove and destroy infected plant debris;
- Always start the planting with disease free seeds or transplants;
- When available, use disease resistant varieties.

### Bacterial Spot of Tomato

**Causal Agent – Xanthomonas campestri. spv. Vesicatoria.** Bacterial spot can be a severe disease of tomato that can cause epidemics during warm, moist conditions. Bacterial spot can cause moderate to severe defoliation, blossom blight, and lesions on developing fruit. The bacteria can survive on the surface of infested seed and has been shown to survive on plant debris in the soil.

*Figure 6.17 Symptoms of bacterial spot on tomato. Source: Plaza Education*

**Disease Symptoms:** On immature fruit, bacterial spot lesions are small (3 to 6 mm) water-soaked spots that become lightly raised and enlarged until they are about 3 to 8 mm inch in diameter. The centers of these spots later become irregular, light brown, slightly sunken with a rough, scabby surface. In the early stages of infection, a white halo may surround each lesion at which time it resembles the fruit spot of bacterial canker. Ripe fruit become resistant to infection.

**Control**

- Rotate tomatoes with non-solanaceous crops with at least two to three years between tomato crops. Avoid rotation with peppers, which areal so susceptible to bacterial spot;
- Plant only seed from disease-free plants or seed treated to reduce any bacterial populations Treatments include fermentation of tomato pulp and seeds at room temperature for four to five days;
- Some decrease in germination maybe expected from these treatments;
- Use only transplants free of disease symptoms;
- Carry out proper sanitation of transplant production green-houses. Remove all weeds and plant debris, clean all tools with disinfectant solution, and wash hands thoroughly before and after handling plants. Water plants early in the day to reduce the amount of time foliage is wet. Do not handle plants when they are wet. After each crop, clean greenhouse walls, benches, etc., with hot soapy water,

followed by thorough rinsing and treatment with a disinfectant. If possible, close up greenhouse after transplant production is completed to allow natural heating during the summer. Use only new plug trays and pathogen-free planting mixes. Avoid growing pepper sand tomatoes in the same greenhouse unless pepper seed has also been treated as instep 2;

- In the field, control irrigation to minimize the time foliage is wet and avoid working among wet plants to minimize spread of disease.

*Figure 6.18 Symptoms of blossom end rot of tomato. Source: New York State University*

## Physiological Disorders

Non-pathogenic disorders, also known as Physiological disorders, are disease like symptoms that are caused mostly by improper temperature, humidity, nutrient, and/or water. Examples of physiological disorders affecting tomato are blossom-end-rot, catface, yellow shoulder, gray wall, fruit cracking, chilling injury, and several others. In this chapter we will cover blossom end-rot, catface, and yellow shoulder.

**Causal factors –** Calcium deficiency in the fruit is the main causal factor. Calcium is one of the major components of the cell wall. Extreme soil moisture conditions either dry or wet hinders the ability of the plant to take up adequate amounts of calcium into the canopy and the fruit. These conditions result in a deficiency of Ca available to the maturing fruit, at the location where the damage becomes apparent. The deficiency is more apparent during the critical phase of early fruit growth. Other factors that contribute to more incidence of blossom end rot are application of excess ammonium, K, and Mg, which are known to interfere with Ca uptake and enhance more vegetative tissue, which can out compete the fruit for calcium reserve.

**Diseases Symptoms:** Blossom end rot starts as a small water soaked spot at the lower end of the fruit and continues to expand as the fruit increases in size. In severe cases, more than half the fruit may turn light to dark brown and the skin texture becomes leathery as the fruit ages. The disorder can also cause secondary infection by molds and bacteria. Affected fruits ripen prematurely, but the fruit is unmarketable. The disorder usually affects the first few developing fruits, especially those that are grown in cold soils and exposed to erratic watering regimes.

**Control**

- Adjust soil pH to about 6.8;
- Add non-dolomite lime to acid soils;
- Spray fruits with Ca, especially during the first two weeks of fruit growth and the last two weeks before harvest;
- Avoid over fertilization with nitrogen, especially ammonia formulations;
- Avoid ions imbalance in soil;
- Avoid fluctuations in soil moisture and water logging;
- Avoid practices that cause root pruning;
- When possible, avoid cultivars prone to blossom end rot like Roma types.

### Catface

**Causal Factors –** The deformity is caused by a combination of internal and external factors that occur during development of the flower resulting in the fruit not developing normally. Catface may be caused by abnormally cool or hot weather or any disturbance to flower parts during blossoming.

*Figure 6.19 Symptoms of catface in tomato. Source:Gardening Know How*

### Symptoms

The defect is usually located on the blossom end of the fruit. Catface is commonly observed in first harvest fruits. The symptoms include enlarged scars and holes in the blossom end. Cold weather occurring about three weeks before flowering begins has been identified as one of the causes. Cold weather alternates with hot, and these cycles are a predisposing factor for tomato catfacing.

#### Control

- Plant varieties that historically have had little problem with catfacing;
- Remove fruits showing the symptom as soon as it appears.

### Yellow Shoulder

**Causal factors –** Several causal factors have been cited to induce yellow shoulder including environment, specifically high temperature above 90°F, cultivar, and virus. Studies have also shown that this disorder can be triggered by insufficient potassium, excess magnesium in relation to calcium, and soil pH above 6.7.

*Figure 6.20 Symptoms of yellowshoulders in tomato. Source: eorganics*

### Symptoms

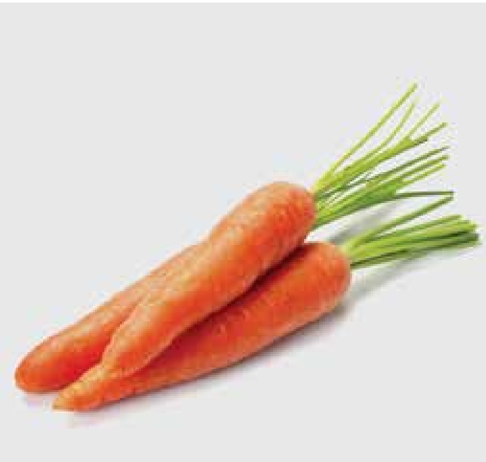
The disorder is characterized by white to yellow regions under the skin, around the stem end, that show through and reduce the quality of the fruit. The disorder can range from very mild with some internal spotting to quite severe with large hardened areas.

#### Control

Growers need to be aware that yellow shoulder is not a delay in the ripening of the fruit, but an actual disorder. The disorder occurs during early stages of fruit development, which makes tissue analysis, especially during early bloom, extremely important.

- Insure that the potassium level in leaf tissue is higher than 3% by dry weight, especially when the fruit diameter is less than 3 cm;
- Adjust soil pH to between 6.4 and 6.7;
- Increase the magnesium to calcium ratio in the tissue to about one to four;
- Plant less susceptible varieties;
- Crop rotation reduces the incidence of yellow shoulder;
- Fruits that have yellow shoulder should be removed as soon as possible to save energy for the remaining fruits;

# CARROT



Carrot (Daucuscarota var. sativus) is a member of the Umbelliferae family, which includes anise, caraway, celery, coriander, dill, fennel, parsley, and parsnip. Carrot is one of the most widely grown and consumed vegetables in the world. Carrots are produced for a variety of uses including fresh market and processing. The largest percentage of carrots produced around the world is for fresh market sales either as peeled baby carrots, carrot sticks, shredded carrots, and/or salad mixes. Carrots are also produced for processing, which includes baby food, frozen, and canned products. One of the reasons for the widespread popularity of carrots is that they are a major source of Vitamin A. They are also rich in other vitamins, minerals, and fiber. Carrots are popular snacks, used in salads, cooked as part of main dishes, and a number of other culinary uses.

## Climatic Requirements.

Young carrot plants are very sensitive to freezing temperatures, however they can tolerate short-term exposure to frost. The ideal temperature for carrots plant growth is in the range of $10^0$ to $27^0$C. Carrot plants grown under higher temperatures develop misshaped roots. Plants grown under lower temperatures may grow very slowly, and the roots will be long, slender, and have lighter color and sugar content. Carrots with a root less than 2 cm in diameter are more susceptible to cold injury than plants with larger roots.

Carrots are classified as a biennial crop with flowering stalks forming in the second season. However, in some areas carrots can flower prematurely depending on weather. In many areas fresh markets carrots are planted in late summer and harvested in early to late fall of the same year. However, planting carrots for seed production usually starts in early fall and seeds are harvested in early to middle spring of the following year. For this reason, carrots grown for seed production are planted in areas with mild winters. The ideal weather conditions for flowering are cool winter days followed by longer spring days. In most years, flowering requires six to eight weeks of temperatures below $10^0$C. Warm temperature at planting in the fall is not damaging to the plants if they are well watered. Carrots tend to produce a higher percentage of seed stems as the weather warms up during the spring and summer.

Small carrot seedlings up to six leaves cannot withstand hard freezes but are somewhat frost tolerant. Optimum temperatures are in the range of $15^0$ to $21^o$C, with daytime highs of $24^o$C and nighttime lows of $13^o$C. Although the crop can be grown outside this range with little or no effect on tops, temperatures differing drastically from the above can adversely affect root color, texture, flavor, and shape. Lower temperatures from this range may induce slow growth and make roots longer, more slender, and lighter in color. Carrots with a root less than one inch in diameter are more susceptible to cold injury than larger roots. Long exposure to hot weather may suppress growth and yield and in severe cases can injure or kill young plants. Additionally, disease infection is enhanced as temperatures warm up in late spring and summer.

Carrots need an ample supply of moisture from rainfall and/or irrigation throughout the growing season since they are not drought tolerant. A consistent moisture supply helps keep the crop growing and reduces the incidence of splitting from growth flushes.

Although technically biennial in nature, carrots can produce seed stems prematurely in Georgia. This is commonly known as bolting. Most carrot production in Georgia occurs during the fall months, through winter and into spring. Cool winter months followed by increasing day length in spring can result in carrots being exposed to conditions that induce flowering. Flower induction in carrots requires a period of six to eight weeks of temperatures below 10⁰C. Increasing day length accelerates flower induction. Once flowering is initiated, the seeds talk elongates rapidly, particularly as temperatures increase. Although fall heat at planting is not injurious if they are well watered, carrots will tend to produce a higher percentage of seed stems as spring warming turns into summer heat. Carrots that have produced seed stems are not marketable.

### Soil Requirements

The type of soil influences the shape, size, and texture of the roots. Ideally, sandy loam soil to loam soil, free of stones and with pH in the range of 6.0 to 6.5 is best for growing carrots. Heavier and lighter soil may be used if they are kept moist. Roots grown in heavier soils tend to be short and blunt, while roots grown in sandy loam soils produce long, smooth, and straight roots. Soils with excessive rocks produce forked or misshapen roots.

### Varieties

There are four basic groups of carrots with many varieties available within each group.

1. **Chant nay group.** This group tends to have tapered roots with a blunt or rounded end. The roots are about 1.0 to 1.5 cm in diameter and about12 to 16 cm long. The root color is mostly light orange with a slightly red coloration in the core of the root. This group serves a dual purpose for processing and fresh market.
2. **Imperator and Danvers group**. Imperator is the most widely grown group for fresh market. The average root diameter is about 3 to 4 cm and the average length is about 15 to 25 cm. This group stores very well in cold storage. Larger roots tend to become woody in texture while the younger roots have excellent texture. Danvers sub-group has deep orange with lightly colored center and they are similar in size and texture to Imperator.
3. **Nantes group.** This group is the most popular group for fresh market. Carrots in this group tend to have cylindrically uniform roots from the crown to the tip. The average root diameter at the crown is about 4 cm and the average root length is about 16 to 18 cm. The root surface is smooth and the flesh is bright orange, with a very small core.
4. **The Amsterdam group.** This group is grown mostly for fresh market and it is considered very easy to grow. The flesh is bright orange. The roots are about 15 cm long and have a round end that extends into a root hair beyond the fleshy part. This group can be grown in protected structures or outdoors.

### Seeding rates, fertility management, and weed control.

Worldwide, carrots are produced by direct field seeding. Usually two crops are grown each year; one in the spring and the other in the autumn. Autumn produced carrots usually have better eating quality and uniform root size than spring carrots.

Carrot are grown on hills or flat ground with seeds spaced at about 5 to 7 cm apart. Ideal plant populations are in the range of 1.1 million plants per hectare for fresh market carrots and 750,000 plants for processing carrots. Planting on raised beds has the advantage of good soil drainage.

Fertility management in carrots has a critical effect on root quality. Although, carrots have a medium requirement for nitrogen, it is advised that the nitrogen rate be divided into six to seven equal applications during the season. The maximum amount that should be incorporated per application should not exceed 16 kg per hectare. This split application allows for adequate root to top balance and reduces the potential for root splitting as a result of growth spurts.

For other nutrients, broadcast one-third to one-half of potassium and all of the phosphorous prior to planting. If raised beds are used, band in the width of the bed then incorporate into the soil prior to planting. The remaining potassium should be applied in two to three applications. Additionally, apply 11 kg zinc, 1 kg of boron, and 11 kg of sulfur per hectare prior to planting.

Controlling weeds in carrots, especially when the plants are young is very critical, because carrots are considered weak competitors with weeds. Proper tillage and herbicide applications to control perennial weeds will reduce competition.

### Storage and postharvest handling

Careful harvesting to reduce root damage is very important for extending the storage life of carrots. Damage to the main root or to the cuticle often results in rapid deterioration of quality. Carrot leaves (tops) are very sensitive to low temperature storage; below 6ºC, however, carrot roots keep best when stored at -1ºC. When cold stored, carrot tops are often removed in order to increase the root shelf-life. During shipping carrot roots are often covered with ice in order to reduce their respiration rate.

*Figure 7.1 Symptoms of carrot brown rot. Source: WikiGardener*

## CARROT DISEASES

Carrots have several diseases that can be very serious under environmental conditions that are conducive to disease development. Diseases of carrots are caused by fungi, viruses and bacteria. Most carrot diseases are caused by fungi. The main diseases that are caused by fungi include: Brown Rot; Black Rot (black carrot root dieback); Cottony Rot; Gray Mold Rot; Crater Rot; and Fusarium Dry Rot; The most important diseases caused by viruses incarrots areParsnip Yellow Fleck Virus and Carrot Red Leaf Virus. Important diseases caused by bacteria are Bacterial Soft Rot and Bacteriosis.

During the first year of development (production in the field), carrots have relatively few disease problem. During the second year of production Black Rot, Brown Rot and Crater Rot are diseases caused by fungi that can become serious in the production field. The majority of damage and yield losses to carrots caused by fungal diseases aretap root rots that occur during storage. It should be noted, that damage caused by tap root rots in storage (mainly Cottony Rot and Gray Mold Rot)) can range from 30 to 70 percent crop loss.

## Carrot Diseases Caused by Fungi

### Carrot Brown Rot

**Causal agent – Phoma rostrupii.** Brown rot is primarily problem on carrot in Russia and surrounding countries. It is considered one of the most important seedborne diseases of carrot in the Ukraine. The disease damages the stalk, spadix, flowers, stems and tap root of carrot. The majority of damage caused by the disease occurs during the second year of production. The causal fungus overwinters in infested plant debris in or on top of the soil and is seed borne. The optimal temperatures for the development of fungal spores are 20° to25°C. When the temperature is below 10°C, spore development is reduced, and when temperatures range from 0° to 3°C, spore development progresses extremely slowly or stops.

**Disease Symptoms:** Dark brown spots appear on above-ground parts of the plant (stalk, branches, spadix and seed). These spots later turn violet and exude a sticky substance. In hot weather, diseased tissues become covered with black fungal fruiting structures (pycnidia). Infected tissues dry and break easily, and the leaves eventually die.

Tap root damage most frequently begins from the foundation. Damaged tap root tissues are dark brown and dry. Disease symptoms are less pronounced in autumn and more visible during winter storage periods. At this time, the tap root foundation rots, while sunken grayish spots appear on its surface, under which the tissue disintegrates, dries and develops cracks.

#### Control

- Use proper agricultural production techniques that minimize damage to the plant and to the root and results in healthy vigorous plants. Handle plants carefully during harvest and packing to prevent damage. Use proper levels of nitrogen fertilization;
- Careful and thorough cleaning and disinfesting of storage areas;
- Crop rotation - use a rotation that excludes the production of carrots for at least two to three years;
- Sanitation - remove and destroy infected plant parts in the field and in storage;
- Applications of an effecting fungicide can be important for controlling this disease;
- The disease is seed borne so effective fungicide seed treatments are recommended.

*Figure 7.2 Symptoms of black carrot root dieback. Source: WikiGardener*

### Black Rot (Black Root Dieback)

**Causal agent – Alternaria radicina.** The causal fungus is commonly seed borne and survives in infested crop debris (residues). It can also survive in soil in the absence of debris for at least eight years. The fungus produces micorsclerotia that function as survival structures in soil.

Black rot is an important storage disease of carrot, but can also cause seedling damping-off and leaf and crown infections in the field. This disease mainly affects tap root crops, which are damaged mechanically or by the carrot fly. Mechanical damage, which occurs during transportation or harvesting, even if it is unnoticeable, significantly contributes to disease development. The causal agent is a fungus which likes warm temperature. Optimal temperature for its development is 25° to 28°C, with prolonged wet periods and relative humidity of 85 to 100 percent. However, it can also develop in conditions of lower temperature and humidity.

**Disease Symptoms:** The disease can affect all organs of carrot plants, at any stage of their development: emerged plants, foliage, tap root, flowers and seed. Initial symptoms are small, brown leaf spots that have chlorotic (yellow) halos or margins. Spots later develop into dark brown or black lesions at the base of the leaf petiole. When the spandex or flowers are infected, symptoms are manifested as black velvety spots on the leaves. The fungus moves from the leaves onto the seed. Infected seeds blacken and often lose the ability to emerge. Emerging seedlings that are infected show weakening and blackening of the crowns and upper roots. In the field, crown lesions usually consist of black lesions that extend below the soil line. Secondary black lesions also develop on the tap root, especially if splitting or other types of damage are present. In postharvest storage, the fungus causes dry, black, sunken lesions that have sharply defined margins.

The black lesions penetrate into the tap root pulp approximately 0.5-1.4 cm. Black rot is characterized by the existence of a dark brown powder on the surface of the spots. The higher the humidity, the more often such powder can be observed. Root to root spread can occur rapidly during prolonged storage.

When the spandex or flowers are infected, symptoms are manifested as black velvety spots on the leaves. The fungus moves from the leaves on to the seed. Infected seeds blacken and often lose the ability to emerge. Plants that emerge from diseased seeds often dampen-off and die.

**Control**

- Use proper agricultural production techniques that minimize damage to the plant and tap root and results in healthy vigorous plants. Handle plants carefully during harvest and packing to prevent injury. Use proper levels of nitrogen fertilization;
- Careful and thorough cleaning and disinfesting of storage areas is necessary;
- Crop rotation - Use a rotation that excludes the production of carrots for at least three to four years, or longer;
- Sanitation - remove and destroy infected plant parts in the field and in storage;
- Applications of an effecting fungicide can be important for controlling this disease;
- The disease is seed borne so effective fungicide seed treatments are recommended.

*Figure 7.3 Symptoms of cottony rot. Source: WikiGardener*

## Cottony Rot (White Mold)

**Causal agent – Sclerotinia sclerotiorum.** The disease damages carrot, parsley, beans, cabbage and crops in the cucurbitceae family primarily during storage. The main source of the fungus is the soil. The fungus produces survival structures (sclerotia) that can survive in the soil for many years. As carrots are produced on the same land plot for year after year, the population of the fungus in the soil increases and the disease continues to get worse. The fungus spreads intensively in storage areas where air humidity is high. Temperature has no special significance for development of this disease, since the causal agent can develop in temperatures ranging from 0° to 30°C. The most optimal conditions for development of this disease are air relative humidity of 95 to 100 percent and temperatures of 15° to 22°C. Losses in storage can be very high because of extensive spread of mycelium from root to root.

**Disease Symptoms:** The first symptoms are small, 5-10 mm in diameter, water-soaked, brown lesions on leaves, crowns, or the upper exposed shoulders of tap roots. White mycelia growth of the fungus can be found on old or dead leaves and other parts of the carrot when soil moisture and humidity is high. As the pathogen develops, the white mycelium produces small mounds of mycelia that become hard, black sclerotia. Infection of leaves can lead to root rots in the field. The roots develop a soft rot and sclerotia are produced on and around the tap root. On stored roots, the fungus produces extensive, fluffy white mycelium, and tissues beneath the mycelium becomes soft and rotted. The mycelium can spread rapidly from root to root spreading the disease.

**Control**

- Use proper agricultural production techniques that minimize damage to the plant and tap root and results in healthy vigorous plants. Handle plants carefully during harvest and packing to prevent damage. Use proper levels of nitrogen and especially phosphorous fertilization;
- Observe optimal storage conditions (temperature: 1° to 2°C, relative air humidity: 80 to 85 percent);
- Careful and thorough cleaning and disinfesting of storage areas is necessary;
- Crop rotation - use a rotation that excludes the production of carrots for at least three to four years, or longer;
- Sanitation - remove and destroy infected plants and tap roots in the field and especially in storage;
- The disease is seed borne so effective fungicide seed treatments are recommended.

### Gray Mold Rot

**Causal agent – Botrytis cinerea.** The causal fungus is a saprophyte that can colonize dead or dying tissues of many plants species. It is a common post-harvest pathogen on many fruit and vegetable crops world-wide. It survives as sclerotia in infected plant debris on top or in the soil. It can also survive in the soil in the absence of plant debris and on various surfaces in storage and packing facilities. Leaves and petioles can be infected in the field, but do not cause much damage in the field. However, field infections provide a source of inoculum for the disease in storage. The fungus enters and rapidly colonizes wounds on the tap root made during harvesting and handling or through tissues damaged by cold temperatures during storage (-1°Can less). The fungus may also penetrate tissue directly. Free water on the surface of the plant promotes infection. Fungus growth is slowed by lower temperatures, but may continue even at temperatures close to freezing. In storage the fungus can move from plant to plant as mycelium or over distances as air-borne conidia. Gray mold is seldom a problem in modern, refrigerated storage and packing facilities.

*Figure 7.4 Symptoms of gray mold rot. Source: Integrated Pest Management: RPD No. 942*

**Disease Symptoms:** On carrot, gray mold can develop on any part of the tap root. First symptoms are water-soaked, light brown or tan lesions. Diseased areas eventually become soft and gray in color. Under conditions of high humidity, the fungus produces mycelium and conidia that cover the diseased areas with a layer of gray powdery growth. This is where the disease gets the name, gray mold. Irregularly shaped, hard, black sclerotia often form in diseased tissue. Eventually, the entire tap root may rot.

**Control**

- Use proper agricultural production techniques that minimize damage to the plant and tap root and results in healthy vigorous plants. Handle plants carefully during harvest and packing to prevent damage. Use proper levels of nitrogen and especially phosphorous fertilization;
- Maintain optimal storage conditions (temperature: 1° to 2°C, relative air humidity: 80 to 85 percent);
- Sanitation - Careful and thorough cleaning and disinfesting of storage and packing areas;
- Sanitation - remove and destroy infected plants and tap roots in the field and especially in storage.

*Figure 7.5 Symptoms of crater rot.*
*Author:Don Edwards*

## Crater Rot

**Causal agent – Rhizoctonia carotae.** Crater rot is a disease that occurs on carrot in storage. The disease is most common when carrots are placed in long-term (one month or more) refrigerated storage. Crop losses of up to 10 percent have been reported. The pathogen is soil borne and some infection of the tap root is thought to occur in the field prior to harvest. The fungus is also able to survive in wooden storage bins. Mycelium on the crown or roots initiates infection during cold storage. Mycelium spreads from root to root even at temperatures of 1° to 3°C. High humidity and free moisture favor disease development. Repeated production of carrot on the same land increases the level of the fungus in soil and makes the disease become worse over time.

**Disease Symptoms:** Typical symptoms develop after several weeks of low temperature storage. Small (5 to 10 mm in diameter) sunken lesions or pits develop on the surface of the tap root. Over time, the roots develop patches of white, flattened mycelium. Brown sclerotia may also form on the stored carrot. Secondary colonization of damaged areas by soft rot bacteria and gray mold can lead to soft rot and entire break down of the roots.

**Control**

- Use proper agricultural production techniques that minimize damage to the plant and tap root and results in healthy vigorous plants. Handle plants carefully during harvest and packing to prevent damage. Use proper levels of nitrogen and especially phosphorous fertilization;
- Crop rotation - use a rotation that excludes the production of carrots for at least 3 to 4 years, or longer;
- Sanitation - careful and thorough cleaning and disinfesting of storage and packing areas;

- Carrots should be stored in polyethylene bags, in conditions of ±0.5°C temperature and relative air humidity of 90 to 95 percent. Avoid overly wet storage condition;
- Sanitation-remove and destroy infected plants and tap roots in the field and especially in storage.

### Fusarium Dry Rot

**Causal agent – Fusarium spp.** Fusarium dry rot is a disease of stored carrots or carrots held in the field after maturity. The disease can occur wherever carrots are grown and is generally a minor disease in modern storage facilities. Fusarium dry rot is caused by at least three species of Fusarium. These fungi are typically soil borne and can survive in the soil for long periods of time. They may also be associated with seeds. Infection occurs through insect wounds or damage caused by other fungi. Surface moisture and temperatures of 7° to 21°C promote infection. Under cooler temperatures, the disease develops more slowly. The fungus can spread from root to root by direct contact.

**Disease Symptoms:** Symptoms first appear on the tap root foundation and the entire tap root surface. Typical symptoms are characterized by light-colored sunken and dry ulcers, at the center of which the epidermis cracks and light-pink tissue can be observed under it. Ulcers are initially small, and later gradually increase in size. In cases of severe infection, the tap root dries and looks mummified. Light-colored tissue can be observed on the tap root when cut in cross section. Discolored tissue is more concentrated in the center of the root and looks emaciated on the edges. Boundaries between diseased and healthy tissue are easy to distinguish. Under storage conditions where relative humidity is high (95 percent and more), diseased areas develops white soft mycelia on the surface. During lengthy storage, under conditions of high humidity, white mycelia change color and turn pink and yellow. Fusarium dry rot can also become a wet rot. In such cases, diseased tissue is moist, has a dark color and there is no sharp boundary between diseased and healthy tissue. Such symptoms appear when relative air humidity is high (95 percent and higher) and temperatures are higher than 10°C in storage. Development of soft rot is also associated with the colonization of diseased tissues by secondary decay organisms. At the initial stage of disease development the symptoms of Fusarium dry rot strongly resembles those of brown rot. The main difference between the two diseases is the optimal temperatures for development of each disease – causal agents of Fusarium dry rot develop strongly at the temperature of 2°C. Brown rot will not develop or develops very slowly at 2°C.

#### Control

- Use proper agricultural production techniques that minimize damage to the plant and tap root and results in healthy vigorous plants. Handle plants carefully during harvest and packing to prevent damage. Use proper levels of nitrogen and especially phosphorous fertilization;
- Crop rotation - use a rotation that excludes the production of carrots for at least three to four years, or longer;
- Carrot should be produced on light soils capable of good moisture penetration;
- Observe the optimal distance (spacing) between plants and rows
- Sanitation - careful and thorough cleaning and disinfesting of storage and packing areas is necessary;

*Figure 7.6 Symptoms of carrot fusarium rot. Source: Agricultural Adaptation Council*

- Accurately observe optimal time periods of crop harvesting;
- Disinfecting storage spaces one to one-and-a-half months before storing carrots, with 2 percent chlorinated lime (1kg/100-200 $m^2$);
- Storage should take place in conditions of temperature from 0° to 1°C and relative air humidity of 90 to 95 percent;
- Sanitation - remove and destroy infected plants and tap roots in the field and especially in storage;
- Because the fungi may be seed borne, fungicide seed treatment may be beneficial.

*Figure 7.7 Symptoms of CtRLV. Source: DPV-web*

## Carrot Diseases Caused by Viruses

### Carrot Red Leaf Virus (CtRLV)

The virus causing this disease damages only plants in the *Umbelliferae* family. This virus often spreads in combination with the virus causing carrot fleck disease. Carrot red leaf virus is mainly transmitted by the carrot aphid *(Cavariella aegopodii)*. For systemic transmission of the virus, it is necessary for the aphid to feed on a diseased plant for a minimum 30 minutes. Several wild plants in the *Umbelliferae* family can also be infected by the virus and serve as a source of the virus.

**Disease Symptoms:** When young carrots are infected, growth is stunted and there is a reddening, chlorotic mottling and overall yellowing of the leaves. There may be a twisting of lower leaves. Roots are severely stunted and some plants may die. Infection of older carrot plants produces milder symptoms and infected plants may show no symptoms when temperatures are above 24°C.

**Control**

- Plant spring crop sat least 1.5 km away from overwintered crops;
- Control aphids (insect vectors) that transmit the virus with the use of affective insecticides;
- Remove volunteer carrots and weeds from inside and near the planting that can serve as a source of the virus;
- Carrot varieties differ in their susceptibility to the disease. Use tolerant carrot varieties if available.

*Figure 7.8 Symptoms of parsnip yellow fleck virus. Source: DPV-web*

### Parsnip Yellow Fleck Virus (PYFV)

This virus is transmitted by carrot aphid *(Cavariella aegopodii)* and other aphids. The aphid feeds on infected plant then moves to a healthy plant where it feeds and delivers the virus in the plant. After completion of an incubation period, the virus is again moved from the infected plant to another healthy plant by the aphid, thus spreading the disease.

**Disease Symptoms:** Young leaves on infected plants wilt, while comparatively mature leaves show no symptoms at the first stage of the disease. Young plants may can die very fast if they are infected. In cases where plantings are very dense, the death of a certain number of young plants may go unnoticed. Infection of mature plants, produces necrosis and deformation of leaf stems (petioles) and chlorosis of older leaves. In addition, the tip and side roots of the tap root wilt.

**Control**

- Control aphids (insect vectors) that transmit the virus with the use of effective insecticides.

## Carrot Diseases Caused by Bacteria

### Carrot Soft Rot

**Causal agent – Erwinia caratovo.** Among bacterial diseases of carrot, bacterial soft-rot can be especially damaging. Most vegetable crops can develop bacterial soft rot. The disease is primarily a problem in storage, but can also cause damage in the field, especially under conditions where the soil stays saturated with water for prolonged periods. The bacteria enter plants through wounds and natural openings and rapidly degrade plant tissues under favorable environmental conditions. High temperature during storage (from 5° to 30°C) and air relative humidity of 90 percent contribute to spread and development of the disease. The disease can also be spread from plant to plant through direct contact.

*Figure 7.9 Symptoms of bacterial soft rot. Source: Departments of Agriculture and Food*

**Disease Symptoms:** On carrot tap roots, soft rot lesions are sunken and dull orange, while the epidermis sometimes remains intact. Eventually infected roots turn into wet, slimy, rotted mass. Soft rot is usually accompanied by every unpleasant odor.

**Control**

- Use proper agricultural production techniques that minimize damage to the plant and tap root and results in healthy vigorous plants. Handle plants carefully during harvest and packing to prevent damage;
- Sanitation-careful and thorough cleaning and disinfesting of storage and packing areas;
- Maintain optimal storage conditions (temperature: 1° to 2°C, relative air humidity: 80-85 percent).

### Bacterial Leaf Blight (Bacteriosis)

**Causal agent – Xanthomonas campestis pv. carotae.** This common disease occurs in most carrot producing areas world-wide. Damaging out breaks is associated with high rain fall and overhead irrigation. The bacteria are seed borne and also survive in soil associated with infested carrot debris. The bacteria are dispersed from plant to plant in the field in water from splashing rain or overhead irrigation. The severity of disease is related to the amount of infected seed used for planting. Optimum temperatures for disease development are 25° to 30°C.

*Figure 7.10 Symptoms of bacterial leaf blight. Source: The Center for Agriculture, Food and the Enviroment*

**Disease Symptoms:** The first symptoms are angular yellow leaf spots that later develop into irregular-shaped, brown, water-soaked spots with yellow halos or margins. These lesions dry out and become hard. Older lesions sometimes appear black. Lesions develop most commonly at the leaf margins. Formation of a gummy exudates and browning of the petioles (leaf stems) also occurs. Stems develop oblong wet areas and growth of diseased plants may be stunted.

*Figure 7.11 Symptoms of mishapen carrot roots. Source: The Vegetable Crops Research Unit*

**Control**

- Use seed that does not have high levels of the bacteria. Grow seed in dry regions without the use of overhead irrigation;
- Treat infected seeds with hot water;
- Crop rotation - use a rotation that excludes the production of carrots for at least two to three years;
- Copper sprays may partially reduce disease severity if applied from an early stage of plant development.

## Physiological Disorders

Carrots, like other root vegetables, are subject to several physiological disorders either in response to environmental or nutritional factors.

- On hot and sunny days, carrot roots may develop bitter flavor due to the accumulation of a *coumarin* compound called 6-methoxymellein. This compound also accumulates in response to insect or physical damaging of the roots or when carrot roots are stored with ethylene producing fruits like tomatoes, peppers, apples, and many others;
- Root splitting often develops from exposure of the plants to in consistent soil moisture. Carrots are drought sensitive so maintaining the soil moist, but not too wet, will reduce the problem;
- Multiple roots and strong root hairs. Excess nitrogen from over-fertilizing can cause carrots to form multiple roots or grow strong hairs on the main root. Multiple roots can also occur when carrots are grown on heavy clay or in rocky grounds;
- Roots with green shoulders. When the tops (shoulders) of carrot roots are exposed to light they will turn green. Hilling the soil around the roots and increasing plant population often reduces this problem.

Peppers (*Capsicum*) are members of the *Solanaceae* family, characterized by their diverse flavor and pungency. A range of varieties are grown for both fresh market and processing. These include varieties that are mild in flavor and those that have varying levels of pungency. Mild flavored varieties include traditional "blocky" with three to four lopes as well as varieties that are longer with more pointy fruits known as European Lamuyo types. The more pungent/hot varieties are numerous and very rich in capsaicin. The active ingredient is a volatile phenolic found only in the placenta or gel surrounding the seeds. The human tongue is capable of detecting 10 parts per million capsaicin. Several varieties of hot peppers are available on the market.

Bell or sweet pepper responds very well to nitrogen fertility. Nitrogen rate of up to 400kg per hectare increased fruit size and yield by as much as 15 percent to 20 percent. For bell pepper, nitrogen application is better when applied in increments starting from bloom until two weeks before harvest. Hot or pungent peppers require less nitrogen early in the growing season and until the fruit reaches full maturity. However, high nitrogen application late in the season reduces the pungency.

Bell and hot peppers require constant supply of soil moisture throughout the growing season. In the case of hot peppers, with holding water after the fruit reaches maturity enhances red color development and increases capsaicin synthesis.

### Climatic requirements

Peppers are warm season crops that are very sensitive to freezing temperature at any growth stage. Optimal temperature for growth is about $2^{\circ}$ to $3^{\circ}$C higher than that for tomatoes. Pepper plants can tolerate temperatures above $38^{\circ}$C, however such extreme temperatures during bloom can reduce pollination, fruit set, and yield. The rate of seed germination decreases rapidly below $25^{\circ}$C with germination becomes exceedingly slow below $20^{\circ}$C. Day temperatures of $24^{\circ}$ to $30^{\circ}$C and night temperatures between $9^{\circ}$ and $12^{\circ}$C are ideal for growth and flowering. Pepper develops well in conditions of increased lighting. Optimal soil moisture for pepper is 70 to 75 percent HB. This crop does well on diverse soils from sand to loam soils, rich in organic soils.

### Crop Rotation

Peppers, like most other crops require effective crop rotation in order to avoid disease infection. The best crop rotation system involves legumes, cereals, and a cruciferous crop like cabbage or broccoli. It is undesirable to grow cucumbers in vicinity of peppers, since the former is considered to be a host of the cucumber mosaic virus, which damages pepper. In order to avoid damage by common pests and diseases, it is not recommended to plant pepper on plots which previously had other members of the solanaceae family like potato, eggplant, and tomato, earlier than after three to four years.

## PEPPER DISEASES

Peppers have several important diseases that are caused by fungi, bacteria, viruses and phytoplasmas. The most common or damaging diseases caused by fungi include: alternariosis (early blight), anthracnose, fusarium wilt, grey mold, stalk rot, verticillium wilt, cercospora leaf spot, powdery mildew and phytophthora blight. The most serious

Figure 8.1 Symptoms early blight in pepper. Source: Plant and Pest Advisory

diseases caused by viruses are cucumber mosaic and alfalfa mosaic. Stolbur is a serious disease caused by a phytoplasma. Significant diseases caused by bacteria include bacterial spot, wet rot, bacterial canker and bacterial wilt.

## Pepper Diseases Caused by Fungi

### Alternariosis (Early Blight)

**Causal agent – Alternarias solani.** The disease usually develops during the second half of the growing season. The fungus survives from crop to crop in old plant debris on top of, or buried in, the soil. It can also survive in damaged or infected seeds as mycelium. Under field conditions, the fungus spreads from diseased to healthy plants by means of conidia. Water on the surface of plant parts is required for infection to occur, therefore, the disease is worse on wet conditions.

**Disease Symptoms:** The disease develops mainly on leaves and fruit. Small dark-grey spots develop on infected leaves. Spots increase in size and eventually merge to form large necrotic (dead) areas on the leaf. Leaves eventually wilt and die. The first symptom in fruit is water soaked spots. Spots enlarge to cover large areas on the fruit that become covered with light-colored fungal mycelia. Under conditions of high humidity, the disease spreads quickly to create large damaged areas (lesions) with a quasi-circular shape. With time, damaged fruit become mummified and covered with dark reddish powdery substance (mycelia).

It should be noted that the pathogen can penetrate apparently healthy fruit and infect the seeds. Infected seeds serve as a source of inoculum for the disease. The disease can also develop on fruit in storage resulting in post-harvest losses.

#### Control

- Sanitation: remove and destroy all old infected plant debris from the field;
- In greenhouses, thermal or chemical disinfecting of soil is necessary;
- Balanced fertilization is important for disease control;
- Timely implementation of agro-technical measures, necessary for crop production;
- Remove badly diseased plants and fruit from the field during the growing season and diseased fruit from storage areas after harvest.

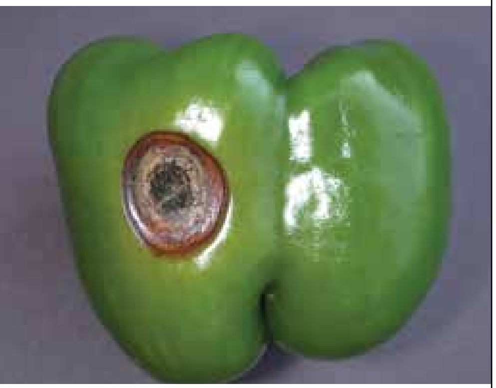


Figure 8.2 Symptoms for pepper anthracnose. Source: Plant and Pest Advisory

### Anthracnose

**Causal agent – Colletotrichum capsisi.** Anthracnose is considered to be one of the most important and damaging diseases of pepper. The pathogen overwinters in plant debris and in infected seeds. The disease spreads by means of fungal spores which are disseminated by wind, water, animals, agricultural equipment and humans. Water is required for infection to occur. High relative humidity (over 90 percent) and temperatures higher than 28°C are favorable for disease development. Anthracnose usually develops as the fruit begin to ripen in the field. It can also develop from latent infections in storage and in transport to the market.

**Disease Symptoms:** Circular or angular sunken lesions develop on immature fruit of any size. Often multiple lesions appear on individual fruit. When the disease is severe, lesions may coalesce. Often pink to orange masses of fungal spores form in concentric rings on the surface of the lesions. In older lesions, black fungal structures called acervuli maybe observed. With a hand lens, these look like small black dots, under a microscope they look like tufts of tiny black hairs. The pathogen forms spores quickly and can spread rapidly throughout a pepper crop, resulting in up to 100 percent yield loss. Lesions may also appear on stems and leaves as irregularly shaped brown spots with dark brown edges.

#### Control

- Sanitation - Remove and destroy old plant debris from the field or greenhouse;
- Use disease free seed;
- Timely harvesting of the fruit is important. Do not let fruit become over ripe in the field. Fruit should be harvested in dry weather;
- Pepper should be stored at 3° to 4°C in conditions of humidity over 90 percent.

### Fusarium Wilt

**Causal agent – Fusarium oxysporum.** The pathogen penetrates the plant through the roots. It then colonizes the vascular system of the plant resulting in wilting and eventually plant death.

The fungus survives in soil for several years. It is spread by means of agricultural equipment, infested plant debris and in water. High soil temperature (33°C) and high humidity contribute to development of the disease.

*Figure 8.3 Symptoms of fusarium wilt in pepper. Source: Diseased pepper and eggplant*

**Disease Symptoms:** The symptoms of Fusarium wilt can be seen either on a single branch, on several branches on one side of the plant, or on all the lower branches. Initially, Fusarium wilt causes a yellowing and wilting of lower leaves on infected plants. The yellowing and wilting progress up the plant as the fungus spreads within the plant. Yellowed, wilted leaves often dry up and drop prematurely. Eventually the entire plant wilts and dies early, producing few, if any, fruit. Plants infected with Fusarium wilt will have a brown discoloration of the vascular system (the food- and water-conducting vessels just beneath the epidermis). This discoloration can be used for diagnosis. Cut and peel back the epidermis and cortical tissue on a section of the main stem slightly above the soil line. If the area just beneath the epidermis has a distinct brown discoloration, then the plant is infected with Fusarium wilt. The discoloration can extend from the roots up the stem through the branches and into the petioles (leafstalks) of the plant.

#### Control

- Sanitation: remove and destroy infected plant debris;
- In greenhouses, thermal or chemical disinfecting of the soil is necessary;
- Balanced fertility and timely irrigation is important;
- Good agricultural practices for pepper production should be used;
- Use disease resistant varieties if they are available;
- The fungus survives for very long periods in the soil. Crop rotation for up to five or six years can be helpful for control. Do not plant solanaceous crops such as tomato, eggplant or potato during the rotation period.

*Figure 8.4 Symptoms of gray mold. Author:D. Maes*

*Figure 8.5 Symptoms of fruit rot and steam lesions. Source: Michigan State University*

*Figure 8.6 Symptoms of pepper verticilium wilt. Source: Ontario Crop IPM*

### Gray Mold

**Causal agent – Botrytis cinerea.** The pathogen penetrates the plant primarily through mechanical damage and develops under conditions of high humidity, within a wide range of temperatures.

The fungus overwinters in plant debris, as sclerotia (fungal survival structures) and mycelium. The fungus has a very wide host range infecting a large number of fruit and vegetable crops. The fungus is often spread mechanically, during various agro-technical activities.

**Disease Symptoms:** The disease can affect leaves, fruits and stalks. The first symptoms are usually water-soaked spots on the fruit. As a rule, the fruit skin remains undamaged, but wrinkles. Diseased areas of the fruit soften and are sunken. In time the surface of diseased tissue becomes reddish and grayish in color. Eventually the fruit surface becomes completely covered with mycelia and grey spores of the fungus. This is where the disease gets its name (gray mold) Leaves can also develop gray wet spots, which eventually become covered with the gray fungal growth.

**Control**

- Maintain optimal temperature sand systematic ventilation in greenhouses;
- Observe optimal planting density;
- Remove lower tier diseased leaves;
- Timely applications of effective fungicides are important for controlling the disease.

### Stem and Fruit Rot

**Causal agent – Didymella lycopersici, Phoma destructiva, Phoma exiqua.** The disease requires water to develop and is most severe under conditions of high humidity. Fungal spores are transported by wind and splashing rain. The pathogen invades the plant through mechanical damage and through natural openings in the plant. Initial infection sources are soil, plant remains and seeds.

**Disease Symptoms:** The disease develops on the plant's main stalk. Dark gray-green spots can be observed on the bottom part of the stem. Eventually, the bottom part of the stem is completely covered by the spots. In later stages of disease development, necrosis develops in the plant's vascular system, and small red dots (fungal fruiting bodies) can be observed on the surface of diseased tissues.

**Control**

- Sanitation - Remove and destroy infected plant debris;
- In case of greenhouses, thermal or chemical treatment of soil and maintaining optimal temperature and humidity are necessary;
- Use disease free seed for planting.

### Verticillium Wilt

**Causal agent – Verticillium dahliae, Verticillium albo-atrum.** The pathogens survive for long periods of time in the soil. They can retain vitality for at least 15 years. Infection occurs from direct penetration of mycelia or through mechanical damage received during transplanting or cultivation. Verticillium wilt is most serious during mono crop production, especially on light-sandy soils. High temperature (25°C) and low moisture content in the soil provide optimal conditions for disease development. Consequently, disease development intensifies in July and August and decreases in as temperatures cool during September and October. This process affects the plant and during this period certain restoration takes place and new growth may develop on the lower part of the plant.

**Disease Symptoms**: The first symptoms of the disease are observed before bloom. Infected plants are characterized by weak growth, and small dark green leaves.

Lower leaves wilt and develop spots, which gradually spread to the whole leaf. Damaged leaves turn yellow, develop necrosis and drop from the plant. Eventually, the plant wilts completely and dies. Plants infected at early stages of development fail to develop knots, while plants infected during later stages of development have small and shrunken fruit. Roots of diseased plants look healthy at first sight, but later darken. A brown discoloration in the vascular system can be observed if stems are cut vertically.

**Control**

- Crop rotation must be done for long periods of time and may not be practical for controlling the disease. If soils are heavily infested with Verticillium, peppers and other solanaceous crops should not be planted;
- Soil fumigation is effective for controlling the disease, however, the fungus can rapidly decolonize fumigated soil;
- Sanitation - Remove and destroy infected plant debris;
- If available use disease resistant varieties and hybrids.

### Cercospora Leaf Spot

**Causal agent – Cercospora capsici.** The fungus survives in infested plant debris in the soil, at a depth of up to 10 cm. If infested material is placed deeper than 10 cm below the soil surface, the fungus quickly loses vitality. In the field, the disease spreads by means of fungal conidia. The disease is general most severe near the end of the growing season older and physiologically weak plants. High humidity and dew provide favorable climatic conditions for disease development.

**Disease Symptoms:** At first, lower leaves of the plant develop multiple spots, which have whitish centers and dark red ring around them. When the disease is severe, lower leaves may yellow and dry completely and die, while upper leaves remain relatively healthy in appearance.

**Control**

- Timely application of effective fungicides is highly effective for controlling the disease;
- Sanitation - Remove and destroy infected plant debris from the field or greenhouse;
- Deep plowing to bury plant debris below 10 cm.

*Figure 8.7 Symptoms of cercospora leaf spot. Author: Matthew Orwat*

*Figure 8.8 Symptoms of powdery mildew on pepper leaves. Source: Feeding Knowledge Organisation*

## Pepper Powdery Mildew

**Causal agent – Erysiphe oronti.** Powdery mildew can be a serious disease of peppers in warm, arid, and semiarid growing regions. Infection often leads to defoliation, which can lead to severe losses of fruit. The fungus can infect many hosts for overwintering and long-term survival. Powdery mildew can occur in both dry and humid climates. Unlike most other fungal pathogens, free water on the plant surface is not required for infection. Conidia of the fungus can germinate at any relative humidity when the temperature is between 10° and 35°C. The pathogen is spread by windblown conidia. Once infection has occurred, warm days (above 30°C) with humid, cool nights (below 25°C) favor rapid disease development. The incidence of powdery mildew in pepper is greatest in humid climates, but defoliation of infected plants is more severe in dry climates.

**Disease Symptoms:** The most noticeable of the sign of the disease is a white powder growth on the underside of leaves. Light green to yellow lesions with necrotic centers may form on the upper leaf surface. Eventually, the entire leaf turns pale yellow or brownish. Symptoms develop on older leaves first. When conditions are highly favorable for disease development, the pathogen may sporulate on the upper leaf surface. The edges of infected leaves eventually curl upward, revealing the fungus on the lower surface. Infected leaves drop prematurely from the plant, exposing fruit to the sun, so that they may subject to sunscald.

### Control

- Timely applications of effective fungicides are important for controlling this disease;
- Sanitation-Remove and destroy infected plant debris;
- Isolating the greenhouse plantings from field plantings of pepper;
- Disinfect greenhouse soil and structures.

*Figure 8.9 Symptoms of phytopthora blight in pepper. Source: Feeding Knowledge Organsiation*

## Phytopthora Blight

**Causal agent – Phytophthora capsici.** The fungus that causes Phytophthora blight survives as thick - walled, resistant spores (oospores) in the soil and as mycelium in infected plant issues. Once introduced, these fungi can survive up to 15 months in moist soil in the absence of host plants. They can also be carried on seed or transplants. The fungus requires free water in the soil for infection to occur. Because of this, initial infections usually occur on plants growing in poorly drained areas of fields. Once stem infection occurs the fungi produce spores on infected stem tissues, which are then carried by splashed rain onto nearby plants. Lower branches of adjacent plants can also be infected by rain-splashed soil contaminated by run-off water. Fruits in contact with the soil are especially prone to infection. Spores are produced on newly infected fruit and stems, and new infections can develop quickly. Warm wet weather is most favorable for disease development and spread. Disease progress declines under dry weather conditions.

**Disease Symptoms**: The disease affects both seed ling sand mature plants. Infected seedlings show typical damping-off symptoms. Infection of older plants usually begins at or below the soil line. Water-soaked, dark brown lesions on the lower stem usually extend up ward above the soil line and may expand to girdle the stems, preventing upward movement of water and nutrients. This often results in a sudden wilting of foliage. Root infections may also occur which kill roots and causes wilting of the plant without the appearance of stem cankers. The foliar phase of this disease commonly occurs at forks in the branches, resulting in dark, girdling canker sand wilting of leaves and fruits. Infected leaves develop circular or irregular, dark green, water-soaked lesions which dry and appear light. Fruit lesions may also appear as enlarging, water soaked areas, which then shrive land darken. A mass of white fungal growth may develop inside the fruit, and seeds usually turn dark brown or black. A fine, grayish-white to tan mold may also become evident over the lesion on the fruit surface. Under humid conditions, fungal growth develops extensively over the entire fruit.

**Control**

- Use only certified disease-free seed or transplants;
- Avoid depressions on the surface of the beds where water can accumulate, especially around the base of plants. Avoid planting peppers or cucurbits in poorly drained fields;
- Use crop rotation so that peppers are grown only every three to four years to reduce the amount of Phytophthora in the soil. Use non-susceptible crops such as corn, small grains beans, crucifers, or potatoes in the rotation.
- Applications of fungicides may reduce disease development and spread if used in combination with cultural practices such as crop rotation and raised beds.

## Pepper Diseases Caused by Viruses and Phytoplasmas

### Stolbur

**Causal agents – Phytoplasma.** Stolbur is caused by a phytoplasma, which essentially is a bacterium without a cell wall. The disease usually appears during periods of high soil temperature and can affect several plants in the family *Solanaceae* such as pepper, tomato, eggplant and potato. The pathogen is transmitted by insects. In Georgia, the dragonfly *Hyalestes mlacosewichi* is considered to be the most important insect vectors.

*Figure 8.10 Symptoms of stolbur in pepper. Source: Phytoplasmas and pyroplasmas*

Spread of this disease significantly depends upon the rate of reproduction of the pests which transmit or vector the disease. Larvae of the insect vector overwinter on roots of various plants, of which weed hosts are especially important.

Stolbur is characterized with sharply manifested cyclical pattern – after epiphyte ends, spreading of the disease significantly weaken.

**Disease Symptoms:** Infected plants are stunted and develop chlorosis or intense yellow color of the leaves. Symptoms are observed most clearly on upper leaves, which yellow and tear. At this time, the upper leaf surface has a yellow color, while the lower leaf surface is violet. Diseased leaves are initially hard and breakable, due to accumulation of starch in them. Flowers become sterile. Fruits that are set before the disease develops do not develop normally. They are thin-walled and tasteless. Eventually, plants begin to wilt and die. Wilting of the plant is a result of rotting of the root system. Rot begins from the root tips. Infected roots are dark in color and easily separated from the root.

**Control**

- It is recommended to plant pepper early in the growing season, before the insects which transmit the disease begin flying, which occurs in the beginning or middle of June;

- Inter planting corn or sunflower together with pepper aids in controlling the disease because it confuses the flying pattern of the insects that transmit the disease;
- Timely applications of insecticides to control the insect vector are recommended. Preference should be given to systemic insecticides with prolonged effect capability.

*Figure 8.11 Symptoms of CMV on leaves. Picture Source: Crocus*

### Cucumber Mosaic Virus (CMV)

**Causal agent – Cucumber mosaic virus.** This virus spreads rapidly under favorable climatic conditions.

It overwinters in infected plant debris and is transmitted by aphids and is mechanically transmitted by agricultural machinery and equipment.

**Disease Symptoms:** Symptoms of the disease can be highly variable, depending upon the variety of pepper and the time of infection. Diseased leaves may become narrow and deformed and develop shot holes. When mature plants are infected, leaves fall down and leaf discoloration can be observed. The top of the plant may also dry up.

As a rule, diseased plants grow weakly and have deformed fruit, on which concentric circles are sometimes noticeable.

Heaviest economic damage is caused when plants are infected at an early age. Severely infected plants produce fruits that are useless for consumption and marketing.

The number of the CMV virus host plants is quite large and includes up to 800 different plants.

**Control**

- Control the insect vectors (Aphids) that transmit the disease;
- Remove and destroy infected plants and plant debris from the planting.

*Figure 8.12 Symptoms of AMV in pepper. Source: Cornell University*

### Alfalfa Mosaic Virus (AMV)

**Causal agent – Alfalfa mosaic virus.** Alfalfa mosaic virus has a very wide host range infecting many broad leaf plants. As a rule, this disease spreads to pepper when it is grown near fields planted with alfalfa. The virus is transmitted and rapidly spreads by many types of aphids. It also spreads by means of agricultural equipment and seeds.

**Disease Symptoms:** Alfalfa mosaic is characterized with sharp-yellow mosaic. Fruits are often dotted and deformed.

**Control:**

- Grow pepper away from alfalfa fields;
- Use effective insecticides to control the insect vectors (Aphids).

## Pepper Diseases Caused by Bacteria

### Bacterial Leaf Spot

**Causal agent – Xanthomonas campestris pv. Vesicatoria.** Bacterial spot of pepper is one of the most destructive diseases of pepper in climates where high temperature and frequent rainfall occur during the growing season. The disease causes spots on leaves and fruit, leaf defoliation, and reduction in plant growth, fruit yield, and quality. Bacterial spot is also a serious problem on tomato, although no tall strains of the pathogen can cause disease on both hosts. The bacteria can overwinter in crop residue (debris) in or on soil, on or in seeds, and on wild host plants. Pepper seeds infested with the pathogen are a major source of inoculums for the disease as well as the major means of long distance spread of the pathogen. The pathogen can survive on dried seeds for up to 10 years. It is notable to survive free in soil for a long time, but can survive up to six months in infected crop debris in soil. The bacterium penetrates leaves through stomata (natural openings in the plant) and wounds. Bacteria often enter fruits through wounds created by wind-driven sand, insect punctures, or mechanical injury. Dissemination of the bacteria occurs between and within fields by water splashing, aerosols, or during cultivating, hoeing, thinning of direct seeded plants, transplanting, or harvesting.

*Figure 8.13 Symptoms of bacterialleaf spot. Source: Plant Pest Advisory*

**Disease Symptoms:** On sweet pepper, disease symptoms appear on the leaves, stalks and fruit. In case of hot pepper, symptoms are comparatively less expressed. First symptoms manifest as irregularly shaped, water-soaked spots, appearing on the bottom sides of the leaves. Under wet conditions the spots appear water soaked. These spots later grow in size and become dark brown or black in color. During this period, spot centers are yellowish-brown, while their margins are semi-transparent yellow. Diseased areas on top sides of the leaves are, as a rule, slightly sunken, while on the bottom of the leaves, they protrude. Leaves severely damaged by infection often develop chlorosis and dry up. Severely infected plants may also defoliate prematurely or develop shot holes and have a ragged appearance.

On stems and petioles, lesions are elongated and blackened, and can kill leaflets.

On fruit, spots initially develop as water-soaked areas, which later turn necrotic. Spots have a pimply surface, which bursts with time, as their size increases. It should be noted, that under wet, humid weather conditions, secondary fruit rot often develops on the damage caused by bacterial spot.

**Control**

- Spraying with fungicide containing copper may aid in controlling the disease;
- Control weeds in and near the planting, especially weeds in the family *Solanacacae;*
- Remove and destroy infected plants and plant debris from the planting area;
- Use high-quality disease-free seed and transplants;
- Refrain from walking or conducting agricultural practices in the planting when the plant leaves are wet from dew, rain or irrigation;
- Practice crop rotation with non-host plants such as corn, so that peppers are grown only every three to four years;
- Cleaning (disinfesting) agricultural equipment and machinery before entering new land areas aids in reducing the spread of disease and its introduction into new areas.

*Figure 8.14 Symptoms of bacterial canker on leaves. Source: Ohio State University*

### Bacterial Canker

**Causal agent – Clavibacter michiganensis.** Bacteria representing the *Clavibacter* family are most often spread through the use of infected seeds or transplants. The disease requires water to infect plants and develop. Therefore, the disease is most severe under conditions of high relatively humidity, rain or overhead irrigation. Day temperatures of 25° to 30°C are ideal for disease development. Dense plantings that prevent good air circulation and increase drying time of plant tissues also contribute to disease development. Movement of agricultural equipment, human activities in the planting, and insect pests are also factors which contribute to spreading the disease. The bacteria penetrate the plant mostly through mechanical damage or other wounds.

**Disease Symptoms:** Disease symptoms on the plant are represented by spots on the foliage and fruit. At times the plants can become systemically infected, but this is relatively rare. During local infection, initial symptoms appear as small bubbles or protruding white spots on leaves and stems. Gradually, the center of the spots turn brown and a semi-transparent margin develops around them. Stems develop areas of stiffened tissue, which grow in volume and form large lesions. Disease symptoms on fruit appear as small, round, slightly bulging spots. These spots later grow in size, their centers turn brown and white, and they develop a semi-transparent margin or halo around them. When spot numbers and size increases, plant tissue develops stiffened areas. If plants become systemically infected they usually die.

**Control**

- Spraying with fungicide containing copper may aid in controlling the disease;
- Control weeds in and near the planting, especially weeds in the family *Solanacacae;*
- Remove and destroy infected plants and plant debris from the planting area;
- Use high-quality disease-free seed and transplants;
- Refrain from walking or conducting agricultural practices in the planting when the plant leaves are wet from dew, rain or irrigation;
- Practice crop rotation with non-host plants such as corn so that peppers are grown only every three to four years;
- Cleaning (disinfesting) agricultural equipment and machinery before entering new land areas aids in reducing the spread of disease and its introduction into new areas.

*Figure 8.15 Symptoms of bacterial wilt on pepper stem. Source: Hawaii Plant Diseases*

### Bacterial Wilt

**Causal agent – Ralstonia solanacearum.** Bacteria of the *Ralstonia* family spread from the soil and are capable of retaining vitality in the soil and plant remains for long periods of time. Bacteria penetrate the root through damage, which may be caused to the root by nematodes, during seedling transplanting, soil cultivation and other agricultural practices. Many weeds may harbor the bacteria in their roots yet show no symptoms. High temperatures (eg. 30° to 35°C) and high soil moisture favor development. High soil moisture increases the survival of the bacteria in soil, the rate of infection, the rate of disease development after infection, and the number of bacterial cells released from the host into the soil. Bacterial wilt is a greater problem in heavy soils and in lowly in areas that can retain soil moisture for long periods.

**Disease Symptoms:** The disease occurs in scattered plants or groups of plants in the field. Wilting begins with the youngest leaves during warm or hot weather conditions during the day. The plants may recover temporarily in the evening under cooler temperatures. A few days later sudden, permanent wilt occurs. The wilted leaves maintain their green color and do not falls the disease develops.

The roots and lower part of the stem have a browning of the water-conducting tissues (vascular system) of the plant. Infected roots may rot due to secondary infections from other pathogens. Diseased roots or stems that are cut and placed in a small container of water will show a steady, yellowish or gray bacterial ooze coming from the contend.

**Control**

- Maintain the soil pH within the limits of 5.5 to 5.7;
- Plant pepper only on sites with good soil drainage. Avoid poorly drained, wet sites;
- Practice crop rotation with non-host plants such as corn, so that peppers are grown only every four to five years;
- Remove and destroy infected plants and plant debris from the planting area;
- Use only high-quality disease free transplants;
- Control weeds in or near the planting, especially weeds in the family *Solanaceae*.

## Physiological Disorders

Peppers, like tomato and several other crops, are susceptible to a variety of physiological disorders. Blossom end rot, fruit cracking, and sunburn/sunscald can be problems under certain conditions.

Blossom end rot (BER) is a serious problem in peppers. Similar to tomato and melons, blossom end rot affects only the distal end of the fruit starting at early stages of development. BER is more serious in bell or sweet peppers than in hot peppers because of the tendency of farmers to use heavier doses of nitrogen on bell than hot peppers. Also, the larger size fruits of bell pepper are more prone to BER than the smaller fruits of the hot varieties.

**Control**

- Apply similar recommendation for tomato;
- Use calcium nitrate instead of other formulations of nitrogen;
- Use resistant varieties or varieties that tend to have smaller fruit sizes.

### Sunburn/Sunscald

High temperature, clear skies, and intensive light radiation can cause severe sunburn in pepper fruits, especially bell or sweet varieties. There are three types of sunburn. The first is known as sunburn necrosis, which is induced by exposure of the fruit to intensive and direct sunlight. Fruit skin and peel of affected areas of the fruit turn brown and die. Sweet peppers develop this type of sunburn when the fruit temperature reaches 40° to 42°C. Hot peppers develop sunburn but at a much lower percentage.

The second type of sunburn is called sunburn browning. In this type of sunburn, the exposed fruit tissues turn light brown but they do not die. This type of sunburn occurs at 5° to 6°C cooler temperatures than sunburn necrosis or between 35° to 37°C. Intensive light radiation also contributes to this disorder.

The third type is called photo-oxidation sunburn. This sunburn develops in shaded fruits that are suddenly exposed to direct sunlight either through pruning or through shoot breakage.

**Control**

- Fruit sunburn is controlled by developing adequate leaf canopy to keep the fruits from direct exposure to the sun, especially in the afternoon;
- Diseases that defoliate the leaves and wilting due to moisture stress can also exaggerate the problem. So keeping plants healthy reduces the disorder;
- Some varieties, especially those that are tender or have darker fruit color, are more susceptible to sunscald;
- Excessive pruning or damage to the canopy can increase the incidents.

### Fruit Cracking and Scarring

Fruit cracking is not as serious a commercial problem in pepper as it is in tomato, except when some varieties are grown under high tunnels or in greenhouses. However fruit scarring, sometimes called rusting, especially in hot pepper varieties, can be a serious problem.

**Control**

- Fruit scarring is genetically controlled and so selecting a resistant varieties is the best strategy to reduce the disorder;
- Keep soil consistently moist. Fluctuation of soil moisture can cause cracking in some varieties.

Beet (*Beta vulgaris* var. *crassa*) belongs to the family *Chenopodiaceae*, commonly known as goosefoot family. This family also includes sugar beet, Swiss chard, and the common weed lambs quarter (*chenopiodium album*). The following information covers only table or fresh market beets. In many parts of the world, the bulk of table beet is grown as an annual crop for its edible roots. However, a small percentage of the *orientalis* group, known as Spinach beet, is grown for its leaves. At least three different colours of beet roots are available commercially; red, white, and yellow. Beet is a cool season crop that tolerates occasional frost and mild freeze. The optimum temperature for seed germination is at about 5ºC. Fully developed plants prefer temperature in the range of 10º to 18ºC, with exposure to higher temperature resulting in faster growth and formation of white rings in the root, known as "zoning." Beet plants grown for seed production require a cold period of about two weeks at 4º to 10ºC to induce flower stocks formation (bolting).

### Soil, water and pH requirements

Beet plants prefer deep and well drained sandy or silt loam with higher organic matter content. However, plants can also grow on heavier soils, but root growth will be restricted and harvest maybe difficult to manage. Beet plants have relatively large roots that can extend several feet in the soil, therefore it is highly desirable to grow the plants in soils rich in organic matter.

Maintaining uniform soil moisture and following an appropriate crop rotation is important in reducing the potential of serious root-rot diseases like damping-off. Beet roots are sensitive to damping-off when grown in poorly aerated soil or in sites that tend to flood. Beet is sensitive to acid soils; therefore the ideal soil pH should be maintained between 6 and 7.5. Application of acidifying fertilizers, like ammonium sulphate, to soils with high buffering capacity may result in reducing the soil pH to below 6. This situation usually corrects itself after the fertilizer finishes reacting with the soil. However, continuous application of acidic fertilizer to soils with high buffering capacity may lead to reducing its buffering capacity and so reducing the use of acidic fertilizers and/or lime application maybe needed to correct the problem. Lime is usually needed in acidic soils that have low pHs An application of 2.5 to 8 tons of lime per hectare, depending on the soil buffering capacity, is usually needed to raise the pH to above 6.

### Fertilizers Management

Under ideal situations, fertilizer types and rates should be based on soil and tissue analysis.

**Nitrogen.** Nitrogen application rates depend on the soil type and crops grown before the beet. Generally, an application rate of 170 to 240 kg per hectare is recommended for good leaf growth. The lower rate is usually recommended when beet is grown after a legume crop while the higher rate is applied after a non-legume crop. The amount of nitrogen is usually split into two applications, one incorporated into the soil before planting and the other side dressed about two weeks after planting.

**Phosphorus.** Phosphorus is important for establishment of healthy plants that can tolerate damping-off. An application of 60 to 80 Kg per hectare of superphosphate or triple phosphate incorporated at 2 to 3 cm below the seed depth is recommended for beet. However, combinations of phosphorus and nitrogen and potassium and boron should be broadcasted and not incorporated under the seed in order to avoid burning the young seedlings.

**Sulphur.** Sulphuric another macro element needed by the plants in order to survive. Sulphur is marketed in two formulations, as sulphate and as elemental sulphur. Plants are capable of absorbing only the sulphate form, but not the elemental form. Elemental sulphur has to be converted by the soil bacteria to the sulphate form so the plant can use it. The conversion is faster in finer soil under moist and warm conditions. The recommended sulphate rate is 18 to 22 kg/hectare applied to the soil at planting time. Finely ground elemental sulphur should be applied the year before planting at 35 to 45 kg/hectare.

**Boron.** Boron is the most important micronutrient required by beet roots. Plants require 3 to 6 kg/hectare of boron as a pre-plant treatment, as well as, additional two to three sprays of water soluble boron (1 kg/hectare) in order to prevent collapse of young leaf tissue and development of root canker. Root canker is characterized by hollow and black crown, due to water accumulation. Rough black spots can appear on the roots, which gives the roots a bitter taste. The roots may eventually become entirely discoloured, hollowed, and/or split. The yield and quality of cultivated beet roots can therefore be severely affected. Boron deficiency can also result in corky growth on the shoots and stalks. Roots from boron deficient plants store poorly.

## BEET DISEASES

Table beet and sweet beets have the same diseases. Important diseases of beets in Georgia that are caused by fungi include: Black Leg (Phoma root rot and leaf spot); Cercospora Leaf Spot, Downy Mildew, Rust, Gray Mold and Powdery Mildew. Important diseases that are caused by viruses include: Beet Mosaic and Beet Curly Top (BCTV). Among bacterial diseases of beets, the most common diseases are Crown Gall and Root Tuberculosis.

### Beet Disease Caused by Fungi

#### Black Leg (Phoma Root Rot and Leaf Spot)

*Figure 9.1 Symptoms of black leg in beet. Source: New York's Food and Life Sciences Bulletin*

**Causal Agent – Pleospora bjoeringii (Phoma betae).** Black leg is an important disease of beets and can result in serious crop losses under environmental conditions favourable for disease development. Black leg is caused by the fungus *Pleospora bjoeringii.* The asexual stage of the fungus is *Phoma beta* . The pathogen is usually encountered in the field on diseased plants as the asexual stage *(Phoma betae)*. Phoma produces small black globosely pycnidia (fungal fruiting structures) on the surface of infected tissues, and these pycnidia are useful in diagnosing the disease. *Phoma betae* is a seed borne pathogen and is commonly introduced into the planting in infected seeds. The optimum conditions for disease development are temperatures of 14° to 18°C and long periods of high relative humidity. Water on the surface of the plant is required for infection to occur. The pathogen is spread between seedlings by fungus spores (conidia) that are splashed by rain or irrigation. Later in the season, the sexual stage of the fungus *(Pleospora bjoerinii)* develops and produces another type of fungal fruiting structure (*pseudothecia*). These structures can survive and over winter in crop residues in and on top of the soil. In the spring, the *pseudothecia* can produce air borne spores which cause leaf spots in newly planted crops and stem infections in seed crops. At harvest, if beet leaves are trimmed to the root or if roots are wounded, the fungus can enter the root and cause a root rot in storage. Postharvest root rot is favoured by temperatures above 15°C, but can occur at much lower temperatures. If rain occurs close to seed crop harvest time, seed borne infection can increase.

**Disease Symptoms**: Symptoms on young plants include pre-emergence damping off, where seed and germinated seedlings die before growing above ground. Young seedlings that emerge can develop black lesions (spots) on stem tissues that are in contact with soil. These lower stem infections can turn the entire stem black and rotted. This is where the disease gets the name "black leg."

Symptoms on leaves are pale brown leaf spots that can measure up to 2 cm in diameter and contain concentric rings of the fungal fruiting bodies (pycnidia) of *Phoma betae*. These spots are mostly found on older leaves.

In seed crops, infected stems develop dark streaks and lesions (diseased areas) with gray centres. Severe infection causes stems to break at the crown and roots to have a dry black rot.

Infected roots initially have water-soaked lesions (diseased areas) which turn brown and develop into deep, sunken black lesions containing gray white mycelium and pycnidia. Severely infected roots become spongy and full of cavities. Root rot often develops during storage of table beets.

**Control**

- Always start the planting with pathogen free seeds. If infected seed is used, it should be treated with an effective fungicide seed treatment. Seed can also be treated using hot water soaks. Water is warmed to a temperature of 50°C and seeds are soaked at this temperature for 20 minutes. Seeds are then removed from the water and chilled in cold water and allowed to dry;
- Crop rotation - If this disease occurs, beets should be rotated with non-susceptible crops for at least three to four years;
- Correct application of fertilizers, in particular, timely application of boron;
- Sanitation - Remove and destroy infected plants and plant parts from the field. Deep ploughing to bury crop residues after harvest is beneficial;
- Store beets properly to prevent root rot in storage. Beets should be kept in small boxes with a capacity of 15-20 kg. Storage facilities should be thoroughly disinfested with chlorine (40 grams per litre of water). After disinfection, the storage facility should be ventilated for at least 24 hours;
- Maintain proper storage conditions. The optimal temperature for beet storage is 0° to 2°C with a relative humidity of 90 to 95 percent;
- The timely application of effective fungicides can be beneficial for controlling certain diseases.

## Cercospora Leaf Spot

**Causal agent – Cercospora beticola.** Cercospora is one of the most widespread and damaging beet diseases in Georgia. It affects not only Table Beet, but also alfalfa, peas, bindweeds, amaranth and many other cultivated or wild plants. Crop losses can exceed 40 percent on a root weight basis and, under conditions highly favourable for disease

*Figure 9.2 Symptoms of cercospora leaf spot of beets. Source: The Centre for Agriculture, Food and the Environment at the University of Massachusetts*

development, almost complete crop loss can occur. The fungus over winters as sclerotia in infected leaves, these sclerotia can remain viable in soil for up to two years. The fungus also overwinters in infested crop residues in and on top of the soil, infected seeds, and on infected wild weed hosts.

Spores of the pathogen are spread by slashing water and wind. Spore germination and infection occurs most rapidly at 25°to 35°C when night temperatures are above 16°C and relative humidity is above 90 percent. Disease activity is reduced below 15°C. Spots appear at seven to 10 days after infection.

**Disease Symptoms**: Circular leaf spots are at first small (up to 2 mm in diameter), and can be very numerous, covering almost the entire leaf. Spots have a pale brown or off white centre with a reddish margin. Later, spots expand in size, remain circular or oblong, and can result in severe loss of foliage (defoliation). The centres of the spots eventually become gray and may fall out causing a shot-hole effect. Usually, infection and leaf drop begins on the lower leaves then moves up the plant to affect younger leaves.

**Control**

- Use disease resistant varieties if available;
- Sanitation - remove and destroy infected crop debris and destroy volunteer plants;
- Do not plant vegetable production crops close to seed crops;
- Use seed that do not have high levels of infection. If infected seeds are used, apply an effective fungicide seed treatment;
- Ensure appropriate plant spacing and distance between rows to promote better air circulation in the planting to reduce drying time of plant tissues;
- Timely applications of effective fungicides can provide effective control of the disease.

*Figure 9.3 Symptoms of downy mildew. Author: Melodie Putnam*

## Downy Mildew

**Causal agent – Peronospora farinosa. f. sp. betae.** The oomycete pathogen can overwinter as mycelia in seeds, on infected weed hosts, and on volunteer beet plants. The pathogen produces thick walled resting spores called oospores that can survive for long periods in the soil, alone or inside infested plant residues. The pathogen is seed borne so it can spread in seed. About one percent of infected seeds result in infected plants. Overwintering mycelia produce structures called sporangia that are airborne and are spread by wind. Optimum conditions for disease development is cool, moist weather (optimum temperature is 8°C). The pathogen requires at least six hours of leaf wetness and cool temperatures (optimum 7° to 15°C) infecting. Little infection occurs above 20°C.

**Disease Symptoms:** Downy mildew can infect plants at all stages of development. First symptoms are yellowing and distortion of the youngest leaves. The pathogen grows systemically within the young leaves and may invade the growing point, resulting in reduced growth and spindly, deformed, yellow leaves which curl downwards. Under humid conditions, a dense purple-gray growth of mycelium appears on both upper and lower leaf surfaces of infected leaves. Individual spots can also develop on leaves.

These spots are yellow and are irregular in shape. Later they dry up and turn brown. If the growing point has been invaded, a dark heart rot of the crown may occur. If older plants are infected, sometimes they can recover and produce additional leaves that are healthy.

#### Control

- Use seeds that do not have a significant level of the pathogen. Obtain and use seeds produced in dry regions that are not favourable for downy mildew development;
- Remove volunteer beet and weed plants that can carry the disease;
- Sanitation - remove and destroy infected plants and plant residues from the field;
- The timely application of effective fungicides can be effective for control.

*Figure 9.4 Symptoms of beet rust. Source: Rheinische Friedrich-Wilhelms-Universität Bonn*

### Black Leg Beet Rust

**Causal agent – Uromyces betae.** The fungus attacks plants during the vegetation period. The pathogen has a complex life cycle and produces several different types of spores. The pathogen overwinters in seed crops, volunteer beet plants and susceptible weeds. The fungus may also be seed borne. Urediniospores are the primary spores responsible for spreading the disease. These spores are windborne and the optimum temperatures for their germination are in a range from 10to 22ºC. Another type of spore (teliospore) is important as an overwintering structure that can survive on crop residues and for up to one year on the soil surface. Rust development if favoured by warm (15ºto 22ºC) and moist conditions. The disease is inhibited by dry conditions and higher temperatures.

**Disease Symptoms**: The main symptoms are a typical orange rust pustule that is raised and is 1 to 3 mm in diameter. Pustules develop on both the top and bottom of the leaf. Necrotic tissue develops around the larger pustules, especially when pustules develop in clusters or rings. When the disease is severe, leaves may be completely covered by pustules, and become covered with the powdery orange spores that are produced within the pustules. Severely infected leaves eventually turn yellow and die. When the disease is severe, it can cause premature death of leaves and result in reduced yield and quality.

#### Control

- Sanitation - remove and destroy infected plant residues from the field;
- Search for and remove diseased volunteer beet plants and susceptible weed hosts from the area;
- Crop rotation;
- Insure appropriate spacing between the plants and crop rows to improve air circulation in the planting;
- The timely application of effective fungicides can provide effective control.

*Figure 9.5 Symptoms of beet root gray mold. Source: The AgroAtlas*

### Gray Mold

**Causal agent – Botrytis cinerea.** The disease is primarily a problem in storage. The fungus infects beet roots in storage primarily though mechanical injury (wounds) or tissues damaged by cold injury, insects, or other diseases. The fungus is spread by air borne spores from infected to healthy roots and is also spread by direct contact of diseased to healthy roots. The major cause of this disease is poor storage conditions.

**Disease Symptoms**: First signs of the disease appear during harvest. Roots develop brown spots. The tissue under these spots may become yellow. The yellowing appears only under conditions of high humidity. Infected tissues develop gray flakes and black fungal sclerotia. In storage, infected roots become water soaked and rot. They become covered with a dense layer of gray fungal mycelium and spores. This is why the disease is called "gray mold."

**Control**

- Store beets properly to prevent root rot in storage. Beets should be kept in small boxes with a capacity of 15-20 kg. Storage facilities should be thoroughly disinfested with chlorine (40 gr. per litre of water). After disinfection, the storage facility should be ventilated for at least 24 hours;
- Maintain proper storage conditions. The optimal temperature for beet storage is 0° to 2°C with a relative humidity of 90 to 95 percent;
- Use proper agricultural production technique that minimize damage to the plant and results in healthy vigorous plants.

*Figure 9.6 Symptoms of beet powdery mildew. Author: Howard F. Schwartz*

## Powdery Mildew

**Causal agent – Erysiphe betae.** Powdery mildew is a dry weather disease. Wet, rainy conditions will slow disease development. Powdery mildew spores have high water content (60 percent) and can germinate at low relative humidity in the absence of free water. Spore germination occurs over a wide range of environmental conditions, with an optimum of 25°C and 70 to 100% relative humidity. Epidemics are associated with dry weather alternating with periods of high relative humidity. Spores can germinate and penetrate into the plant within a few hours. The fungus soon produces a layer of powdery white mycelium and conidia growth on the surface of infected plant parts. This powdery white growth is where the disease gets its name "powdery mildew." The fungus overwinters in buried roots and on volunteer beet plants and susceptible weed hosts. The fungus also produces sexual fruiting structures called cliestothecia. These structures can overwinter in crop debris and release another type of spore (ascospore) in the spring that can cause new infections. Severe attacks of the disease can reduce yield buy up to 25 percent and table beet crops with badly diseased leaves may be unmarketable.

**Disease Symptoms**: The first signs of powdery mildew are scattered, small colonies of the fungus consisting of superficial white fungal growth. This growth usually starts on older leaves and occurs on both upper and lower leaf surfaces. As the disease develops, the entire leaf can become heavily covered with extensive patches of the white powdery fungal growth. Older leaves with severe powdery mildew will turn yellow and may eventually die. If the disease is very severe, younger leaves can also be infected.

**Control**

- Timely applications of effective fungicides are important for controlling this disease on highly susceptible varieties;
- Sanitation - remove and destroy infected plant residues from the field. After harvest, plough down and destroy crop residues;
- Search for and remove volunteer beet plants and susceptible weed hosts.

## Beet Disease Caused by Viruses

### Beet Mosaic Virus (BtMV)

**Causal agent – Beet Mosaic Virus.** Virus diseases are of major economic importance on beets. Beet mosaic virus is common worldwide. The disease usually appears first in seed production plots during early spring, on the first leaves produced from the root. The appearance of the disease in seed plots is due to the fact that the roots used for planting became infected with the virus during the first year. Therefore, mosaic virus infected roots were used for planting. The virus is spread (vectored) by several species of aphids including the peach aphid. The virus has a very wide host range that includes many species of crop plants in several different plant families. Several weed species are also important hosts.

*Figure 9.7 Symptoms of beet mosaic virus. Authors: C. M. Rush and G. B. Heide*

**Disease Symptoms**: Disease symptoms on infected plants are not always visible. Symptoms are often masked (not visible) if temperatures are high or too low. If the temperature is more than 21$^0$C and less than 10$^0$C, disease symptoms will not appear on newly formed leaves. Once symptoms appear on leaves, they will not be disappearing under adverse temperatures. The most common symptom is a pale green to yellow green mottle or mosaic pattern on the leaf. This mosaic symptom is similar to other mosaic disease symptoms. The younger the leaf, the more easily noticeable is the mosaic mottling. As leaves mature, disease symptoms gradually subside on new leaves and eventually vanish. This mosaic pattern can be seen on annual plants and seed plants. The latter develop disease symptoms after cutting of sprouts, during growth of new leaves. In addition to mottling, the leaf blade often undergoes deformation. This disease can also cause an intensive growth of vegetation and, rarely, tissue necrosis, where part of the leaf blade dies and has dry spots appearing on it.

A backward curling of the leaf tip may occur. This is a characteristic symptom of the disease, but does not always occur on infected leaves. Infected plants may become stunted.

#### Control

- Always use disease free (virus free) seeds and planting material;
- Search for and remove wild species of susceptible weeds and volunteer beet plants near the planting;
- Control the aphid vectors that introduce and spread the virus.

### Beet Curly Top Virus (BCTV)

*Figure 9.8 Symptoms of BCTV. Author: Howard F. Schwartz*

**Causal agent – Beet curly top virus.** The virus is an important pathogen on table beets. It can infect many other crop plant and several common weed species. In addition to beets, this disease also affects pepper, tomato, spinach, legumes, cucurbits, and plants in the solanaceae, caryophyllaceae and umbellíferae families. The virus is vectored by leaf hoppers. In the Mediterranean region, the leaf hopper, *circulifero pacipennis,* has been reported to be a vector.

**Disease Symptoms**: The most common symptoms are reduced growth (stunted plants) and reduced leaves. Leaf veins appear thickened and lose colour and become transparent. If the disease is severe, the veins will develop necrotic brown lines of various lengths along their sides. These lines will later exude glue-like fluid. Leaves are severely rolled upwards, crinkle, and sometimes form swollen growths that are visible on the lower leaf surface. Infected leaves may also become thick and powdery. Leaf petioles may be shortened and bend inwards. The root can be distorted and have a proliferation of fine roots, resulting in a "hairy root" symptom. The virus is restricted to the phloem of the plant and phloem tissue can be necrotic when seen in dissected roots.

**Control**

- Always use disease free (virus free) seeds and planting material;
- Search for and remove wild species of susceptible weeds and volunteer beet plants near the planting;
- Control the leaf hopper vectors that introduce and spread the virus.

*Figure 9.9 Symptoms of crown gall. Source: KWS UK - Product Portfolio*

## Beet Disease Caused by Bacteria

### Crown Gall

**Causal agent – Agrobacterium tumefaciens.** This disease most often occurs in sugar beets, though it can also affect table beets. Causal agent attacks many cultural and wild plants.

**Disease Symptoms**: Underground parts of beets develop protuberances of various sizes. They can be the size of a kidney bean or larger than the roots themselves. This disease mainly appears in the area of the root neck and more rarely in the lower parts of roots. The surface of the galls is mostly uneven, knobby or wrinkled, and covered with protective tissue. At first the galls are soft and white. In time they become hard and usually turn brown. As a rule, it does not rot. Tissue under protuberances is white. There are no bacteria in older galls. Bacteria can only be found in young galls during early stages of the disease development.

**Control**

- Adhere to agro-technical rules and timing of beet production, harvesting and storage;
- Use disease-free seed materials;
- Remove and destroy infected plants and roots from the field and storage areas.

*Figure 9.10 Symptoms of tuberculosis of beet. Source: agroatlas*

### Tuberculosis of Beet

**Causal agent – Xanthomonas beticola.** Causal agent is stored in the soil, from where it penetrates roots through mechanical injuries.

**Disease Symptoms**: Symptoms are very similar to those of crown gall but differ from it by the size of protuberances, which are not large in the case of tuberculosis. Protuberances are dark-coloured, knobby growths that are attached to the roots by a wide base. Unlike crown gall, these protuberances have holes. Bacteria are always concentrated in damaged tissues. Rot may develop in the centres of the knobby growths during the vegetation period.

Roots infected with tuberculosis are not suitable for storage. Tissues in the knobby growths rot easily and are often invaded by secondary organisms that rot the roots.

#### Control

- Adhere to agro-technical rules and timing of beet production, harvesting and storage;
- Use disease-free seed materials;
- Remove and destroy infected plants and roots from the farm and storage areas.

### Harvesting and handling

Harvest of table beet begins about 45-65 days from seed sowing. Harvesting should be done at the coolest part of the day, usually early in the morning. Roots should be thoroughly washed and cooled as soon as possible. The optimum temperature for storage is between 1° and 4°C. To prevent or reduce root cracking, avoid wetting and drying of the roots after harvest.

*Figure 9.11 Root zoning. Source: Gardening Cornell University*

### Physiological Disorders

Root zoning is characterized by alternating red and white rings in the root tissue. The disorder is associated with hot weather and when both day and night temperatures are warm or hot. In contrast, the disorder does not develop as readily under warm days and cooler nights.

#### Remedy

The most effective strategy to reduce root zoning is to plant resistant varieties. Another practice to reduce root zoning is to reduce soil moisture by using reflective mulches, keeping the soil damp, and planting cooler sites.

# ONION, GARLIC

Onion (allium cepa) and garlic (allium sativum) belong to the family aliaceae, which also includes chive, shallot and leak. Onions and garlic are among the most widely adaptable vegetables in the world. They can be grown successfully from tropical to subarctic regions.

### Temperature and Day Length Requirements

Onion and garlic are cool to moderate season vegetables. Plants require cooler (about 20°C) temperatures during the early stages of growth and moderately higher temperatures (28°C) for best bulb development and maturation. Yellow varieties are usually planted earlier than red varieties, because they can tolerate higher temperatures.

They grow best when the day time temperature is cool and night temperature is relatively warm. However, the wide adaptation of onion and garlic is primarily due to their response to day length. Unlike many other vegetables, day length influences bulb formation rather than flower development.

Onion bulbs are classified into three groups based on their response to day-length.

1. Short-day varieties. These varieties form bulb when day-length is between 11-12 hours;
2. Intermediate day-length varieties. Includes varieties that form bulbs at day-lengths of 13-14 hours. These varieties are adaptable to the central region of Georgia;
3. Long-day varieties. These varieties start to form bulb at day-lengths of 16 hours or more.

### Soil Requirement.

Many types of soils are suitable for growing onions and garlic, but the ideal soil should be loose (friable) and well-drained. Soggy and heavy soils become firm when they are dry, making them difficult for the bulbs to grow. Ideal soils should also be fertile and high in organic matter. Onion and garlic plants, however, do not perform well when over fertilized.

The optimum soil pH for plant growth is in the range of 6.0 to 6.5. Applications of dolomite lime or calcite lime is highly recommended, if soil pH is below or the above the recommended range. Dolomite lime is preferred if soil magnesium level is low, while calcite lime is recommended if soil magnesium is high. Is pH is adequate, but the soil test indicates low calcium then use gypsum instead. Soil pH can take several months to change with lime applications. If soil testing indicates low pH, lime or gypsum treatments should be done as early as possible to ensure that soil pH is corrected in sufficient time for planting.

## Varieties

### Onion

In addition to classification of onion varieties based on day-length, there are also classification based on bulb color, country of origin, and shape of the bulb. Storage onions, also called fall and winter onions, have three main colors - red, white, or yellow.

Varieties named after their country or city of origin include Bermuda onion, a mild flavored onion, Egyptian onion, a strong flavored onion with edible leaves, Spanish onion, a milder flavor onion that has red, white and yellow bulbs, Walla onion, a large sweet onion, and Vidalia onion, also a sweet and very tender onion from the State of Georgia in the USA. There are also scallions or spring onion, shallots, a milder flavor onion that resembles garlic, and several others.

### Garlic

Garlic varieties are classified into hard neck (allium sativum var. ophioscorodon) and soft neck (A. sativum var. sativum). Soft neck varieties are adaptable to a wider range of climates, they keep longer in storage, tend to mature faster, and they are generally more productive than hard neck varieties. Most of the hard neck varieties do best where winter is cold, spring is damp and cool, and summer is dry and warm. The cloves of hard neck varieties are fewer per bulb, relatively larger in size, and easier to peel than soft neck varieties. Hard neck varieties also demand more attention than soft neck varieties to produce good-quality large bulbs. But they are more colorful and offer varieties of flavor. Hard neck varieties produce an edible flower stalk, prized for its delicate flavor when harvested while it is still tender. Removing the stalk encourages more bulb production.

### Production Practices

Onion and garlic require relatively similar production practices. Short-day onions can be grown from both seed and transplants, but the majority of onions are grown from transplants. However almost all commercially grown garlic is produced mostly from cloves but a few growers prefer using transplants.

Transplant production begins in late summer with land preparation followed by seed sowing in September. Land for transplant production should not have been in onions or related Alliums for at least three years.

A hectare of onion and garlic requires about a kilogram of seeds. An area of 300-500 m seed bed produces enough transplants for one hectare. Seeds are usually sown in rows set on beds 7-10 cm apart. Seeds are distributed thinly and evenly to prevent damping off. Plants are hardened by reducing watering and exposing the seedlings to full sunlight for about seven to ten hours prior to transplanting in the field.

At four to five weeks after sowing, transplants are hardened for about 10 days by placing them in a partially shaded area and watering them less frequently but maintaining sufficient moisture to prevent wilting. Hardened transplants are moved into the field and planted at a distance of 15 cm between rows and 3-5 cm between transplants in the row.

### Irrigation

Transplants should be watered with about 2.5 cm soon after planting in the field. Depending on soil types, irrigation varies between four and seven days until about two to three weeks before harvest or when 20-30 percent of the tops start to fold over. The last irrigation should be a light one.

### Nutrient Management

As mentioned earlier, onion and garlic plants require sufficient nutrients in order to produce an economically viable crop. The best strategy to nutrient management is to base fertilizer application on soil and plant analysis. As a general rule, fully developed onion and garlic plants require about 130 to 150 kg/hectare of actual nitrogen, usually applied in three equal increments starting two weeks after transplanting and continuing during the early stages of bulb formation.

Low level of potassium causes plants to become more susceptible to cold injury, while low level of phosphorous reduces the ability of carry its biological functions. Assuming that soil analysis indicated low to moderate levels of potassium and phosphorous, the recommended rate to apply is about 100 to about 130 kg/hectare of each of these elements. Heavy rainfall or irrigation causes soil applied potassium to leaching readily. Therefore, it is recommended to split potassium application by incorporating half of the recommended rate before planting and splitting the remaining half into one to two side dressing applications.

Sulfur is very important for onion and garlic plant growth and bulb quality. The recommended sulfur rate is between 45 to 50 kg/hectare split into two equal applications, one before planting and the other side dressed before plants start to form bulbs. Boron is required by onion and garlic plants. If soil boron is low, a single soil application of 1.2 kg per hectare needs to be incorporated prior to transplanting of seeding. Higher rates of boron can cause injury to growing plants.

### Weed Control

Onion and garlic are weak competitors with other plants and so they do not thrive well in weedy areas. There are only a limited number of herbicides currently registered for use on garlic and onion. For best growth start with a weed-free area and mulch with clean straw after planting.

## ONION AND GARLIC DISEASES

Onions and garlic have several diseases that can be very serious under environmental conditions that are conducive to disease development. Diseases of onion and garlic are caused by fungi, viruses and bacteria. Most onion and garlic diseases are caused by fungi. The main diseases that are caused by fungi include: Downy Mildew, Leek Rust, Neck Rot of Garlic, Alternaria Blight, Neck Rot of Onion, Onion Smut, Fusarium Wilt, White Rot of Onion, and Black Mold Rot of Onion Bulbs.

The most important disease caused by a virus is onion mosaic virus, and the most important disease caused by a bacterium is bacterial soft rot.

## Onion and Garlic Diseases Caused by Fungi

### Downy Mildew (Peronosporosis)

*Figure 10.1 Symptoms of downey mildew in onion. Source: Plantesygdomme*

**Causal agent – Peronospora destructor.** Downy mildew is caused by the oomycete pathogen, *Peronospora destructor*. It is a very destructive disease of onion and can greatly reduce yield and quality of foliage and bulbs. The disease is most severe and epidemics develop best under prolonged periods of cool, wet weather. Infection requires cool temperatures (less than 22°C) and the presence of free water. The optimum temperature for germination of sporangia (spores) is 10° to 12°C. Spores can germinate and penetrate the leaf through natural openings (stomata) in two to four hours. Spores are produced at night and are released and carried by wind currents during the day to healthy leaves where they infect and spread the disease. Spores can survive on the leaf surface for up to three days. Periods of warmer and dry weather can stop disease development. The oomycete pathogen is an obligate parasite and produces thick walled survival structures called oospores that can survive alone in the soil or in infected bulbs. Mycelium of the pathogen can also survive within infected bulbs. Cold winters appear to reduce the incidence of the disease during the following year. The pathogen can also be seed borne.

**Disease Symptoms:** The disease is manifested both as diffusive (widespread) and local damage. Plants that emerge from damaged bulbs develop widespread damage. Initially, the plant develops normally. After two to four weeks, leaves become yellowish, and are covered by a wax like powdery growth of the pathogen. Diseased leaves become deformed. During severe damage, leaves become softened and may collapse. In humid weather they are covered with dark gray-violet powdery growth of the pathogen, which consists of spores (sporangia) of the pathogen. These spores are transferred to healthy plants on wind currents where they infect the leaves in the presence of free water resulting in new infections and further spread of the disease. At this time, leaves develop oval yellow spots of various sizes, which grow quickly and their surface is covered with a dark gray-violet powdery growth of the pathogen. The powdery growth gradually spreads to the whole surface of the leaf, which is followed by wilting. In dryer weather, damaged areas appear mainly as white (chlorotic) spots. At times, infected leaves may not be covered with the powdery growth, but damaged leaves eventually die in this case as well.

From infected above-ground organs the pathogen penetrates into the onion bulbs, where it develops mostly in the top part of the bulb. It is impossible to differentiate damaged onion bulbs from healthy ones through visual inspection. However, damaged bulbs do not survive well in storage. Most infected bulbs will develop mold and rot easily. Bulbs damaged in storage are not marketable.

With time, the color of the dark gray-violet powdery growth, existing on damaged organs, changes and turns to dirty gray. Also, many saprophytic fungi (Alternaria, Cladosporium, Stemphylium and others) cause secondary infections on diseased leaves and stalks and begin to reproduce through the formation of spores. A symptom of this process is blackening of diseased plant parts. Seed material taken from such plants is of very poor quality and will give rise to diseased plants in the field.

**Control**

- Use disease free planting material. Heat treatment may reduce the viability of the pathogen in infected planting material. Proper heat treatment of seed material is conducted by placing seed material at the temperature of 43° to 45°C for a period of 20-24 hours or at the temperature of 35° to 37°C for a period of five to seven days and nights;
- Use proper agricultural production techniques that minimize damage to the plant and results in healthy vigorous plants;
- Careful and thorough cleaning and disinfesting of storage areas must be performed;

*Figure 10.2 Symptoms of leek rust. Source: Naga negi*

*Figure 10.3 Symptoms of neck rot of garlic. Source: Plant Diseases Management Handbook, Midwest*

- Crop rotation - Use a rotation that excludes the production of onions for at least three to four years;
- Sanitation - Use sanitary measures such as the use of clean seed beds away from the production of crops. Remove and destroy infected plant parts in the field and in storage;
- Control weeds, especially volunteer onion plants in and near the planting;
- Applications of an effecting fungicide can be important for controlling this disease. Weekly applications may be required starting before significant disease develop.

### Leek Rust

**Causal agent – Puccinia allii.** Leek rust is caused by the obligate parasitic fungus, *Puccinia allii*. The rust fungus does not survive in soil. Orange urediniospores are the primary inoculum for the disease. These spores can be carried over long distances by winds. The source of the primary inoculum for some major epidemics in California, U.S.A., was never identified. Optimum conditions for infection are 15°C and 100 percent relative humidity for four hours. Rust infections can be favored by high nitrogen applications and low potash levels.

**Disease Symptoms:** The first symptoms consist of small (1to 2 mm in diameter) leaf flecks and spots that are irregular in shape and white or light tan in color. These spots increase in size to 3 to 5 mm then develop into bright orange pustules (warts) that are full of orange dusty spores. These "rust pustules" are typical symptoms of many rust diseases on other plants. Rust usually appears on older leaves first and later spreads to younger leaves. Severely infected leaves can be almost completely covered with pustules. Severe infection can result in death of leaves, reduced plant size and yield.

#### Control

- Use disease free planting material. Heat treatment may reduce the viability of the pathogen in infected planting material. Proper heat treatment of seed material is conducted by placing seed material at the temperature of 43° to 45°C for a period of 20-24 hours or at the temperature of 35° to 37°C for a period of five to seven days and nights;
- Use proper agricultural production techniques that minimize damage to the plant and results in healthy vigorous plants. Avoid over or excessive fertilization with nitrogen and maintain sufficient levels of potash;
- Crop rotation - Use a rotation that excludes the production of onions for at least two years;
- Applications of an effecting fungicide can be important for controlling this disease.

### Neck Rot of Garlic

**Causal agent – Sclerotinia porri.** The pathogen overwinters as mycelium in diseased bulbs, as mycelium in infected bulbs in storage, and in plant debris in the field. It can also overwinter in soil a ssclerotia which are tiny black survival structures produced by the fungus in infected tissues.

Environmental conditions that favor disease development and spread are high levels of soil moisture and relative humidity combined with cool temperatures (13° to 15° C).

**Disease Symptoms:** During storage, garlic cloves develop small, slightly sunken, yellowish or dark spots that are several millimeters in diameter. These spots later increase in size, the cloves wilt and eventually dry down and mummify. Under conditions of high moisture, diseased tissue is covered with a gray powdery growth of the fungus. If diseased cloves are used for planting, the emerging plants are weak and chlorotic (yellow). When mature leaves of autumn garlic are infected, they rot and plants eventually die. Internal layers of infected bulbs darken and develop black sclerotia which are visible within infected tissues.

**Control**

- Sanitation - Remove and destroy infected plant parts in the field and in storage;
- Crop rotation - If the disease occurs, use a rotation that excludes the production of garlic for at least four years;
- Use disease free planting material. If planting material is infected, use an effective seed treatment fungicide (Bayleton, Fundazol);
- Maintain proper storage conditions. Storage facilities should be thoroughly cleaned and disinfested. Dry bulbs before placement in storage.

### Alternaria Blight

**Causal agent – Alternaria alli.** The pathogen overwinters in infected seed material, diseased onion bulbs, and plant remains in the field. During the vegetation period, the fungus spreads from infected to healthy leaves by means of conidia that are produced by the fungus on infected tissues. Conidia are spread by wind or in splashing water. The disease can develop over a wide range of temperatures from 2° to 35°C. The pathogen penetrates the plant primarily through mechanical damage. Free water from rain, dew or overhead irrigation is required for conidia germination and for the production of conidia on infected tissues. The disease is most severe on physiologically weak plants, as well as older plants. Excessive nitrogen fertilization also results in increased damage from the disease.

*Figure 10.4 Symptoms of alternaria blight in leaves. Source: Information for Commercial Vegetable Production in Ontario*

**Disease Symptoms:** The disease first appears on onion leaves or its veins, initially as light spots. The spots quickly grow and their length often reaches 10 cm and more. Finally, spots surround the diseased areas. Color of the spots changes constantly and finally assumes a brownish-violet color. Spots often have white margin or halo. Damaged tissues eventually dry and break. Later the disease moves on to onion bulbs. At this time, diseased tissue is initially colorless and then assumes a reddish-dark gray coloring. Greenish-dark gray mold appears between the layers of the bulb. Diseased areas often develop a secondary black mold.

**Control**

- Sanitation - Remove and destroy infected plant parts in the field and in storage;
- Crop rotation - If the disease occurs, use a rotation that excludes the production of garlic for at least two years;
- Use proper agricultural production techniques that minimize damage to the plant and results in healthy vigorous plants. Avoid over or excessive fertilization with nitrogen;

- Applications of an effecting fungicide can be important for controlling this disease.

*Figure 10.5 Symptoms of neck rot in onion. Source: WikiGardener*

### Neck Rot of Onion

**Causal agent – Botrytis allii.** Neck rot is mainly a storage disease. Under poor storage conditions, the disease can result in losses greater than 50 percent. Producers that do not have facilities for drying onions prior to storage may have significant losses. The pathogen is transmitted on seed and planting material. If seed is stored at sufficiently low temperatures the fungus can survive on seed for more than three years. The pathogen produces conidia on infected seeds that spread the disease to new leaves to cause infections. During the growing season, infection may be restricted to the leaves. Just prior to harvest, the bulb onion foliage is topped or bent creating wounds on the bulb that are open to infection. While neck tissue retains moisture, the pathogen grows into the bulb where it causes rot. Tiny black sclerotia, which are survival structures produced by the fungus, are produced within infected tissues. Sclerotia can survive for at least two years in buried debris in the field.

**Disease Symptoms:** In the field, plants develop white spots, with the length of 1-5 mm and a light green margin or halo. These spots may resemble herbicide injury. They can be differentiated from one another only by means of the light green margin or halo that develops around the spots caused by neck rot. Although bulb infection may occur in the field, most of the damage caused by the disease occurs in storage. Typical symptoms in storage are a water-soaked or light brown rot at the neck of the stored onion bulb. A dense gray growth of mycelium is produced around the neck and between the bulb scales (layers). Many tiny black sclerotia (5 mm in diameter) also develop on the neck of the bulb. The mycelium growth usually becomes apparent after several weeks in storage. The pathogen continues to spread through the bulb and eventually most of the bulb becomes a soft, rotted mass.

The tissue on cuts of diseased bulbs differs radically from healthy tissue: it is black and softened.

In some cases, diseased bulbs develop dry rot. They mummify, and become covered with a powdery fungus growth and black sclerotia. Diseased bulbs are often invaded by secondary bacteria and fungi that result in various types of rot.

**Control**

- Crop rotation - If the disease occurs, use a rotation that excludes the production of garlic for at least two to three years;
- Timely harvesting of the crop is important;
- Avoid mechanical damage to the bulbs;
- Observe optimal storage regimes: Temperatures should not exceed 30° to 32°C and relative humidity should be maintained below 80 percent as long as possible;
- Rational use of mineral fertilizers: Fertilizers containing nitrogen should be added during the crop growth period, while phosphorus fertilizers should be used during the second half of vegetation. It is undesirable to use fertilizers containing nitrogen eight to nine weeks after planting;
- Timely and high-quality proper chemical treatment.

### Onion Smut

**Causal agent – Urocystis cepulae.** The fungus is soil borne and can survive for up to 20 years in soil. Spores produced by the pathogen (chlamydospores) are spread by wind and splashing water. The optimum temperature for spore germination is 13° to 22°C. Most plant infections occur at 10° to 12°C. Disease development and spread is greatly reduced at temperatures above 25°C. Infection and symptom development are most serious in production fields where onions are produced from seeds. Plants are far more sensitive to the disease during the period from seedling emergence until formation of the first leaf. After reaching the height of 8-10 cm, onions rarely become diseased with smut.

*Figure 10.6 Symptoms of onion smut. Source: WikiGardener*

**Disease Symptoms:** Symptoms can appear as early as seedling emergence, when cotyledons show symptoms. The cotyledons and first leaves develop oblong to elongated, dark, raised blisters on outer surfaces. These growths can cause a downward curling of the leaves. When mature, the dark blisters break open to expose a black, powdery growth of the fungus. There is progressive spreads of the disease inward which can kill seedlings in three to four weeks. Infected bulbs remain firm; however, secondary decay organisms can penetrate damaged areas and cause the bulb to rot.

#### Control

- Use fungicide treated seeds;
- Use healthy transplants because they are able to resist infection from soil borne inoculums;
- Plant when soil temperatures are higher;
- Sanitation - remove and destroy infected plant debris.

### Fusarium Wilt and Bulb Rot

**Causal agen – Fusarium ozysporum, Fusarium moniliforme and Fursarium culmorum.** The disease is common and can result in severe loses of both onion and garlic. The pathogens are soil borne. They survive in soil as resistant spores (clamydospores). The pathogens are carried on onion sets and garlic cloves. The fungi may also be seed borne. The optimum temperature for disease development is 25° to 28°C, and the disease is seldom a problem when soil temperatures are less than 15°C. These fungi can penetrate the roots and spread to the base of the bulb. They can also penetrate the bulb directly. Damage from insect feeding or other causes can increase the disease. Wet weather close to harvest favors disease development, especially in garlic.

*Figure 10.7 Symtoms of fusarium wilt on onion. Source:WikiGardener*

**Disease Symptoms:** Symptoms on leaves develop at any time during the growing season and include a general yellowing (chlorosis) of the leaf and necrosis of the leaf from the tip downward. Plants also wilt. A tan to pink root rot may develop on onion and a red to purple discoloration of the stems and bulbs of garlic. A rot develops on basal tissues where the roots are attached to the bulb. This rot is usually water-soaked (appears wet), tan to darker brown in color, and tissues usually remain firm. In time, the infection can spread up into the bulb causing a soft rot. This results in the plant collapsing and dying. Under wet, humid conditions, a fluffy white to pinkish-red growth of fungus mycelium is produced on diseased areas. Bulbs that show no obvious symptoms may still be infected and rot in storage. Especially under poor storage conditions, the disease can result in serious loses in storage.

If growth of diseased plants is stunted, root system is weakly developed and dark in color, while tips of leaves yellow. Roots of the plants diseased during storage (leek, green onion) develop necrosis; false stalk at the length of 3 to 10 cm darkens and rots. Light or pinkish-red mycelia appear between leaves. At the final stage of the disease, damaged tissue becomes wet.

**Control**

- Sanitation-Remove and destroy infected plant parts in the field and in storage;
- Crop rotation-If the disease occurs, use a rotation that excludes the production of onion and garlic for at least four years;
- Maintain proper storage conditions. Storage facilities should be thoroughly cleaned and disinfested. Dry bulbs before placement in storage;
- Store leeks in sand or well-drained soil, or freeze them;
- Use resistant or less susceptible varieties if available;
- Use proper agricultural production techniques that minimize damage to the plant and results in healthy vigorous plants. Avoid wet areas for planting and practices that result in excessive soil moisture, such as over irrigating.

*Figure 10.8 Symptoms of white rot of onion. Source:WikiGardener*

### White Rot of Onion and Garlic

**Causal agent – Scleriotinia cepivorum.** White rot is a major root disease of onion and garlic. Under severe conditions, it can result in complete crop loss. The disease is associated with soil borne inoculum, so infested fields and disease incidence will continue to increase as onions and garlic continue to be produced in infested fields. The fungus produces survival structures called sclerotia. The sclerotia can survive in the soil without a plant host for 20 years or more. The sclerotia remain dormant in the soil until onion or garlic is planted. The roots of onion and garlic produce a substance that stimulates the sclerotia to germinate. Sclerotia germinate and mycelium can grow 1 to 2 cm through the soil where they penetrate the roots and base of the bulb. The fungus can spread by mycelium from plant to plant if roots are close to each other. Temperature is important for disease development. The fungus is not very active when soil temperatures are below 9°C or above 24°C. The optimum temperature range for infection and disease development is 14° to 18°C. The disease is most severe when soil pH is from 5.5 to 6.5. Sclerotia germinate in moist soil, but germination is inhibited in very wet soils. Bulb onion crops appear to before severely affected than direct seeded crops because of a more vigorous root system early in the season.

**Disease Symptoms:** Disease symptoms are observed both in the field and in storage. White rot affects the roots and crown of the plant. Above ground symptoms are not observed in the field until after root infection is well established. Leaves on infected plants turn yellow, wilt, collapse, and eventually die and become brown and dry. In badly affected areas, growth of leaves is reduced and groups of plants die rapidly. White mycelium develops on diseased roots and the base of bulbs in contact with soil. Many tiny, black, round, sclerotia measuring less than 1 mm in diameter form on the mycelium and diseased tissue. In advanced stages of disease development, roots and bulbs become soft and rotted primarily from invasion of diseased tissues by secondary decay organisms.

The disease also develops in storage and can result in serious losses. Diseased bulbs shrink and become lighter in color. Similar symptoms are observed on leek in the field, near the end of the production period.

**Control**

- Crop location is of limited value because the pathogen can survive in soil for 20 years or more. It is best to select field and plant crops where there is no history of the disease. If crop rotation is used, it is not desirable to grow onions or garlic on infected land for at least 10 years;
- Sanitation - Remove and destroy infected plant parts in the field and in storage. Removing infected plant debris and plants from the field will aid in preventing the increased build-up of sclerotia in the field;
- Be aware that the sclerotia can survive passing through the digestive tract of animals and may be present in manure;
- Use only disease free transplants;
- Soil fumigation of heavily infested field may be useful, but will not eradicate the fungus from the field;
- Fungicides used as onion seed or garlic clove treatments or transplant drenches can be partially effective;
- Flooding of infested fields has been used to control white rot in some regions of the world.

### Black Mold of Onion Bulbs

**Causal agent – Aspergilus niger.** Black mold of onion is most prevalent in tropical and subtropical production areas where high temperatures favor its development. Black mold can be a problem in the field, but it causes most losses in storage. The pathogen is seed borne in onion. It also occurs widely in field soils and is a saprophyte that colonizes dead plant foliage. The fungus grows on old dying onion leaves then grows to the neck of the bulb and eventually into the bulb. Bulb infection in the field is usually associated with damage to the fleshy scales. During harvesting, spores of the fungus on infected foliage are released and moved by air to other plants in the field and to plants in nearby fields. The optimum temperature for growth is 28° to 34°C. The minimum temperature for spore germination is 17°C. Humidity greater than 80 percent is required for spore germination and the presence of free water for six to 12 hours is required for infection.

*Figure 10.9 Symptoms of black mold of onion.Author:Paul Cowan*

**Disease Symptoms:** The disease affects onion and garlic bulbs mostly during storage. The fungus causes black, dusty fungal growth on and between the bulb scales. In severe cases the entire surface of the bulb may turn completely black. They are ugly and not marketable. Severely affected bulbs may also rot. Secondary bacterial organisms usually contribute to the rot in storage.

**Control**

- Use clean, pathogen free seed. If clean seed is not available a fungicide seed treatment should be used;
- Foliar fungicides can reduce black mold if applied near the end of the season;

- Harvest the crop under dry conditions and minimize damage to the neck tissue of the bulbs;
- Maintain temperature and relative humidity at appropriate levels during storage. Monitor the temperature when using high temperatures to dry out the onions after harvest. Temperatures should not exceed 30° to 32°C and relative humidity should be maintained below 80 percent as long as possible. Long term storage at low temperature stops growth of the fungus, but the fungus can become active at temperatures above 15°C.

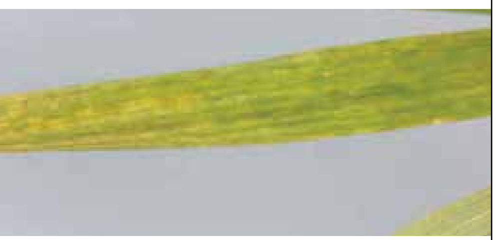


*Figure 10.10 Onion mosaic virus. Author Paul Cowan*

## Diseases Caused by Viruses

### Onion Mosaic Virus

**Causal agent – Onion Mosaic Virus.** The disease affects many plants in the *Alliceae* family. Plants may be infected at all stages of their development. The virus causing the disease overwinters and moves from crop to crop in infected onion bulbs and garlic cloves. It cannot survive in the soil for long periods of time. High temperatures both in storage and in the field contribute greatly to infection and disease development. The virus is transmitted (vectored) by various types of mites, nematodes in the soil, and the four-legged garlic mite.

**Disease Symptoms:** The disease mostly damages leaves and spadix, and can cause crop losses up to 20 to 25 percent. Diseased leaves or spadix become covered with light yellow or light green spots in a mosaic pattern. In garlic, the spots cover the whole length of the leaf. With time, chlorosis develops and wilting of the leaves occurs. The disease can also cause deformation of the leaves. Flower stalks also develop clearly visible mosaic symptoms. In onion, infected plants often produce unripe bulbs that are not marketable.

#### Control

- Maintain optimal storage conditions;
- Use healthy virus free seed material;
- Control insect, mite, and nematode vectors that transmit the diseases.

*Figure 10.11 Symptoms of bacterial soft rot in onion. Source: Keith Foster Blog*

## Diseases Caused by Bacteria

### Bacterial Soft Rot (Bacteriosis)

**Causal agents – Pectobacterium carotovorum and Burkholderia cepacia.** The disease can result in serious losses in the field during storage.

**Disease Symptoms:** Disease mostly affects plant that is weakened as a result of unfavorable climatic conditions or poor agricultural practices. In onion, the disease may develop both in the field and in storage. As infected bulbs reach maturity, slightly sunken, soft areas develop on the bulb that are clearly different from healthy tissue. Damaged layers are dark gray, water-soaked and soft. Eventually, infected bulbs can turn into a soft rotted mass of tissue with a very unpleasant odor. Atypical symptom of this disease is alternating healthy and damaged layers in the bulb.

Bacteriosis damage on garlic during storage is manifested as sunken ulcers or areas on garlic cloves. Damaged clove tissue develops a pearly-greenish color and may appear like it's frozen. Infected garlic cloves also have an unpleasant odor.

### Control

- Use proper agricultural production techniques that minimize damage to the plant and results in healthy vigorous plants;
- Use healthy, disease-free seed material.

## Physiological Disorders

Onion and garlic are prone to physiological disorders. One of these disorders is doubling or splitting of the bulb. This condition is caused by genetic, cultural, and environmental factors. Over-fertilization, uneven watering, and temperature fluctuations are all believed to influence double bulb formation. Some varieties are more prone to production of double bulbs than others. Varieties prone to doubling should be seeded or transplanted seven to 10 days earlier in order to minimize the disorder.

Both onion and garlic are biennials, forming bulbs the first year, which serve as food source for plant growth and flowering the following year. The process of flowering is called bolting. Under cool temperature during the latter part of the growing season a seed stalk, bolt, or scope forms very quickly. However, plants with large bulbs may bolt in the first year if appropriate environmental conditions are met.

Greening occurs when actively growing onion and garlic bulbs are exposed to sunlight for an extended period of time. Hilling (covering the bulbs with soil) and conditions that encourage strong healthy leaves, such as early fertilizer application, shades the bulb during development. Sunscald is another disorder that affects onion bulbs, and to a lesser extent garlic bulbs; it occurs when the bulbs have reached maturity but harvest is delayed. This disorder occurs at the shoulder of most onion bulbs that are exposed to sunlight for an extended period of time. Scales several layers deep will dry and turn brown. Under severe conditions, the internal tissue may actually die and become soft and translucent.

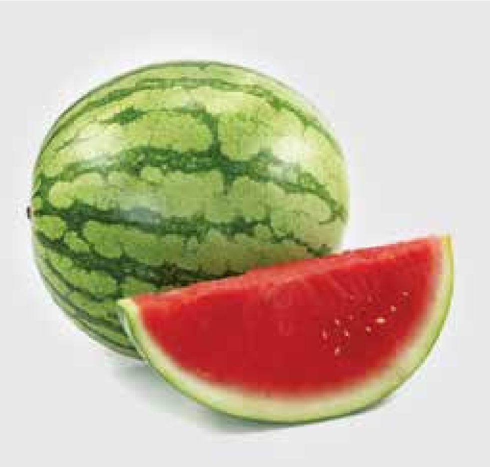
Translucent scale is a physiological disorder similar in appearance to freeze injury. The big difference is freeze injury will always affect the outer scales whereas translucent scale may first appear on scales several layers deep in the bulb. Translucent scale is a post-harvest phenomenon caused by exposure to high $CO_2$ during storage facilities. This is most likely to occur in refrigerated storage without adequate ventilation.

### Harvesting and storage

Mature onion and garlic bulbs may be harvested when the tops start to dry. This is usually in late summer or early fall. Bulbs should be dug up rather than pulled to avoid injury. Allow the tops to dry either in wind rows in the field or in door if the field is wet. It is essential that onion and garlic bulbs are well cured before they are stored. Cure harvested bulb for 10-14 days in a sunny, well-ventilated area. Align onions so that the leaves of one onion cover the bulb of another.

Mature bulbs are best stored at 0°C. Garlic stores well under a wide range of temperatures, but sprouts are produced quickly at 5°C or higher temperature. Storage humidity should be maintained at 65 to 70 percent at all times to discourage mold development and root formation. Onion and garlic bulbs will keep for up to seven months cured and stored at ideal temperature and humidity.

# WATERMELON



Watermelon *Citrulluslanatus* belongs to the *Cucurbitaceae* family, which includes cantaloupe, muskmelons, pumpkin, squash, and cucumber, among several others. Watermelon fruits are very popular worldwide, especially during the hot summer months, for their refreshing taste and flavor.

## Pollination Requirements

Watermelon and other members of the same family produce both male and female flowers on the same plant. The first flowers produced by each plant are usually males. Depending on weather condition and the health of the plants, female flowers start to appear within about seven to 10 days from the start of flowering. It is estimated that only one out of every seven flowers on a shoot is a female. Most male and female flowers usually abort before pollination takes place causing fruit set to be irregular throughout the season. The number of fruits already set on the plant and its health determine the number of female flowers that set into fruits later on. Therefore, removing misshaped and damaged fruits when they are small is important in order to encourage more female flowers to develop and set fruits. Flowers open for only a short time, one to two hours after sunrise, then close in the afternoon, but never to reopen again regardless if they have been pollinated or not. Honeybees and other insects are required for adequate pollination and fruit set. Usually four to five hives per hectare are needed. Bees must drop adequate pollen grains on all three lobes of the female flower stigma in order to reduce the risk of producing a misshapen fruit. Cold, rainy and windy weather reduce the bee's activity, which can cause poor melon production due to inadequate pollination. Poor pollination reduces the number of seeds per fruit, which results in a reduction in fruit size and slowing down of the ripening process.

Seedless watermelons are becoming more popular in the US and Europe. Seedless watermelons are not exactly seedless, their seeds develop but they do not grow into full size. Seedless watermelons are sterile (Triploid), however, they do need to be pollinated with viable pollens preferably from a seeded variety in order for the fruits to grow. Usually one seeded variety should be planted with every five to six seedless variety, or one row to every three to four rows should be the seeded variety. It is better to select a seeded variety with a different color in order to be able to distinguish between the seeded and seedless varieties at harvest.

## Climatic Requirements

Watermelons are very sensitive to cold and frost conditions. They prefer hot and dry climate. Plants can tolerate a minimum of 18°C and a maximum of 35°C temperatures, but they grow best at temperatures in between. The optimum soil temperature for root grow this in the range of 20°to35°C. Transplants should not be moved into the field until the soil temperature at 6 to 7cm beneath the soil surface reaches about 15° to 16°C. Fruits grown under hot and dry conditions have higher sugar content than those grown under cooler and humid conditions.

## Soil Requirement

Watermelons grow best on sandy loam with high organic matter, good water holding capacity, with adequate air and water infiltration rates. Optimum soil pH is between 5.8 and 6.6. Lower soil pH enhances the development of blossom end rot, while higher soil pH enhances iron chlorosis. Watermelons are high water-requiring plants. Keeping a constant supply of moisture during the growing season is essential for good fruit size. However, excess water at any time during crop growth, especially as fruit reaches maturity, can cause the fruit to crack, which will reduce crop yield and fruit quality. Commercial growers prefer to grow watermelons on raised beds using drip irrigation.

### Planting and Fertilization Requirements

Commercially grown watermelons start from transplants or are directly seeded in the field. Transplants take four to six weeks of growth under controlled environment before they are ready for field planting. On average approximately 7,000 to 12,000 plants are transplanted per hectare in single rows/hills spaced at 200 cm apart and 200 to 250 cm between plants in the row, with some adjustments for vigor. In some countries growers direct seed watermelons in hills (two to three seeds per hill). However, direct seeding takes a longer time for the fruit to reach full maturity, which reduces potential income from early harvest.

Fertilizer rates should be based on annual soil test results. The general fertilizer recommendation is to side dress soon after transplanting with about 44 kg per hectare nitrogen and 60 kg per hectare of each of potassium and phosphorous. Another application of similar amounts needs to be applied either through drip or side dressing as soon as the first male flowers start to form.

### Harvest and Storage

It is difficult to know when fruits are ready for harvest. Also, watermelon fruits do not continue to ripen after harvest. Usually it takes about three to four months after planting for the fruit to reach full maturity, depending on the cultivar and weather conditions. Multiple pickings are usually needed, because each fruit is pollinated at different times. Fruits should be harvested at full maturity for best taste and texture. Indicators of watermelon maturity include a yellow spot on the fruit surface in contact with soil or plastic mulch; a brown, dried tendril where the fruit stem is joined to the watermelon vine; and a dull surface on top of the fruit. Because individual fruits are pollinated at different times, multiple harvests are usually necessary.

Fruits should be harvested at the coolest part of the day which is usually very early in the morning. Damaged or misshaped fruits should be discarded to ensure good quality fruits reach the consumer. Fruits should be moved out of the field and into a shaded area or cold storage as soon as possible. Keeping fruits in the sun or not cooling them reduces their quality. Fruits should be cooled to between 9° and 14°C and 85-90 percent relative humidity. Watermelons will maintain good quality for about 20-25 days if stored properly.

## DISEASES OF WATERMELON

Watermelon is affected by several important plant diseases in Georgia. The most important diseases caused by fungi include: white mold (sclerotiniosis), anthracnose, downy mildew and powdery mildew. Watermelon mosaic virus and cucumber mosaic virus are the most important diseases caused by viruses and bacterial wilt is the most important disease caused by bacteria.

## Diseases Caused by Fungi

### White Mold (Sclerotinia rot)

*Figure 11.1 Symptoms of white mold on watermelon.Source: University of Delaware*

**Causal agent – Sclerotinia sclerotiorum.** White mold (sclerotinia rot) has been observed worldwide and is one of the most destructive and widespread disease of horticultural crops worldwide. However, the disease is considered a minor problem on cucurbits in many regions. When the disease does occur under conditions favorable for disease development, it can result in serious losses. The fungus survives in soil as sclerotia and mycelium in plant debris both on top of and in the soil. The sclerotia can survive in soil in the absence of plant debris. The disease is favored by low temperatures and prolonged wet periods. Infections tend to occur in dead tendrils and petioles or through withered flowers still attached to developing fruit. The fungus can cause fruit rot both in the field and postharvest.

**Disease Symptoms:** White mold first develops on the flower, leaves, stems and fruit. Infected tissues often become covered with a cottony white growth of fungal mycelium and sclerotia may also develop. Stem injuries can provide entry points for the fungus, which spreads through the stem, producing mycelium and sclerotia inside it. Symptoms on fruit vary from none to a water-soaked appearance, and a cottony white growth of mycelium and sclerotia may develop where the fruit is in contact with the soil. Occasionally diseased fruit dry and become mummified. Internal symptoms appear as soft or wet rot with numerous sclerotia.

#### Control

- Crop rotation may be of limited benefit because of the wide host range of the pathogen and the production of sclerotia that can survive in the soil for relatively long period of time;
- Sanitation - Remove and destroy infected plants and fruits from the field;
- There are reports that deep plowing and careful irrigation management can aid in controlling disease incidence;
- The timely application of effective fungicides may aid in disease control, but it is difficult to get effective fungicide coverage where the fruit or other plant parts are in contact with the soil.

### Anthracnose

*Figure 11.2 Symptoms of anthracnose lesion on watermelon fruit. Source: Purdue University*

**Causal agent – Colletotrichum orbiculare.** Anthracnose occurs worldwide on many cucurbit crops and several cucurbit weeds. The fungus over winters on infected crop residues, volunteer cucurbit plants and cucurbit weed species. Conidia from these sources move to uninfected plants by splashing water from rain of overhead irrigation, contaminated tools and workers, and possibly insects. To germinate and infect the plant, conidia require 24 hours of 100 percent relative humidity and optimum temperatures of 22° to 27°C. Spores can take up to 72 hours to infect and first symptoms appear at four days after infection. The pathogen can also be seed borne and result in early infections on germinating seedlings or transplants placed into production fields.

**Disease Symptoms:** First symptoms appear as irregularly shaped water-soaked leaf lesions that soon turn chlorotic (yellow). Lesions can expand to become greater than 1 cm in diameter and appear dark brown to black. Lesions can cover most of the leaf making it become distorted. Tissues in lesions dry, crack, and fall out. Lesions can also occur on petioles and stems and appear as elongated, oval to diamond shaped, water-soaked lesions that turn tan to brown in color. Stem lesions can be covered with tiny black fungal fruiting structures (acervuli) and pink spore masses that are exuded from these structures. Fruit symptoms are circular water-soaked areas that later become dark brown to black sunken lesions. Acervuli and pink spore masses will also develop on fruit lesions during wet periods with high relative humidity.

#### Control

- Use resistant varieties if they are available;
- Use clean seed that does not have significant levels of the pathogen;
- Practice crop rotation in which cucurbit crops are not planted for at least two years;
- Avoid the use of overhead irrigation, especially if the disease is present in the planting;
- The timely use of effective fungicides can aid greatly in control of this disease.

### Downy Mildew

**Causal agent – Pseudoperonospora cubensis.** *Pseudoperonospora cubensis* is an oomycete and an obligate parasite. It cannot survive in the absence of a living host such as susceptible cucurbit crops and weed species. Infected plants are the main source of inoculum for starting the disease. The spores that cause infection can be spread over great distances by wind. Spores (sporangia) are produced on infected tissue if humidity is at 100 percent for six hours and the temperature is between 15° to 20°C. These spores are blown in wind or splashed onto susceptible tissue where they germinate and infect if free water is present for at least two hours at 20° to 25°C. Symptoms may appear in three to 12 days.

*Figure 11.3 Symptoms of downy mildew in watermelon fruit and leaves. Source: Brooks Country Ag Connection*

**Disease Symptoms:** First symptoms are small, pale green angular or rectangular spots that develop on the upper leaf surface. These spots on the upper leaf surface later turn chlorotic to bright yellow. As the spots age, they become brown and necrotic (dead). Severe leaf infection can result in shriveling and death of large areas of the leaf. Under conditions of high humidity, the surface of the spots on the underside of the leaf can become covered with a growth of light gray to dark purple fungus mycelium and spores. Downy mildew can cause stunting or death of young plants if infection occurs early and is severe. Fruit maturation and production can be prevented and fruit flavor and sugar content can also be affected if infection is severe.

#### Control

- Avoid using overhead irrigation, especially if the disease is present in the planting;
- The timely use of effective fungicides is important for controlling this disease.

### Powdery Mildew

*Figure 11.4 Symptoms of powdery mildew on leaves. Source: Télédétection et SIG en Agriculture*

**Causal agent – Erysiphe cichoracearum, Sphaerotheca fuliginea.** Powdery mildew is a very common disease of most cucurbit crops worldwide. Several powdery mildew fungi infect various cucurbit crops. If not controlled, the disease can cause early plant senescence, a reduction in yield and even death of the plant. Powdery mildew fungi are all obligate parasites that cannot survive in the absence of a living host plant. They overwinter or survive on cucurbit crop plants in the field, volunteer crop plants or cucurbit weed species. Conidia of the fungus can be blown over long distances by wind. Unlike most other fungal plant pathogens, the conidia of powdery mildew do not require free water to germinate and infect the plant. In fact, free water can inhibit powdery mildew development. Conidia require high relative humidity to germinate and infect plants; however, conidia can germinate and infect at 50 percent relative humidity or lower. Diseased development is optimum at temperatures of 20° to 27°C.

**Disease Symptoms:** The first sign of the pathogen is a white, powdery growth of the fungus that develops on the upper and lower surface of the leaf, and on leaf petioles and stems. Symptoms first develop on older leaves. In severe cases the entire leaf can be covered with the white growth, turn brown and die. Severely infected plants can be stunted, have smaller fruit and reduced yields. Fruit from severely infected plants may have less sugar content, poor flavor and deformed shape.

#### Control

- Plant resistant or less susceptible varieties if available;
- The timely application of effective fungicides is important for controlling this disease.

*Figure 11.5 Symptoms of watermelon mosaicvirus. Source: Ephytia Inra*

## Diseases Caused by Viruses

### Watermelon Mosaic Virus (WMV)

**Causal agent – Watermelon mosaic virus.** Watermelon mosaic virus (WMV) is found in cucurbit producing areas throughout the world. WMV infects cucurbits. Legumes and many other plants and has a host range of over 150 species. The virus survives from season to season in infected crop plants and susceptible weed species. The pathogen is vectored by aphids.

**Disease Symptoms**: WMV causes leaves to develop mosaic patterns of light yellow and light green patches and sometimes ring-shaped spots are produced. When severely infected, leaves can be crinkled. Fruit may be distorted or have variations (breaks) in surface color. Fruit may also develop tumors and spots. Severely infected plants may be stunted.

#### Control

- Control volunteer cucurbit crop plants and weeds pieces in and near the painting that can serve as a source of the virus;
- Sanitation - Remove and destroy infected plant parts and fruits from the field;
- Control aphid vectors that spread the virus with effective insecticides.

*Figure 11.6 New growth on watermelon with CMV. Author: G. Brust*

### Cucumber Mosaic Virus (CMV)

**Causal agent – Cucumber mosaic virus.** CMV is commonly found throughout the world and infects over 800 plant species including cultivated crop plants and many weed species. It is probably the most commonly encountered virus on cucurbit crops. CMV is transmitted by a number of aphid species and commonly survives in many weed species. CMV can also be seed borne.

**Disease Symptoms:** CMV can severely stunt plant growth and causes leaves to be distorted (develop bubble-like ulcers and wrinkles), reduced in size, curled or rolled, and show a mosaic or mottled pattern of light yellow and light green patches. Flowers can be distorted and may have green petals. Fruit can be small, malformed, and have various discolorations. The disease is especially common on protected soil (in high tunnels or green houses).

**Control**

- Always use disease free seed and planting material. If infected seed must be used, seed treatment is highly recommended. Heat treatment has been shown to be effective for neutralizing the virus. Seed material, is initially heated at the temperature of 50°C, for three days and nights and afterwards at the temperature of 78°to 80°C, for 10 seconds;
- Control aphids that spread the virus with effective insecticides;
- In high tunnels and greenhouses (protected soil), maintain the appropriate temperature regime;
- Control volunteer cucurbit crop plants and weeds that can serve as source for the virus in and near the planting;
- Use disease resistant varieties or hybrids when available.

## Diseases Caused by Bacteria

### Bacterial Fruit Blotch

**Causal agent – Acidovorax avenae. ssp. Citrulli.** Bacterial fruit blotch is a very important disease on watermelon. The bacteria can overwinter in watermelon rinds and other plant debris in the field, volunteer watermelon plants and other infected cucurbits, including many weed species. The bacteria are also seed borne and commonly infect transplants. The pathogen may also be transmitted by contaminated workers and equipment. The disease develops rapidly under moist (wet) and warm conditions. The pathogen is splashed dispersed and infection can occur with leaf wetness periods of only 30 minutes at temperature around 26°C. When the disease is severe, up to 80 percent of the fruit can be lost.

*Figure 11.7 Symptom of bacterial fruit blotch in watermelon fruit. Author: E. Lookabaugh*

**Disease Symptoms:** A characteristic symptom of bacterial fruit blotch is a dark olive green stain or blotch on the upper surface of the fruit. The blotch is first noticeable as a small water-soaked area, less than 1 to 2 cm in diameter. Later the blotch rapidly expands to cover much of the fruit surface within seven to 10 days. As the blotches increase in size, the area around the initial infection site becomes necrotic (dead). In advanced stages of disease development, the skin of the rind ruptures and often a transparent or amber-colored substance is exuded. Colonization of the fruit by secondary organisms results in fruit rot and collapse of the entire fruit. The pathogen is seed borne and is commonly transmitted on infected transplants. The first symptoms on seedlings are a water-soaked area on the underside of the cotyledons. As the cotyledons expand the lesions become necrotic. Lesions also develop on young leaves and appear as small, dark brown areas with a chlorotic (yellow) margin or halo.

*Figure 11.8 Symptoms of blossom end rot of watermelon. Source: Minesota Ministry of Agriculture*

**Control**

- Always use healthy (pathogen free) seeds and transplants;
- Practice crop rotation in which cucurbit crops are not planted for at least two years;
- Sanitation - Remove and destroy infected plants and fruits from the field.

## Physiological Disorders

### Blossom End Rot

Watermelons fruits are susceptible to development of blossom end rot (BER). As mentioned earlier in tomatoes and peppers, blossom end rot is related to calcium deficiency, moisture fluctuation, and stress. Prevention recommendations include adequate amounts of calcium, proper soil pH (6 to 6.5), and a uniform and sufficient supply of moisture. The incidence of BER usually varies from season to season and tends to affect oblong varieties (Charleston Gray type). Fruits that have blossom end rot are considered unmarketable.

### Hollow heart and white heart

These two physiological disorders are influenced by genetics, environment, and several other nutritional and non-nutritional factors. To ensure fewer incidences of the disorders, plant only cultivars that have some degree of resistance. In addition, the crop should be grown under optimal nutrient management and moisture conditions. Application of high nitrogen and low calcium during fruit development encourages the development of the disorder. Also fluctuation of watering and drought can increase the problem.

Melons are very important members of the *Cucurbitaceae* family. Generally, melons have the same cultural requirements as watermelons. Refer to the watermelon section for more detailed information. The most important melons grown in the world are muskmelons and/or cantaloupe.

## Planting Methods

### Direct Seeding

Muskmelons may be planted by direct seeding or by transplants after the danger of frost has passed. The optimum temperature range for seed germination is between 21° and 35°C. Direct seeded melons should be sown when the soil temperature is above 18°C. It is important to use fungicide-treated seed, because muskmelons are sensitive to damping off, especially under cool, wet, soil conditions. Sow seed at a depth of 13 to 25 mm. Seeding will require 2.2 to 4.4 kg of seed per ha (16,000 to 20,000 seeds per 454 g), unless a precision-type seeder is being used.

## Transplanting

The use of transplants can reduce seed cost compared to direct-seeding and result in earlier production, especially when used with polyethylene mulch. Seeding for transplant productions should be done two to four weeks prior to date of transplanting.

## Varieties

In the United States, muskmelons are classified into two groups, Eastern shipper sand Western shippers.

1. Eastern shippers - Fruits are round to oval in shape with sutures and netted rind. Flesh of this group is soft which makes them more suitable for local markets.
2. Western shippers - Fruits are also round to slightly oval in shape, with heavily netted but suture-less rind. Fruits in this group have firm flesh, which make them suitable for storage and long distance shipping.

Within each of these two groups there are many commercially available varieties to choose from. It is best to select a few seeds of some of these varieties each year and plant them at your farm before deciding what to grow on a large scale. There are some varieties that are resistant to important diseases while others are very sensitive to sulfur. So be aware that if you use sulfur for disease control you must avoid the use of sulfur sensitive varieties or plant injury can be severe. Your local seed distributor should tell you if the variety of your choice is sensitive to sulfur.

In addition to muskmelons/cantaloupes, there are several specialty melons that may also have a good market in Georgia. The following is a list of some of these groups.

- **Honeydew melons**. Fruits in this group have smooth and green-to-white rind, turning creamy in color when ripe. The flesh is cream, light green, or orange in color. Fruits usually weigh between 1 to 2 kg. Seeds germinate best when the soil temperature is between 30° to 35°C. Fruits mature between 70 to 80 days from bloom.

- **Casaba melons.** Casaba melon has a very thick rind, and the external appearance of the fruit differs from that of the honeydew and the cantaloupe. The skin of a casaba is smooth, but wrinkled, with longitudinal furrows. Rind color is usually yellow to greenish yellow. The fruit is not as sweet as muskmelon but it stores very well. Fruits weigh between 3 to 3.5 kg.
- **Crenshaw melons**. When ripe, Crenshaw melons are roughly ovoid, with a greenish-yellow, slightly ribbed skin. The flesh is a rich pinkish -orange color with a large seed cavity and a very sweet flavor. Fruit are late maturing. Fruits weigh between 3 to 4 kg.
- **Canary melons**. These melons are very sweet with a distinctive flavor. Rind is bright yellow and the flesh is pale green to white with a pale orange seed cavity; Fruit is late maturing requiring between 80 to 90 days after bloom. Plants need plenty of heat to reach maturity. Fruits weigh between 2 to 3 kg.
- **Charente's.** A popular European melon, also known as French or Italian melon. Rind is smooth and slightly netted with a green to grayish color. Flesh is deep orange, firm, and sweet. Fruit is round and relatively small, weighing 0.5 to 1 kg.

## DISEASES OF MELONS

Melons are affected by several important plant diseases in Georgia. The most important diseases caused by fungi include: powdery mildew, Fusarium wilt, anthracnose and downy mildew. Watermelon mosaic virus and cucumber mosaic virus are the most important diseases caused by viruses and bacteria leaf spot is the most important disease caused by bacteria.

*Figure 12.1 Symptoms of powdery mildew in melons. Source: Specialty Cropportunities*

### Diseases Caused by Fungi

#### Powdery Mildew

**Causal agent – Sphaerotheca fuliginea.** Powdery mildew is a very common disease of most cucurbit crops worldwide. Several powdery mildew fungi infect various cucurbit crops. If not controlled, the disease can cause early plant senescence, a reduction in yield and even death of the plant. Powdery mildew fungi are all obligate parasites that cannot survive in the absence of a living host plant. They overwinter or survive on cucurbit crop plants in the field, volunteer crop plants or cucurbit weed species. Conidia of the fungus can be blown over long distances by wind. Unlike most other fungal plant pathogens, the conidia of powdery mildew do not require free water to germinate and infect the plant. In fact, free water can inhibit powdery mildew development. Conidia require high relative humidity to germinate and infect plants; however, conidia can germinate and infect at 50 percent relative humidity or lower. Disease development is optimum at temperatures of 20° to 27°C.

**Disease Symptoms:** The first sign of the pathogen is a white, powdery growth of the fungus that develops on the upper and lower surface of the leaf, and on leaf petioles and stems. Symptoms first develop on older leaves. In severe cases the entire leaf can be covered with the white growth, turn brown, and die. Severely infected plants can be stunted, have smaller fruit and reduced yields. Fruit from severely infected plants may have less sugar content, poor flavor and deformed shape.

### Control

- Plant resistant or less susceptible varieties if available;
- The timely application of effective fungicides is important for controlling this disease.

### Fusarium Wilt

**Causal agent – Fusarium oxysporum.** The disease cycle of Fusarium wilt of melon is almost identical to Fusarium wilt on watermelon. Spread of the pathogen occurs mainly from movement of infested soil and plant debris. The fungus can also be seed borne. The fungus can survive in soil as spores (chlamydospores) for relatively long periods The fungus can colonize crop residues and roots of most crops that would be grown in rotation with melon; therefore, crop rotation is not highly effective for controlling the disease. Disease severity is maximum at soil temperatures of 18° to 25°C and declines rapidly at temperatures above 30°C. At high soil temperatures, plants may become infected but may not wilt. Instead, yellowing and severe stunting may occur. High nitrogen, particularly in the form of NH4, and light, sandy, slightly acidic soils (pH 5.0 to 5.5) favor disease development.

*Figure 12.2 Symptoms of fusarium wilt. Source: Specialty Cropportunities*

**Disease Symptoms:** Symptoms of Fusarium wilt of melon are very similar to those of Fusarium wilt of watermelon. The most common symptom is a general yellowing of the leaves and a sporadic (scattered) occurrence of diseased plants in the field. Plants may be affected at any stage of development. Infected seedling may develop root rot, dampen off and die. In older plants, the older leaves turn yellow, and one or more stems (runners) wilt. In certain cases, sudden wilting of the plant may occur without any yellowing of leaves. Wilting may occur on only one side of the plant, and a lesion may develop on the base of the stem near the crown extending 20 to 50 cm up the stem. Once tissues are dead, the fungus may grow on the surface of infected plant parts producing a white mat of fungal growth (mycelium) on the surface. Infected plants dry up and die.

### Control

- Select and use resistant or less susceptible varieties if they are available;
- Adjusting soil pH with lime to 6.5 to 7.0 and reducing the level of nitrogen in the soil can aid in disease control;
- Sanitation- Remove and destroy infected plants and plant debris from the planting.

### Anthracnose

**Causal agent – Colletotrichum orbiculare.** Anthracnose occurs worldwide on many cucurbit crops and several cucurbit weeds. The fungus overwinters on infected crop residues, volunteer cucurbit plants and cucurbit weed species. Conidia from these sources move to uninfected plants by splashing water from rain of overhead irrigation, contaminated tools and workers, and possibly insects. To germinate and infect the plant, conidia require 24 hours of 100 percent relative humidity and optimum temperatures of 22° to 27°C. Spores can take up to 72 hours to infect and first symptoms appear at four days after infection. The pathogen can also be seed borne and result in early infections on germinating seedlings or transplants placed into production fields.

*Figure 12.3 Symptoms of anthracnse in melons. Author: Thomas. A. Zitter*

**Disease Symptoms:** First symptoms appear as irregularly shaped water-soaked leaf lesions that soon turn chlorotic (yellow). Lesions can expand to become greater than 1 cm in diameter and appear dark brown to black. Lesion can cover most of the leaf making it become distorted. Tissues in lesions dry crack and fall out. Lesions can also occur on petioles and stems and appear as elongated, oval to diamond shaped, water-soaked lesions that turn tan to brown in color. Stem lesions can be covered with tiny black fungal fruiting structures (acervuli) and pink spore masses that are exuded from these structures. Fruit symptoms are circular water-soaked areas that later become dark brown to black sunken lesions and usually develop as the fruit approaches maturity. Acervuli and pink spore masses will also develop on fruit lesions during wet periods with high relative humidity.

**Control**

- Use resistant varieties if they are available;
- Use clean seed that does not have significant levels of the pathogen;
- Practice crop rotation in which cucurbit crops are not planted for at least two years;
- Avoid the use of overhead irrigation, especially if the disease is present in the planting;
- The timely use of effective fungicides can aid greatly in control of this disease.

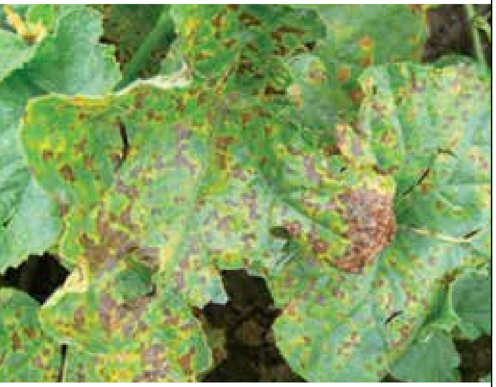


*Figure 12.4 Symptoms of downy mildew in melons. Source: Ontario Ministry of Agriculture, Food and Rural Affairs*

## Downy Mildew

**Causal agent – Pseudoperonospora cubensis.** *Pseudoperonospora cubensis* is an oomycete and an obligate parasite. It cannot survive in the absence of a living host such as susceptible cucurbit crops and weed species. Infected plants are the main source of inoculum for starting the disease. The spores that cause infection can be spread over great distances by wind. Spores (sporangia) are produced on infected tissue if humidity is at 100 percent for six hours and the temperature is between 15° to 20°C. These spores are blown in wind or splashed onto susceptible tissue where they germinate and infect if free water is present for at least two hours at 20° to 25°C. Symptoms may appear in three to 12 days.

**Disease Symptoms:** First symptoms are small, pale green angular or rectangular spots that develop on the upper leaf surface. These spots on the upper leaf surface later turn chlorotic to bright yellow. As the spots age, they become brown and necrotic (dead). Severe leaf infection can result in shriveling and death of large areas of the leaf. Under conditions of high humidity, the surface of the spots on the underside of the leaf can become covered with a growth of light gray to dark purple fungus mycelium and spores. Downy mildew can cause stunting or death of young plants if infection occurs early and is severe. Fruit maturation and production can be prevented and fruit flavor and sugar content can also be affected if infection is severe

**Control**

- Avoid using overhead irrigation, especially if the disease is present in the planting;
- Avoid planting new plantings close to plantings that are infected with downy mildew;
- The timely use of effective fungicides is important for controlling this disease.

## Diseases Caused by Viruses

### Cucumber Mosaic Virus (CMV)

**Causal agent – Cucumber mosaic virus.** CMV is commonly found throughout the world and infects over 800 plant species including cultivated crop plants and many weed species. It is probably the most commonly encountered virus on cucurbit crops. CMV is transmitted by a number of aphid species and commonly survives in many weed species. CMV can also be seed borne and is easily transmitted mechanically from plant to plant on workers hands or equipment.

**Disease Symptoms:** CMV can severely stunt plant growth and causes leaves to be distorted (develop bubble-like ulcers and wrinkles), reduced in size, curled or rolled, and show a mosaic or mottled pattern of light yellow and light green patches. Flowers can be distorted and may have green petals. Fruit can be small, malformed and have various discolorations. The disease is especially common on protected soil (in high tunnels or green houses).

*Figure 12.5 Symptoms of cucumber mosaic virus. Author: Thomas A. Zitter*

#### Control

- Always use disease free seed and planting material. If infected seed must be used, Seed treatment is highly recommended. Heat treatment has been shown to be effective for neutralizing the virus. Seed material, is initially heated at the temperature of 50°C, for three days and nights and afterwards at the temperature of 78-80°C for 10 minutes
- Control aphids that spread the virus with effective insecticides;
- In high tunnels and greenhouses (protected soil), maintain the appropriate temperature regime;
- Control volunteer cur bit crop plants and weed that can serve as source for the virus in and near the planting;
- Use disease resistant varieties or hybrids when available.

### Watermelon Mosaic Virus (WMV)

**Causal agent – Watermelon mosaic virus.** Watermelon mosaic virus (WMV) is found in cucurbit producing areas throughout the world. WMV infects cucurbits, legumes and many other plants, and has a host range of over 150 species. The virus survives from season to season in infected crop plants and susceptible weed species. The pathogen is vectored by aphids.

**Disease Symptoms:** WMV causes leaves to develop mosaic patterns of light yellow and light green patches and sometimes ring-shaped spots are produced. When severely infected, leaves can be crinkled. Fruit may be distorted or have variations (breaks) in surface color. Fruit may also develop tumors and spots. Severely infected plants may be stunted.

*Figure 12.6 Symptoms of watermelon mosaci virus. Source: California Agriculture*

#### Control

- Control volunteer cucurbit species in and near the painting that can serve as a source of the virus;
- Sanitation - Remove and destroy infected plant parts and fruits in the field and in storage. Special care should be given to removing infected fruit during sorting and packing;
- Control aphid vectors that spread the virus with effective insecticides.

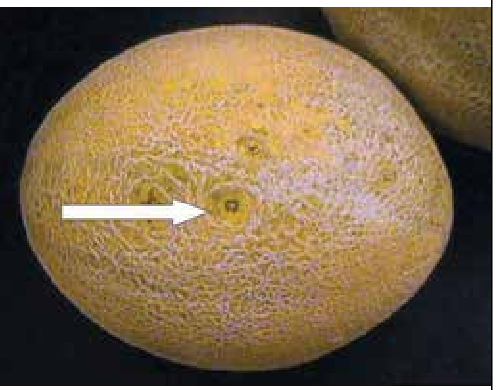


*Figure 12.7 Symptoms of bacterial fruit blotch.Author: David B. Langston*

## Diseases caused by Bacteria

### Bacterial Fruit Blotch

**Causal agent – Acidovora xavenae. ssp. Citrulli.** Bacterial fruit blotch is a very important disease on melon and watermelon. The bacteria can overwinter in melon and watermelon rinds and other plant debris in the field, volunteer melon and watermelon plants and other infected cucurbits, including many weed species. The bacteria are also seed borne and commonly infect transplants. The pathogen may also be transmitted by contaminated workers and equipment. The disease develops rapidly under moist (wet) and warm conditions. The pathogen is splashed dispersed and infection can occur with leaf wetness periods of only 30 minutes at temperature around 26°C. When the disease is severe, up to 80 percent of the fruit can be lost.

**Disease Symptoms:** A characteristic symptom of bacterial fruit blotch is a dark or live green stain or blotch on the upper surface of the fruit. The blotch is first noticeable as a small water-soaked area, less than 1 to 2 cm in diameter. Later the blotches rapidly expand to cover much of the fruit surface within seven to 10 days. As the blotches increase in size, the area around the initial infection site becomes necrotic (dead). In advanced stages of disease development, the skin of the rind ruptures and often a transparent or amber-colored substance is exuded. Colonization of the fruit by secondary organisms results in fruit rot and collapse of the entire fruit. The pathogen is seed bore and is commonly transmitted on infected transplants. The first symptoms on seedlings are a water-soaked area on the underside of the cotyledons. As the cotyledons expand the lesions become necrotic. Lesions also develop on young leaves and appear as small, dark brown areas with a chlorotic (yellow) margin or halo.

#### Control

- Always use healthy (pathogen free) seeds and transplants;
- Practice crop rotation in which cucurbit crops are not planted for at least three years;
- Control volunteer melon and watermelon plants in fields that are being rotated away from melon and watermelon and volunteer plants near established plantings;
- Sanitation - Remove and destroy infected plants and fruits from the field;
- Foliar applications of copper fungicides as protectant sprays may be beneficial. Copper sprays must be initiated before the disease becomes well established in the planting.

*Figure 12.8 Symptoms of angular leaf spot. Source: Ministry of Agriculture Barbados*

### Angular Leaf Spot

**Causal Agent – Pseudomonas syringae. pv. Lachrymans.** Angular leaf spot is the most widespread bacterial disease of cucurbits. The bacteria overwinter in infested crop residues (debris) and can survive for up to two-and-a-half years in dry leaves. The pathogen is also seed borne and can overwinter in infected seeds. As infected seeds germinate, the young emerging seedlings are infected. The disease first appears on leaves, later infecting fruit and contaminating seed. The bacteria is carried from leaf to leaf and plant to plant by splashing water from rain or irrigation, by insects, on the hands and arms of pickers, and on farm machinery. The bacteria enter the plant through natural openings and wounds caused by abrasion. Windblown sandy soil containing infested debris is very effective in spreading the disease. Within the canopy, bacteria are washed by water from infected leaves onto flowers and fruit where additional infections occur. The disease can affect the plant at any stage of development, but is especially damaging during early stages of stages of plant development.

**Disease Symptoms:** The disease first appears as small, water–soaked spots on leaves. The spots usually expand until they are delimited by larger veins in the leaf, which gives them an angular appearance. Under conditions of high relative humidity, a drop of clear to milky exudates develops on the lower surface of the leaf spots. The exudates dry to form a thin white crust on or next to the leaf spot. On leaves the spots become dry, turn tan brown, and may drop out. On highly susceptible cultivars, leaf spots may have a yellow halo or margin. Spots can also develop on petioles, stems and fruits. The white, crusty exudates can be observed on these spots. On fruit, spots are small, circular and water-soaked, 1to 3 mm in diameter and often have a light tan center. Fruit rot can penetrate deeply into the fruit causing an internal rot. Rotted tissues are often colonized by bacteria causing a secondary soft rot. Fruits infected when they are young can become deformed and curved.

**Control**

- Always use healthy (pathogen free) seeds and transplants;
- Practice crop rotation in which cucurbit crops are not planted for at least two years;
- Sanitation - Remove and destroy infected plants and fruits from the field;
- Where possible, use furrow irrigation and avoid overhead irrigation especially if the disease is established in the field. Avoid using surface drainage water from near cucurbit fields for irrigation;
- Avoid entering fields for cultivation or harvesting if foliage is wet from rain, dew or irrigation water;
- Select and use resistant varieties when available;
- Foliar applications of copper fungicides as protectant sprays may be beneficial. Copper sprays must be initiated before the disease becomes well established in the planting.

# INSECTS

The large majority of insects belong to the phylum Arthropoda, which includes the classes of Insecta (the insects) and Arachnida (the mites and the spiders). The list of pests also includes a number of representatives of other phyla such as: the round worms (nematodes), mollusks (snails & slugs), and mammals (mouse-like rodents). The number of species of insects on the earth is over a million. These include numerous harmful, beneficial and indifferent insects. In this respect, Acarina (a subclass of the Arachnida) is significant, with more than 500,000 species. Among the nematodes, intervention is required by special measures for root gall nematode, potato stem nematode, beet nematode, and southern gall nematode.

A large majority of the above-listed harmful organisms are capable of bringing on catastrophic damage and, without implementation of special preventative measures; even the possibility of growing specific nutrient plants may be questioned. However, it should also be noted, that among insects and mites there also exist many beneficial species, which also partly regulate the numbers of harmful insects and mites and often play a significant role in maintaining the balance of biocenosis.

The insect body consists of three segments: head, thorax and abdomen. The head contains one pair of complex faceted eyes and simple eyes, one pair of antennae, and assorted mouth organs for feeding in various ways on a variety of hosts. They are modified for gnawing, puncturing-sucking, sucking, drilling, cutting-sucking, licking, scraping, etc. The thorax is the point of attachment for the wings and legs, thus key in dispersal of these creatures. The thorax has one pair of legs for each of the three thorax segments. The abdomen consists of 11 segments, though in a few of the insects, these segments may be fused or reduced in size. The abdomen also contains most of the digestive, respiratory, excretory and reproductive structures. Considerable variation and many adoptions in the body of insects occur, especially wings, legs, antennae and mouthparts.

The outside of the insect body is covered with a dead layer called the cuticle. It neither stretches nor grows and performs as a protective outer coat or skeleton, in addition to many other functions. Insects replace their cuticle several times during their larval phase and once in their pupal phase. In their body insects accommodate the following organ systems: blood circulation (the so-called spinal pipe), food digestive (front, middle and back intestines), breathing (tracheas and tracheoles), excretion (malpighian tubules, fat tissue), and neural (neural ring and stomach neural chain), and reproductive organs (testicles and ovaries).

Insects reproduce through gender (gamogenetic), genderless (parthenogenesis without male participation) and sometimes hetero genetic (gender and genderless reproduction in turns) reproduction. Their development includes two periods: embryonic and post-embryonic. Embryonic development progresses in ovum and ends in formation of a larva, which exits the ovum's covers and begins to feed. With this begins the post-embryonic period, which progresses through the various stages of metamorphosis. Complete metamorphoses are most common. During incomplete metamorphosis, newly hatched larvae resemble their adult form, gradually increasing in size until they reach the adult form. Such transformation is characteristic of Orthoptera, Homoptera, Hemiptera, etc. This is drastically different from complete metamorphosis which undergoes four phases of development: egg, larva, pupa, and mature insect (imago). In insects with complete metamorphosis (Lepidoptera, Coleoptera, Diptera, etc.), a newly hatched larva does not resemble the adult form and undergoes an additional fourth pupal phase during its development cycle. One full development cycle, starting with the egg phase to the imago capable of producing offspring, is a generation. During a year, they produce various generations depending on the type, nourishment, hygrothermal conditions of the environment, and other ecological factors.

Insects and mites are cold-blooded (poikilothermic) organisms, since their body temperature depends on the temperature of the environment. For the majority of insects, their lower thermal threshold of development is 10°C and the upper is 38° to 40°C, although exceptions do exist. Temperature recorded in natural conditions above 10°C is called effective temperature. Total of effective temperatures is extremely significant for reproduction and development of specific harmful types in given regions, as well as forecasting harm to be expected from it.

The science which studies mites is called acarology. There are more than half a million known species of mites, although only about 50,000 have currently been studied. They are small animals. For example, tetrapodilian are not visible to the unarmed eye. Mites have no primary segmentation, although their body is segmented, divided into divisions, i.e. tagmas and, in tetranychid mites, is represented by the gnathosoma (comprising the mouth and feeding parts) and the idiosoma. Idiosoma includes propodosoma, metapodosoma and opisthosoma. Bristles of various shapes and purposes, located on their outside shell, form the body. Mites undergo the following phases during their development cycle: egg, larva, protonymph, deutonymph, tritonymph and mature phase. Also, four-legged mites omit the larval phase, while eight-legged mites do not undergo the tritonymph phase. Larvae of the latter have three pairs of legs. In order to diminish the damage caused by insects and mites, as well as other pests (nematodes, mollusks, mouse-like rodents), there exist various control measures: agro-technical, physical, mechanical, genetic, biological, chemical, quarantine, biotechnical and integrated methods.

Agro-technical measures imply all those activities, which need to be undertaken for development of specific agricultural crops or other plants: soil cultivation, cleaning land plots from weeds and disposing of plant remains, observing the deadlines and rules of sowing and planting, irrigation, etc.

Biological control is a way of reducing the numbers of harmful organisms, by utilizing natural enemies, other living organisms, to assist in their control. The most common bio-control agents are predators, parasites, and pathogens. Predators attack the prey and suddenly destroy them. Parasites, meanwhile, live inside or externally on the host's body and feed on its tissues. The host remains alive for a while but gradually loses vitality and finally dies.

This chapter describes the main insect/mite pests which commonly attack vegetable crops in Georgia, as well as their composition, relationship with environmental factors and integrated methods for their management/control. Attached to the chapter are tables which contain the main pesticides used against pests in Georgia, along with their dosages, in addition, each pest is illustrated to aid in recognition.

### Mole Cricket

(Gryllotalpidae)

**Description:** The body length of an adult mole cricket ranges from 35 to 50 mm. The front foot of the insect is covered with four finger-like teeth, while back feet have four or five claws, with almost equal distance between them. Foundation of the back part of the female cricket is almost parallel, vertical dark brown veins are found on the upper wings.

*Figure 13.1 Picture of mole cricket. Source: Wikipedia*

Mole crickets are light brown insects whose front legs are large and resemble small shovels. Mole crickets tunnel under the soil and feed on plant roots. They also disrupt and dislodge plants by their digging. Like cutworms, mole crickets are active only at night and hide in their tunnels during the day. The tunnels are approximately 1 cm. in diameter and the soil surface appears loosened and raised as if a miniature mole (a mammal) had tunneled. Mole crickets winter in the soil, mainly as older larvae and adults, at different depths. This pest thrives in rich soils, especially those being fertilized with organic fertilizers.

Overwintered individuals begin laying eggs after completing growth and becoming sexually mature, which lasts until August. Overwintering adults, meanwhile, begin laying eggs after additional nutrition and sexual maturation. This process lasts from April until June. The pest prefers humus-rich soils for egg laying. Its egg production reaches 200-300 eggs per female. Mole crickets place their eggs in the nest it makes in advance. Duration of embryonic development lasts up to three weeks.

Newly hatched larvae live together for 3 to 4 weeks and then disperse. Mole crickets like humidity, drought in the soil forces them to move to moister areas and if they fail to find a moist environment nearby, they die. They can swim well, which contributes to their ability to disperse rapidly.

In Georgia, this pest completes its developmental life cycle in one year.

**Negative economic significance:** Mole crickets damage tomato, potato and other vegetable crops, on sandy and especially clay soils. It gnaws roots and stems, quite often destroying 25 percent of the seedlings. Traces of this pest are easily noticeable on the soil surface.

**Control measures**

- Make traps and place them on the infested area in the spring, or seven to 10 days before transplanting seedlings or sowing seed-material. This same measure is also effective on clay soils. One of the methods of making a trap is as follows: start with 20 grams of chlorpyrifos (Dursban) insecticide, add one liter of water than mix in five kg of wheat bran and add 200 grams of oil. After mixing this product scattered over an area of approximately 100 square meters.

*Figure 13.2 Picture of click beetles. Source: Corn Insect and Disease Guide*

## Wireworms (larvae)

Click Beetles (adults)

**Description:** Most wireworm larvae are hard, chestnut brown, smooth, varying from 10 to 30 mm in length when fully grown. Some species are soft, and white or yellowish in color. Even in small numbers (one to two specimens per $1m^2$) they can significantly damage tomato crops. Chances of them spreading are increased in cases where the tomatoes are grown near uncultivated land. Click beetles have a three to four year development cycle.

**Negative economic significance:** Wireworm larvae damage root systems of potato, beet, carrot, tomato and other vegetable crops. They penetrate the stalk, gnaw on it and move through it in various directions. Damaged plants break. Larvae are capable of moving on to other undamaged plants. In the holes which appear as a result of insect activity, micro-organisms develop, causing rot.

Crops attacked by wireworms have reduced plant populations, since they feed on the seeds prior to germination or just after germination. The plant stand may continue to deteriorate, because wireworms bore into underground portions of the stem, causing plants to wither and die. They continue to feed upon the small roots of many plants throughout the season.

**Control measures**

- Timely cultivation of soil for weed destruction purposes is recommended; plant nutrition with chemicals containing nitrogen also helps in insect management;
- Timely and high-quality appropriate chemical treatments are recommended to manage this pest, such as thiamethoxam, carbosulfan, ethoprophos and imidacloprid.

## Nematodes

(Round worms)

Nematodes are among the most dangerous pests of vegetable crops. Two of the most notable are the root-knot nematode (Meloidogy nemarioni) and potato rot nematode (Ditylenchus destructor).

**Description:** Nematodes are small (1-5 mm) circular worms, which penetrate plant root hairs and then root branches.

**Negative economic significance:** Nematodes damage beet, potato and several other vegetable crops. Bulging spots of various shapes appear in areas of damage. As a result of damage, plant nutrition regime is disrupted, which is followed by its death. Damage is significantly increased by hot, sunny weather.

**Prevention:** In order to mitigate the spreading of nematodes, it is first of all necessary to observe the measures envisaged by quarantine legislation: it is inadmissible to use seedlings from contaminated zones, where nematodes have been discovered. Water flowing near affected land cannot be used. It is necessary to place disinfecting mats in greenhouse entrances, as well as to disinfect equipment. Measures against spreading of nematodes include soil mulching with straw or sawdust, because that weakens the effect of heat and draught and strengthens the plant, which, in its turn, predetermines increase of the plant's resistance to pests. When nematodes are encountered in clay soils, it is necessary to sterilize or fumigate the soil. Effective chemicals with good results include nematicides such asethoprophos, oxamyland metam-sodium.

## Root Knot Nematode

(Meloidogyne marioni)

**Description:** The length of the mature male ranges from 1.2 to1.9 mm, and the width ranges from 0.3 to 0.36 mm. The body of the nematode is somewhat tapered from the front to the broader tail end. Females are white in color; the length of mature nematodes is up to 1mm, the width is up to 0.5 mm. Their body is rounded at the end and has two gender tubes, each of them with strongly developed ovaries.

*Figure 13.3 Root-knot nematode. Source: Edible San Marcos*

**Negative economic significance:** Among vegetable crops, this pest significantly damages watermelon, cantaloupe, cucumber, beet, carrot, potato and eggplant. Apart from this, it damages over 1,500 species of plants. Its larvae penetrate the tips of growing roots of nutritious plants, get to their center, and begin feeding. As a result, the root's parenchyma begins to grow through rapid and multiple cell divisions and surrounds the larva causing galls, which cause the plants to decline.

**Control measures**

- healthy seed and planting materials.
- timely and high-quality appropriate sprays.

*Figure 13.4 Symptoms of potato rot nematode infected potatoe. Source:The Global Potato Industry*

### Potato Rot Nematode

(Ditylenchus destructor)

**Description:** The body length of mature male nematode ranges from 0.72 to 1.35 mm, while the width ranges from 0.02to 0.025 mm. The mature female has asimilar length. However, she can be a little wider. The body of the nematodes is covered with hard and transparent cuticle. Bodies of both females and males are thread-shaped. Their bodies are narrowed at the ends, the head part is obtuse. This pest survives low temperature without damage. The lower thermal margin of its embryonic development is 5°C, while that of post-embryonic development is 3°C. This pest is also able to tolerate high temperatures (50°C. over a period of four hours). During its development cycle, potato root nematode undergoes egg, larva and mature stages. The developmental cycle lasts for 20 to 25 days; during that time larvae undergo five stages. In winter it can be encountered in all stages.

**Economic significance:** This pest damages potato both in the field and in storage. Damaged tuber skins turn grey and leathery in damaged areas. These areas are sunken, while the skin cracks, which distinguishes it radically from healthy areas.

It should be noted that in the field it damages the potato stems and foliage, along with the tubers. Important note: Potato root nematode damages the early and medium varieties of potato most intensely.

**Control measures**

- Select healthy planting material;
- Crop rotation - It is not recommended to produce potato for four to five years on the same land, where this pest is present;
- Weed control is important;
- Utilize timely and high-quality chemical treatments.

*Figure 13.5 Picture of Colorado potato beetle. Source: Wikipedia*

### Colorado Potato Beetle

(Leptinotarsa decemlineata)

**Description:** The larva of the Colorado potato beetle is about 15 to 16 mm in length. Its head, front side of back and legs are black. Young larvae are reddish or orange in color; mature larvae are orange with shades of yellow. Middle segments of the larva abdomen are extremely wide and bulging and are lined on the sides with two longitudinal rows of black dots. The beetle body ranges up to 15 mm in length.

Adult antennae have 12 segments, from below they are yellow and on top they are black. It has eleven spots of various shapes and sizes on its front side of back and a triangular spot on its forehead. Wings are yellow in color, on which longitudinal black stripes can be clearly seen. The pest overwinters in the soil as an adult. The depth depends on agro-environmental features of the location. Beetle overwintering takes place when temperature in the layer, where the pest is, reaches 14°C+. During this period, beetles require additional nutrition, for which they feed on leaves of both potato and other plants in the family

Solanaceae (tomato, eggplant, pepper, etc). After additional nutrition, beetles begin to lay eggs on the bottom side of foliage of the plants representing the solanaceae family. Eggs are laid in clusters, each containing several dozen. Egg-laying process progresses most intensely when temperature exceeds 17°C+. After growth is complete the larvae descend and pupate in the soil. In the conditions of Georgia there two to three generations of Colorado potato beetle per year.

**Negative economic significance:** Mature larvae of the Colorado potato beetle cause significant damage by feeding on leaves and stems of tomato, potato, pepper, eggplant and other crops representing the family solanaceae. As few as 25 larvae can destroy up to 50 percent of the plant's foliage, which rapidly diminishes productivity of the plant.

**Control measures**

- Conduct fall plowing in the spring;
- In order for overwintered beetles not to spread on large territory, arranging a trap plot can be effective, the area of which is determined according to necessity and may constitute 200-5000 $m^2$. On such plots they plant early potato, which attracts overwintered beetles and it then becomes easier to eradicate them by chemical or other means;
- During chemical spraying against the Colorado beetle, it is recommended to use insecticides such ascypermethrin, thiamethoxam, pirimiphos-methyl, acetamiprid, dimethoate, deltamethrin and chlorpyrifos.

## Aphids

The Melon aphid (Myzuspersicae), beet aphid (Aphis fabae) and cabbage aphid (Brevicoryne brassicae) are the aphids which inflict the most damage on vegetable crops in Georgia. Aphids are small, pear-shaped pests which live in colonies. Aphids multiply by laying eggs or, in hot climate areas, they often reproduce without coupling. Aphids can move from plant to plant or leaf to leaf both in the wingless nymph stage and in the winged or wingless imago stages. After settling on a plant, aphids feed on leaves. Their existence causes considerable damage to crops. Aphids transmit various diseases; provoke leaf spot, chlorosis, as well as leaf curl, deformation and blossom drop. The number of viruses spread by aphids significantly exceeds the numbers of viruses spread by other pests. These include cucumber mosaic virus, tobacco mosaic virus, alfalfa mosaic virus and others.

**Control measures**

- Destroy plant remains;
- Timing of appropriate chemical treatments is very important;

*Figure 13.6 Picture ofaphis gossypii. Source: Gestión Integrada de Plagas y Enfermedades en Cítricos*

- In case of necessity of undertaking chemical measures against aphids on vegetable crops, the following products have been utilized successfully: cypermethrin, alpha-cypermethrin, thiamethoxam, pirimiphos-methyl, dimethoate, deltamethrin, chlorpyrifos, bifenthrin, thiacloprid, lambda-cyhalothrin, methomyl, and malathion.

### Melon Aphid

(Aphis gossypii)

**Description:** Mature melon aphids can be both winged and wingless. Winged aphids have transparent wings, as well as antennae (moustaches), black heads and thorax. Antennae of wingless females are pale yellow in color with six segments. The first and second are brown, while the one at the tip is black. Cornicles, head, middle and rear part of back are also black. They have black spots on the abdomen. The aphid's body is oval-shaped with the length of 1.2 to 2.1 mm. Larvae are initially pale green and later turn yellowish-green in color.

This pest mostly overwinters on weeds, in the imago stage, although it can also overwinter as a nymph. In spring, when air temperature reaches 12°C, aphids begin to reproduce and feed. They initially feed on weed foliage and then move to agricultural crops.

**Negative economic significance:** In sandy soils, aphids move to cucumber in July-August, while on clay soils this happens earlier in spring. Aphid colonies settle on bottom sides of cucumber leaves, in side vegetative branches and on knots in the blossoms. They suck out juices and cause their deformation. Fungal powder sometimes develops on leaf surface, as a result of aphid activity.

**Control measures**

- Weed control is important;
- Destroy plant remains;
- Timely and high-quality appropriate chemical treatment is usually needed.

*Figure 13.7 Picture of black bean aphid. Source: Wikipedia*

### Black Bean Aphid

(Aphis fabae)

**Description:** Winged black bean aphids are glossy dark green or brownish-black in color. Wingless aphids are black, with a slightly green or brown coloring. Nymphs have dark maroon wing-rudiments, as well as clearly visible small white dots on abdominal segments. Legs are greenish or yellowish grey, with dark ankles and thigh tips. Cornicles (sap-tubes) are longer than the tail. Back ankles of egg-laying females are thickened, as compared to males; they are winged, with narrow, straight-angled bodies.

**Negative economic significance**: This pest causes significant damage to beet crops. It lives on the bottom side of the crop leaf; it sucks on the leaves, damaging their veins and causing them to become deformed and curl up. Aphids especially damage seed beet plantings, their stalks and flowers, causing stunted growth and diminished seed production.

**Control measures**

- Destroy plant remains;
- Utilize timely and high-quality appropriate chemical treatments.

## Cabbage Aphid

(Brevicoryne brassicae)

**Description:** The body length of this wingless parthenogenesis aphid ranges from 1.8 to 2.4 mm. It is covered with whitish-waxy dust. Wider varieties do not have secondary rhyniales, while winged ones have them only on the third and sometimes fourth segment of the antennae (moustaches). Length of the cornice (sap-tube) twice exceeds its width, while its color is dark brown. Aphids are light green, with black heads and have six segmented antennae. The length of the winged viviparous female is 1.5 to2 mm, while her front wings are 1.5 times longer than her body. Antennae are almost as long as the body. Body and chest are dark brown, while the abdomen is yellowish-green and covered with waxy dust. Length of gamogenetic females is up to 0.8 to 1.7 mm. They are not covered with waxy dust. Tarsi of their hind legs are enlarged. Males look similar to winged females and have across dark stripes on the dorsal side of their abdomen. Head and thorax are shiny black. Cabbage aphid's eggs are oval in shape and assume a shiny black color in the process of embryo development.

*Figure 13.8 Cabbage aphids on curly kale. Author: Rasbak*

**Negative economic significance:** The cabbage aphid severely damages representatives of Cruciferous vegetables, especially cabbage. Leaves inhabited by pest colonies are damaged and fail to perform their functions. In such cases, leaves are twisted and misshapen, plant growth is slowed down, and seeds loose productivity.

**Control measures**

- Weed control is quite important;
- Collecting and destroying plant remains delays and reduces aphid attack;
- Timely and high-quality appropriate chemical treatment is warranted.

## Red Cabbage Bug

(Eurydema Ornatum)

**Description:** The nymph in its mature stage (last in star) is up to 4 mm in length. Its head is grayish-brown; the body is black and covered with small warts. However, the adult is 7.8 to

8.5 mm long. It has six black spots on the front side of its thorax. The outer edge of upper wings is red, yellowish-white or white, with black spots in the center. The thorax is red on the bottom, sometimes with one or several spots. It has a sucking mouth parts.

*Figure 13.9 Picture of red cabbage bug. Author: Luis Fernandez Garcia*

**Negative economic significance**: This pest significantly damages cabbage. While feeding, it pierces leaf tissues with its proboscis (trunk) and sucks the juice. Pierced areas of cabbage leaves develop hardened yellow spots. Red cabbage bug feeding activities cause the leaves to die. Cabbage, damaged by this pest, can't form a head and in the seed plots, lose their blossoms.

**Control measures**

- Collect and destroy plant remains;
- Fall plowing is recommended;
- Use timely and high-quality appropriate chemical treatment. In this case, effective results in vegetable crops are brought by use of selective insecticides such ascypermethrin, dimethoate, deltamethrin and fenitrothion.

## Mites

The most severe damage to vegetable crops is caused by the carmine mites (Tetranychus telarius), the dry bulb mite (Aceria tulipae), the bulb mite (Rhizoglyphus echimopus), the red spider mite (Tetranychus urticae) and the tomato russet mites (Vasatesly copersici). It should be noted that as a rule, mites inflict most damage under drought conditions. Mites must be eradicated before bloom begins.

**Control measures**

- Destroy plant remains;
- Disinfect greenhouses;
- When undertaking chemical measures against mites on vegetable crops, effective results are brought by use of selective acaricides such aspyrimiphos-methyl and dimethoate.

*Figure 13.10 Picture of carmine mite. Source: TurbosQuid*

## Carmine Mite

(Tetranychus telarius)

**Description:** In summer, this pest is greenish, yellow or brown, while from autumn to spring it is reddish or dark orange. Male mites are smaller than females. The Carmine Mite has large dark spots on the sides and also prominent bristles on the back.

**Negative economic significance:** The carmine mite damages green parts of the crops and causes physiological changes. Water evaporation process of the plant intensifies at the point of piercing. Consistency of damaged leaves changes, due to loss of moisture and they become thin. Such changes negatively affect not just viability of the plant, but also quantitative and qualitative parameters of the harvested crop. Pest activities are expected to result in radical weakening or death of the plant and poor vegetable quality.

**Control measures**

- Destroy plant remains;
- Disinfecting greenhouses;
- Timely application of insecticide is critical, as is the use of high-quality appropriate chemical treatment.

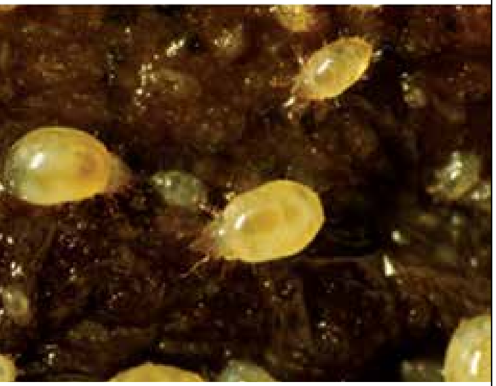


*Figure 13.11 Picture of bulb mite. Source: Macroid*

## Dry Bulb Mite

(Aceriatulipae)

**Description:** *Aceria* is a genus of mites belonging to the family eriophyidae (the gall mites). These tiny animals are parasites of plants. Several species can cause blistering and galls, including erineum galls. A few are economically significant pests, while others are useful as agents of biological pest control of invasive plants. Body length of a mature mite is approximately 0.2 mm. It is colorless and has two pairs of legs, directed towards the front of the body.

**Negative economic significance**: This pest severely damages garlic. Damage is especially noticeable in the case of spreading of the mite in storage. Garlic bulbs, damaged by the dry bulb mite dry during the second half of winter, become unfit for use in spring. In spring, mites find themselves in the field, along with garlic cloves. Along with plant growth, the pest moves on to the brushes, as a result of which they yellow, dry, and die. In onions, the pest is located on the bottom of brushes, while on garlic and leek it is mostly located in leaf folds, along the main vein.

**Control measures**

- Destroy plant residues;
- Disinfect greenhouses;
- Timely and high-quality appropriate chemical treatments are imperative.

### Bulb Mite

(Rhizoglyphus echinopus)

**Description**: *Adult* - Mature bulb mites vary from 0.5 to 1.1 mm long and have four pairs of legs. Their bodies are shiny, white, somewhat transparent, and smooth with reddish brown appendages.

*Egg*- The egg is white and translucent, 0.12 mm long, and ellipsoidal.

Larva - Fully developed larvae are 0.25 mm long. White and oval, larvae have only three pairs of legs and lack genital suckers.

*Protonymph* - The protonymph has four pairs of legs; it is oval and approximately 0.4 mm long. This stage can be distinguished from the tritonymph by having two genital suckers, whereas the tritonymph has three or four suckers.

*Deutonymph* -This quiescent stage is oval, convex on top, flattened below, brown, and 0.2 to 0.3 mm long. The mouth pans are absent. On the back lower side is a conspicuous sucker plate.

*Tritonymph* - The tritonymph is about 0.5 mm in length and has not yet developed a distinct genital aperture.

**Damage:** The bulb mite damages the bottom of onion and garlic bulbs, as a result of which they become easily separated from the bulb. During the intensive reproduction period, the pest invades the bulb, settles and feeds there as a result. The bulb begins to rot; a rotten bulb is more attractive to pests, due to its being hygrophilous.

It is very important to avoid rough handling of bulbs to prevent injury that would allow bulb mites to obtain access.

**Control measures**

- Destroy plant residues;
- Disinfect greenhouses;
- Timely and high-quality appropriate chemical treatment.

*Figure 13.12 Picture of bulb mite. Source: Macroid*

*Figure 13.13 Picture of red spider mite. Source: Pro Gilles San Martin*

### Red Spider Mite

(Tetranychus urticae)

**Description:** The mite's body is oval-shaped and greenish-yellow in color. The overwintering process begins in August and lasts until October. It overwinters in greenhouse corners and plant remains in the soil. In spring, the pest abandons its overwintering place and settles on weeds. In temperatures of 12° to 13°C, pests begin to lay eggs on bottom sides of weed and vegetable crop leaves. After five to seven days, larvae hatch, which are similar to mature mites. Apart from cucumber, red spider mites damage watermelon, cantaloupe, tomato, and many other agricultural crops. This pest is especially dangerous on clay soil. Damage is especially severe in drought periods and hot weather.

**Economic importance:** Mites live and feed on bottom sides of foliage. When feeding, they suck cell juice from the leaves. Initially, light-colored dots develop on damaged leaves. Later on, discolored areas develop on the leaves, as a result they dry. As a result of mites feeding, blossoms, knots and fruit fall off the plants.

**Control measures**

- Clean greenhouses and remove plant remains from surrounding areas;
- Use weed control on open soil and near greenhouses.
- Remove and destroy damaged leaves.
- Timely application of high-quality acaricides is necessary.

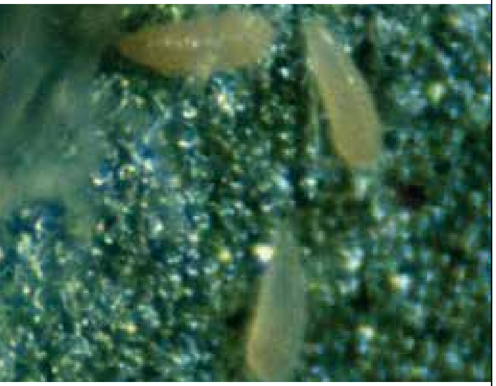


*Figure 13.14 Tomato (and hemp) russet mite. Source: Everwood Farm*

### Tomato Russet Mite

(Vasates lycopersici)

**Description:** This pest is a dark-rust-colored, very small, four-legged mite. It is pale yellow and only turns rust-colored before laying eggs. Its body narrows from the thorax towards the abdomen, which is divided into rings, with lateral grooves. The last two rings of the abdomen carry two threadlike addenda, the length of which equals one third of the body's length.

**Economic significance:** Larvae and mature pests inflict significant damage upon agricultural crops and wild plants representing the Solanaceous plants. Pests gather into colonies on plant leaves and fruit, both on sand and clay soils. Leaves and stalks of damaged plants assume a bronze coloring and then dry. Fruit skin coarsens, cracks, and becomes dark-rusty colored.

**Control measures**

- Disinfect greenhouses;
- Effective results can be achieved through use of acaricides and insecto-acaricidessuch as lambda-cyhalothrin, malathion, deltamethrin and spiromesifen.

*Figure 13.15 Picture of greenhouse whitefly. Source: Weiße Fliege*

### Greenhouse Whitefly

(Trialeurodes vaporariorum)

**Description:** The greenhouse whitefly is a small, white, insect which flies around quickly. This whitefly inhabits the temperate regions of the world. It is a primary insect pest of many vegetables crops, frequently being found in glasshouses and other protected horticultural environments. Adults are 1 to 2 mm in length, with yellowish bodies and wax-coated wings. The wings are held nearly parallel to the leaf surface.

**Economic significance:** The whitefly damages all kinds of plants on clay soil and in some cases also damages vegetable crops on sandy soil. It significantly damages tomato on clay soil, since this pest has several generations during one season. The female whitefly lies from 50 to 250 eggs on the bottom side of young leaves. The egg-laying process lasts for a very long time; thus, during almost all of the plant's vegetation, in the greenhouse there are both mature forms of the pest and its larvae, which significantly complicate control of the pest. Existence of a large number of larvae significantly weakens the plant.

**Control measures**

- Observe sanitary rules in the greenhouse: limit outside access, regularly clean weeds and plant remains, and disinfect entrance mats;
- Among chemical preparations used against pests on vegetable crops, effective results are brought by insecticides such as: pyriproxyfen, cypermethrin, thiamethoxam, pirimiphos-methyl, acetamiprid, imidacloprid and malathion;
- If seedbeds or hotbeds are planted outside, whiteflies can be excluded by covering them with tobacco cloth or screen wire. This can delay the onset of whitefly infestations by several days, often long enough to harvest tomatoes.

### Thrips

Vegetable crops in Georgia are damaged by various types of thrips, the most dangerous pest of which is the onion thrips (Thrips tabaci), which is common all over the world. As a rule, thrips reproduce without coupling. Larvae are less mobile; however, mature pests have wings and move a lot. In fact, adults are so light that they can be blown great distances with only a breeze. The lifespan of the average thrips is approximately 20 days. Thrips feed on young leaves and developing flowers. As a result, leaves fail to develop and their curling and deformation begins. Thrips make nests for their eggs on the fruit, and then the feeding of larvae cause development of wounds on fruit. Fruit loses color and marketable quality. Although it is difficult to notice thrips on plants, they can be seen as a result of shaking young leaves and flowers onto white paper sheets. Certain types of thrips are also capable of spreading viruses (Tospo viruses).

**Control measures**

A. Cultural Control

- Crop rotation;
- Destruction of plant remains;
- Deep ploughing (25-27 cm);

B. Chemical Control

- Among chemical preparations used against thrips on vegetable crops, effective results are brought by insecticides such aspyriproxyfen, cypermethrin, pirimiphos-methyl, thiamethoxam and dimethoate.

*Figure 13.16 Picture of onion thrips. Source: Center for Insect Bioinformatics*

### Onion Thrips

(Thrips tabaci)

**Description:** Onion thrips are cosmopolitan insects that feed on a wide variety of vegetable plants, small grains, field crops, and weeds. They are an important pest of cabbage, cauliflower, and onions. This thrips is a small, yellow insect with a length of 0.8 to 0.9 mm. It has narrow wings and a flattened body. One female can lay 50 to 60 small (length - 0.2-1.25 mm), whitish-colored eggs. Eggs are deposited into tissue of host plants on the bottom side of the leaf. Wingless, initially whitish-colored, and then greenish-yellow larvae hatch from eggs. Nymphs are yellow in color and have rudimentary wings. They overwinter in plant remains in upper soil layers. In conditions of Georgia, this pest can produce from six to seven generations per year.

**Economic importance**: Thrips feed by piercing surface tissues and sucking up the exuded plant juices. On onions with continuing leaf growth, these feeding points elongate to give the typical onion thrips symptoms - whitish spots and streaks on the leaves. Intensive feeding results in a silvery-white stippled appearance, sometimes referred to as white blast or silver top.

#### Control measures

- Crop rotation assists in thrips management;
- Destroying weeds and plant remains reduces pest load;
- Ploughing soil at the depth of 25-27 cm reduces the number of survivors;
- Timely and high-quality appropriate chemical treatments are often necessary;
- Cultural controls are important. If possible, avoid planting cabbage, cauliflower, or onions close to and immediately downwind of small grains or alfalfa.

*Figure 13.17 Picture of crucifer flea beetles. Source: Field Crop News*

### Flea beetles in crucifer crops

**Description:** Flea beetles are small (2-3 mm), jumping insects. Their most dangerous representative is the crucifer flea beetle (Phyllotret acruciferae). This pest's imago is metallic green or blue in color, its upper wings, head, and back are bluish-green, and its legs are black. Its upper wings are sometimes lined with yellow. Larvaehave abrownish color; their heads and the last segments of the abdomen are yellowish. This pest lays eggs in the upper layers of soil, and embryonic development lasts for about a week. Newly hatched larvae feed on roots of cruciferous vegetables for two to three weeks. They then go into pupal stage in the soil in cradles made of earth. Pest overwinters at imago stage, in earth crevices, under plant remains and fallen leaves. The pest comes out of the wintering state at the end of March and the beginning of April. They initially settle on plants representing the cruciferous family and begin additional feeding. Flea beetle activity and damage caused by them increases rapidly in hot, dry weather conditions, when day temperature reaches 20°C and above.

**Economic significance:** On cabbage, this pest gnaws the tissue on both sides of the leaves; as a result leaves seem to develop ulcers. Activities of flea beetles in cruciferous crops are especially damaging to newly planted seedlings. Beetles may damage the growth point, which is followed by the collapse of the seedling.

#### Control measures

- Remove and destroy plant remains;

- Among chemical preparations used against flea beetle son vegetable crops, effective results are brought by insecticides such ascypermethrin, dimethoate, deltamethrin, lambda-cyhalothrin,phosalone, chlorpyrifos and chlorpyrifos-methyl.

**Description:** The imago length measures approximately 1.8 to 2.4 mm. Its legs are black, and its upper wings, back and head are a shiny greenish-blue. The larval head and last segment of the abdomen are a yellowish color. It has dark jaws and three-segmented antennae (mustaches). When mature, its color is whitish. It has yellowish-brown hairs on the body, while its eggs are oval-oblong shaped.

**Economic significance:** Pest beetles damage cabbage, turnip, and other vegetable crops. This pest mostly damages leaves. In case of massive reproduction it completely devours the plant, especially young plants. It is characteristic of the pest that it first of all destroys young parts of the plant. The beetle also damages flowers, stems and stalks.

**Control measures**

- Remove and destroy plant remains;
- Timely and high-quality chemical treatments should be considered where this flea beetle is present in large numbers;
- Recent studies in the management of the crucifer flea beetle on Canola in North America indicate that deltamethrin and bifenthrin were commonly used foliar sprays for control of this pest on canola. They also compared some biopesticides, including a nematode (Steinernema carpocapsae), and two entomopathogenic fungi (Beauveria bassiana and Metarhizium brunneum).These researchers were optimistic about the use of biopesticides, saying that they looked promising.

### Turnip Sawfly

(Athalia colibri)

**Description:** The length of the mature larva of the saw fly is approximately 2.0 cm. Larvae are of cylindrical shape and have many wrinkles around the body. It has a black head, three pairs of thoracic legs and eight pairs of false legs. It has three vertical, parallel dark stripes on the back. It can be either blackish-grey or greenish-grey in color. The length of the pests' cocoon is 8-10 mm. Its inside is silver-colored and consists of pure threads, while the outside is covered with earth particles. The pupa is yellow, with the length of approximately 7 mm. The adult sawfly's back is reddish-yellow. The head, front edge of the upper wings, and antennae are black, and the legs are yellow. Body length ranges from 7 to 8 mm.

*Figure 13.18 Picture of turnip sawfly. Source: NatureSpot*

**Economic significance:** The turnip sawfly damages cabbage, turnip, and other vegetable plants. This pest causes especially grave damage to the cabbage crop in its seedling stage. The adults feed on the flower nectar of umbelliferae and cruciferae crops, and lay eggs on the bottom side of leaves of these crops. At the points where eggs are laid the leaf bulges and becomes deformed and shiny.

**Control measures**

- Weed control is important;
- Fall plowing reduces pest pressure;

- Among chemical preparations used against turnip sawfly on vegetable crops, effective results are brought about by insecticides based on pirimiphos-methyl and deltamethrin.

*Figure 13.19 Picture of diamondback moth. Source: Wikimedia Commons*

### Diamondback Moth

(Plutella maculipennis)

**Description:** Diamondback moth larvae are about 10 to 12 mm long. Its body is light green, spindle-shaped and covered with short, black fur. The head is yellowish dark brown and has many yellowish spots. The wingspread of the imago is 16-17 mm. The front narrow wings are mostly grayish on top, with a vertical yellowish or whitish stripe in the middle. Back wings are shiny and ash-colored. This pest overwinters in its pupal stage in cabbage and other plant remains. In spring (April or May), sexually mature moths exit from pupae and copulate and begin to lay eggs on the bottom sides of plant leaves. Eggs are laid in small clusters along the leaf veins. After three to seven days, larvae hatch from eggs, and a new cycle is begun.

**Economic significance:** Newly hatched larvae penetrate the leaf pulp, gnaw on it and generate winding tunnels. After several days, larvae move from the tunnels to the leaf surface and begin boring roundish and irregular holes in it. This pest causes great damage in drought and hot years. Cabbage crop harvest diminishes significantly as a result of their feeding activities.

**Control measures**

- Remove and destroy plant remains;
- Among chemical preparations used against diamondback moth on vegetable crops, effective results are brought by insecticides such as lambda-cyhalothrin, malathion, esfenvalerate, acetamiprid and malathion.

*Figure 13.20 Picture of cabbage butterfly. Source: Wikimedia Commons*

### Cabbage White (Cabbage Butterfly)

(Pieris brassicae)

**Description:** The mature larva of the cabbage white butterfly is yellowish-greenish, with black dots and yellow stripes on the back and sides and a large white spot on the forehead. The pupa is yellowish-greenish or bluish-greenish, with black bulges and spots with an angular body. The butterfly is large; reaching a wingspan of 60 mm. Female butterflies are larger than males. The male has large thin needle-like antennae and white wings. Female butterflies have two black spots on the bottom section of their front wings with round spots on the top wing. Tips of the front wings are characterized with black, wide, sickle-like spots.

Front wings of male butterflies are monochrome, without a spot on the wing top. They only have two spots on front wing bottom sections and sickle-shaped spots on front wing tips. The cabbage white butterflies overwinter in the pupal stage. It goes into pupal stage everywhere - on plants, fences, in buildings, in plant remain, etc.

In spring, from the month of March, butterflies begin to exit from the pupae. This process lasts until the middle of May. Butterflies newly exited from the pupae are sexually immature and need additional nourishment. They feed on the nectar of cruciferous plants. As a result of additional nourishment, butterflies begin breeding and after three to four days begin laying eggs. This pest lays eggs mostly on the bottom side of cabbage leaves. Eggs are laid in clusters, each of which accommodates up to 100 eggs. One butterfly is capable of laying up to 300 eggs.

In conditions of temperatures of $14^0$ or $15^0$C, the duration of embryonic development is approximately 10 days, while in cooler conditions of $10^0$ to $11^0$C, it is about 19 days. Young larvae move in colonies and then gradually separate.

**Negative economic significance:** The damage inflicted by this pest upon agriculture is extremely grave. Newly hatched larvae feed on the chorion of the egg, while mature ones feed on leaf pulp. As a result of damage, only the main veins of leaves remain. The cabbage plant cannot form a head and loses its economic significance. If the plant is young it dries and dies completely.

**Control measures**

- Remove and destroy plant remains;
- Among chemical preparations used against cabbage white butterfly on vegetable crops, effective results are brought by insecticides such ascypermethrin, deltamethrin, lambda-cyhalothrin, bifenthrin, malathion, imidacloprid and zeta-cypermethrin.

### Cabbage Moth

(Mamestra brassicae)

**Description:** The length of a mature larva of the cabbage moth is approximately 50 mm. Its color varies greatly, starting with green and ending with black colors. Body has two dotted light lines and a dirty yellow stripe on the sides. It has a horseshoe-shaped spot on top of the next to the last segment. With wings spread, this butterfly has a wingspan of 50 mm. Its front wings are dark brown, with a yellowish-white wave-like line on the outer edge. Back wings, slightly dark at the tips, are lighter in color than front wings. Eyes are roundish and covered with short hairs. This pest overwinters as a pupa, in the soil. Butterflies begin to leave the pupae in about the month of May. Some butterflies require additional nourishment, after which they begin laying eggs on the host plants. Such plants include beet, soy, flax, sunflower, tobacco, peanut, etc. This pest lays eggs in clusters, on the bottom sides of the leaves. In case of massive reproduction, one cluster may contain up to 100 eggs.

*Figure 13.21 Picture of cabbage moth. Author: Olaf Lenninger*

A direct proportional relationship can be observed between pupal weight and butterfly fertility. Optimal temperature for embryo development is $17^0$ to 20°C, while air humidity is 70 percent. Larvae change their skin five times in the course their development period, which lasts for approximately a month and a half. After final change of the skin, larvae go into the soil to pupate. They go deeper in winter and into comparatively upper soil layers in summer. In lowlands of our country, this pest produces two generations a year and one in the mountain zone.

**Economic significance**: The cabbage moth severely damages vegetable crops, especially cabbage. Its larvae gnaw on cabbage leaves and make large holes. When the cabbage forms a head, more mature larvae of the pest penetrate the head and gnaw it as well. Rainwater penetrates the plant through holes produced by larvae and bring with them microorganisms which cause rot. As a result, the plant dies.

**Control measures**

- Fall plowing with cultivator;

- Destroying plant remains is important;
- Among chemical preparations used against cabbage moth on vegetable crops, effective results are brought by insecticides such asdeltamethrin, lambda-cyhalothrin, malathion andimidacloprid.

*Figure 13.22 Picture of cabbage maggot. Source: Delia Radicum Maine*

### Cabbage Maggot

(Hylernya brassicae)

**Description:** The female imago of the cabbage maggot is light grey and has a dark brown stripe, divided into narrow spots, on its abdomen. The length of the fly is 6 to 6.5 mm. Males are of the same color, with three dark stripe son the dorsum of their thorax. Its forehead is four times narrower than its eyes. The base of the hind thighs is covered with frequent long hairs.

Larvae are cylindrical, white or yellowish in color, with a length of 7 to 8 mm. They overwinter in the soil in a puparium. In spring, when temperature of upper soil layers reaches12°C, flies leave the puparium. These flies require additional nourishment, for which they take nectar from flowers of Cruciferous plants. After additional nourishment, flies begin to reproduce and lay eggs. They lay eggs in groups, on root necks, bottom of the stalk or directly in the soil, near the plants. During seedling planting, some eggs go with the seedlings. One fly lays up to 100 or more eggs. Duration of embryo development fluctuates between four to 10 days. The larval stage lasts for from three to four weeks.

**Negative economic significance**: Pest activities mostly damage early varieties of cabbage. Larvae damage cabbage roots, as a result of which the plant dies or its development is impeded.

**Control measures**

- Destroy the plant remains left after the cabbage crop is harvested;
- Fall plowing with cultivation is recommended;
- Weed control is important, especially with cruciferous plants;
- Timely and high-quality appropriate chemical treatment is recommended;
- Among chemical preparations used against cabbage maggot on vegetable crops, effective results are brought by the insecticide malathion.

*Figure 13.23 Picture of cabbage stem weevil. Author:David'yan G.E.*

### Cabbage Stem Weevil

(Ceutorhynchus quadridens)

**Description:** The length of the cabbage stem weevil adult is 2.5 to 3.2 mm. Its body is black, with the top covered with hairs and grey scales. The trunk is curved and located between the foundations of the front legs. Larvae are yellowish-white, with brown heads. Pupae are a yellowish color. The pest overwinters in plant remains and under fallen leaves or in the soil. In spring, the beetle completes its overwintering and begins to feed on the bottom side of leaves of any cruciferae plants. After cultivated cruciferous plants appear, the beetles then move to them and feeds, for which they make small holes in leaf stems and stalks. This pest lays eggs in the main leaf vein or the stalk. Eggs are laid in small clusters (two to three units) or single units. One weevil deposits from 20 to 40 eggs. At this time, plant tissue (under which eggs are placed) bulges. Embryonic development lasts five to six days. This pest produces one generation per annum.

**Economic significance:** Larvae hatched from eggs make holes in the stems and stalks, feed on the stalk center and fill it with excrements. Finally, larvae gnaw on the stalk down to the root neck, and that is how they descend into the soil for overwintering, where they make their cradle and pupate.

**Control measures**

- Destroy plant remains after cabbage crop is harvested;
- Fall plowing with cultivation is recommended;
- Weed control, especially of cruciferous plants, is important;
- Among chemical preparations used against the pest on vegetable crops, effective results are brought by insecticides such as deltamethrin.

### Onion Maggot

(Delia antique)

**Description:** The mature larvae of the onion maggot are whitish in color, with a narrow front part and wide rear. Pupae are found in a yellowish or reddish-brown false bag. Pupae have an egg-like shape with a length of approximately 5 to 8 mm. Imago body length is 6 to 8 mm, with a yellow-gray or light gray color, black legs, and a greenish color on the back. It also has antennae (moustaches). Male flies have vertical dark brown stripes on their back and abdomen. Onion maggots spend winters in the soil, at the depth of from3 to 10 meters, or in storages. They begin to fly in early spring. After additional nourishment, flies begin to lay eggs on onion brushes, in earth crevices, and under planted onion scales. Eggs are laid in clusters of up to 10 eggs. One fly can produce up to 100 eggs. Temperature greatly affects the number of eggs that each pest can produce. At high temperatures (35°C and above) they do not lay eggs. The process of egg-laying occurs mostly in warm and dry weather. Time period of its embryonic development is defined at three to eight days. Larval development continues for 12 to 18, and larvae then pupate in the soil. In the territory of Georgia, three generations are characteristic of onion flies. The first generation flies out in the middle of April, the second during the first half of June, while the third comes out in the second half of August.

*Figure 13.24 Picture of onion maggot. Source: Plantvillage*

**Economic significance:** The onion maggot host plants are seed onion, planted onion, garlic, leek, etc. This fly is one of the major onion pests, especially damaging to seed onions. As a result, productivity diminishes significantly. Hatched larvae penetrate onion heads and start scarring them, followed by penetration by microorganisms which cause rot. Plant bulbs rot, while brushes of its above-ground organs wilt, yellow, and die.

**Control measures**

- Destroy plant remains;
- Use weed control;
- Plan to fall plow the harvested field;
- Seed material treatment;
- In case of necessity of chemical treatment against the pest, effective results are brought by insecticides such aschlorpyrifos and lambda-cyhalothrin.

*Figure 13.25 Picture of carrot rust fly. Source: Agroatlas*

### Carrot Rust Fly

(Psila rosae)

**Description:** The carrot rust fly is relatively small in size - about 5 mm. Its abdomen and thorax are shiny black, the head is chestnut-colored and the legs are yellowish, while the wings are transparent. Eggs are milky white and oval-shaped. Larvae are legless, a shiny light-yellow color and taper to points at both ends, 6 to 7 mm long. Pupae are light brown, 4 to 5 mm long and 0.9 to 1.3 mm wide. This pest overwinters in the soil, at the depth of 6 to 25 cm. Soil depth depends on the soil type, cultivation peculiarities, and quality of moisture. Pest starts to fly out in May to June.

**Economic significance:** The carrot rust fly is a severe pest of carrots, killing many seedlings early in the year or making the final crop unsalable due to the level of larval mines, secondary rots and the uneven size of developing roots. Damaged plants have bluish leaves, which turn yellow and dry up later, and the roots rot.

**Control measures**

- Crop rotation - Observe the agro-technology of carrot production;
- Use timely and high-quality appropriate chemical treatment;
- In case of necessity of chemical treatment against the pest, effective results are brought by insecticides such ascypermethrin and deltamethrin;

Timing of sprays can be aided by monitoring with yellow traps. See the following link: http://smallfarms.oregonstate.edu/sfn/su08carrotrust

*Figure 13.26 Picture of carrot psyllid. Author: Joe Botting*

### Carrot Psyllid

(Trioza apicalis)

**Description:** The mature psyllid is yellowish-green and about 2 to 2.5 mm long, with two pairs of wings and hind legs. Nymphs are of greenish-yellowish color, flat-shaped, with bulging backs of a slightly silver coloring. Mature insects overwinter on coniferous trees. In spring, when carrots emerge, they move onto the leaves and begin feeding on the plants.

**Damage symptoms:** Curled leaves and stunted growth become visible on an average of two days after the adults enter the field. The migration flight from conifers to carrot fields continues for several weeks.

Apart from carrot, this pest significantly damages parsley and celery. Parts of the plant, damaged by it, darken and dry. As a result of loss of juice, plant leaves curl, metabolism fails, leaves dry and fall down.

**Control measures**

- Crop rotation - In Finland it was found that cover crops were the only effective method of protecting the yield on organic farms;
- Observe the agro-technology of carrot production;
- In case of necessity of chemical treatment against the pest, effective results are brought by insecticides such ascypermethrin and deltamethrin.

### Beet Weevil

(Bothynoderes punctiventris)

**Description:** Mature beet weevils are1.2 to 1.6 cm long. Their trunk or proboscis is obtuse. Antennae are crooked. Their thoracic shield is wrinkled and covered with dots. Upper wings are lined with vertical rows of regularly placed dots. The body of the beetle is black, but since it is covered with colorless scales, it seems gray at first sight. Larvae are up to 20 mm in length. They are legless, white in color and curved like an arc, with a dark brown head. Larval bodies consist of 12 segments. Ordinarily the beet weevil overwinters mostly in the imago stage; however, a few also overwinter in the larval and pupal stage. Some of the beetles overwinter (diapauses) in spring, when temperature of upper soil layers reaches 9° to 10°C, while others experience a lengthy diapauses and remain in the soil for about a year. After overwintering, beetles require additional nourishment for forming eggs and they feed on both beet plants and various weeds. In Georgia, one or two generations per year are characteristic of this pest.

*Figure 13.27 Picture of beet weevil. Source: Zin Russia*

**Economic significance:** This pest represents a significant threat to the beet crop. Adult beetles damage the leaves, while larvae damage the taproot. Beetle activities are especially destructive when the plants are newly emerged. At this time, the beetle gnaws emerged plants under the cotyledon. As a result, the plant dies.

**Control measures**

- Destroy plant remains;
- Control weeds;
- Deep ploughing of the soil is recommended;
- In case of necessity of chemical treatment against the pest, effective results are brought by insecticides such aschlorpyrifos, chlorpyrifos-methyl and deltamethrin.

### Beet Leaf miner or Spinach Leaf miner

(Pegomyia hyoscyami)

**Description:** The length of a mature larva is 7 to 8 mm. Its body is pale yellow and legless. The front end of the body is pointed, while two hooks can be clearly seen at the around. The hind end is widened and terminates in triangular teeth. Small areas on body segments are covered with tiny scales by means of which the larva moves. Length of a mature insect is 7 to 8 mm. Males are smaller than females. Abdomens of males are smaller, while those of females are wide. Middle of the back and abdomen are dark ashen in color, sometimes reddish. There is a vertical stripe on the top side of the abdomen. The head is almost triangular, antennae have three digits.

*Figure 13.28 Picture of beet leafminer. Source: Wikipedia*

The pest's puparium measures 4.5 to 5 mm in length and oval-shaped. At the first stage of development it is yellow, then dark brown, and then black. Beet leaf miner winters as puparium in upper soil layers and under plant cover. Flies begin to fly out in spring, when air temperature reaches 10° to 11°C. Process of laying eggs begins several days after they fly out. Eggs are laid in clusters, on host plant leaves. Embryo development requires about five days in spring and less in summer. The pest produces about 40 to 50 eggs in spring, while this number increases in summer generations. Newly hatched larvae penetrate the leaf parenchyma and feed on the pulp, as a result of which most of the leaves are covered with tunnels. Duration of larval phase is defined at three weeks. During larval stage, the pest changes its skin four times. When growth is completed, larvae either pupate in the tunnel or go into the soil, to overwinter. In conditions of Georgia, three to four generations are characteristic of this pest.

**Economic significance:** As a result of pest larvae activity, most of the leaf area is covered with tunnels. The tunneled area depends on the number of eggs, laid within each cluster. Damaged leaves fail to fully perform their functions, which negatively affects both quantity and quality of the crop harvested.

**Control measures**

- Crop rotation;
- Cultivate and irrigate soil during the period when the pest is in pupal stage;
- Weed control;
- In case of necessity of chemical treatment against the pest, effective results are brought by methomyl, and chlorpyrifos-methyl is the same.

*Figure 13.29 Picture of beet caspid bug.Source: Agroatlas*

### Beet Caspid Bug

(Poeciloscytus cognatus)

**Description:** The wings of the mature bug are yellow-dark brown in color, with a black pattern and a v-shaped, triangular spot. The thorax is yellowish dark brown. It has two black spots in the back corners of the front back. Wings are glass-like and transparent. Length of the pest's body is 3 to 5 mm. Larvae are green, with red eyes and a black round spot on the top side of the mid-abdomen as well as two black dots on the shield.

Host plants of this pest include: beet, soy, sunflower, cannabis, flax, clover, bean, pea, lentil, etc.

It overwinters in the egg stage, in tissue of the host plant stalk and leaf veins. In spring (end of March – beginning of April), larvae hatch and soon begin to feed on the same plant on which they hatched. Larvae penetrate the plant with its trunk and suck the juice. Larval development continues for three to four weeks, after which it turns into a mature bug, then it begins to reproduce. Sexually mature bugs begin laying eggs in the leaf stem or main vein of the developing beet plant. In order to lay eggs, bugs pierce the plant's surface with their trunk and lay eggs into the tissue. Only the egg can be seen from the leaf, as a small dark dot. The number of eggs laid by the pest depends on the generation, environmental conditions and type of host plant. Depending on these factors, the number of eggs fluctuates between 20 and 2000.

Embryonic development lasts from four days to two weeks, depending on climatic conditions and the generation.

**Economic significance:** Apart from directly damaging beet plants, the capsid can also spread the virus causing mosaic disease. Emerged beet plants, damaged by the pest, have stunted growth and diminished productivity. In most cases, damaged leaves of the plant wilt become deformed, and it dies. Plants are damaged even more if they are infected with mosaic disease as result of pest activities.

**Control measures**

- Weed control in combination with fall plowing aids in managing the capsid;
- Destroy plant remains;

- Correct additions of mineral fertilizers;
- In case of necessity of chemical treatment against the pest, effective results are brought by the insecticide fenitrothion.

### Beet Tortoise (Tortoise beetle)

(Cassida nebulosa)

**Description:** The body of the beet tortoise is flat. Its pronotum and elytraare wide and cover the head from the top. Upper wings are also so wide that they cover the body. The beetle is rusty-brown on top, with irregular black dots. Deep lines are clearly visible on upper wings, in which there are vertically placed large dots. Body is black on the bottom, with a length of 6-7 mm.

*Figure 13.30 Picture of tortoisebeetle. Source: Wikipedia*

Edges of a mature larva's body are jagged, so ends of segments are clearly visible as protrusions. It has two tail protrusions, length of which is one third of the body. Pest overwinters in the adult phase. In spring, overwintered beetles, after additional feeding on saltbush and pigweed, begin to lay eggs on the leaves of these same plants. Eggs are laid on both sides of the leaves, in clusters. The beet tortoise covers its eggs on top with secretion.

**Economic significance:** Pest larvae gnaw on the leaves and pupate right there. The tortoise beetle has double economic significance. On one hand, this is a pest that significantly damages the beet; on the other hand, it is a useful species controlling the development of weeds of the goosefoot family. The beet is damaged by both the beetles and the grubs. The grubs of fourth and fifth in stars are the most voracious, consuming about 87 percent of the total food volume needed for their whole developmental period. The beetles are the most voracious after emergence from pupae and after hibernation before ovipositor. They eat away the round holes in a leaf plate, not damaging veins; whereas the grubs scrape off the leaf pulp on the lower side between veins, leaving the upper rind untouched. The severely damaged leaves have a lacy appearance.

#### Control measures

- Destroy plant remains;
- In case of necessity of chemical treatment against the pest, effective results are brought by use of the insecticide chlorpyrifos-methyl.

### Potato Tuber Moth

(Phthorimaea operculella)

**Description:** The head of the larva is dark brown, with black shields and three hairs at the foundations of false legs. It has six dark shields on the bottom of the second segment of the abdomen. Length of a mature larva is about 10 to 12 mm, with pink or yellowish white coloring. The moth has a wingspan of 12 to 16 mm. The abdomen is pale grey from the bottom and yellowish-grey from the dorsal side. Front wings are silver-ashen, with dark spots on the back edge. Eggs are mother of pearly-white and oval in shape, with the diameter of about 0.8 mm.

*Figure 13.31 Picture of potato tuber moth. Source: Microlepidoptera on Solanaceae*

Pest reproduces both in the field and in storage. It resists low temperatures well and, apart from cultivated plants, can feed on weeds representing the Solanaceae family.

These characteristics significantly contribute to its acclimatization and reproduction in new areas.

**Economic significance:** As it has been noted above, this pest damages potatoes both in the field and in storage. In the field, it lays eggs on the bottom of the leaves of potatoes and other plants representing the Solanaceae family. Hatched larvae begin to feed on the leaves, as a result of which tunnels appear on them. Also, larvae severely damage the plant's stems and stalks.

During potato storage, the moth lays eggs on potato tuber buds. Larvae, hatched from the eggs, penetrate tubers and damage their pulp. Tuber skin, at the points of penetration by larvae, becomes pink or violet. Also, larva excrements accumulate in these areas.

**Control measures**

- Weed control;
- Observe optimal deadlines for crop harvesting;
- In case of necessity of chemical treatment against the pest, effective results are brought by use of insecticides such as cypermethrin, imidacloprid, alpha-cypermethrin, dimethoate, deltamethrin, lambda-cyhalothrin, methomyl, and carbosulfan and zeta cypermethrin.

## INTEGRATED PEST MANAGEMENT OF VEGETABLE CROPS IN GEORGIA

One of the first people to understand the relationship of insects to their natural environment was an entomologist by the name of Stephen Alfred Forbes. In 1880, Forbes documented the feasibility of ecological management approaches to insect control. He advocated an ecological approach and combinations of resurgence of primary pests, selection of strains of pests resistant to insecticides and the general contamination of the environment. Although the term pest management seems new in controlling pests it is based on decades of development. Forbes is said to be the first to work on various features in shaping of what we now term integrated pest management.

Extensive progress was made during the next half century in laying the foundation for applied ecology through investigations of cultural practices, including crop rotations, tillage, the identification of resistant varieties of crops, to the conservation of natural enemies, and the importation of exotic biological control agents.

About the time of the Second World War, a time of multiple advances dominated by the discovery and development of successive generations of chemical insecticides; the arsenicals and the fluorides, the organochlorines, the organophosphates, the carbamates, and the pyrethroids. Each successive group seemed to be more effective than its predecessors and more likely to reduce the intensity and even the expectation that some insect pests might even be eradicated. In the excitement and euphoria surrounding the use of these powerful tools, the natural laws of ecology were all but forgotten, until we were all awakened by Rachel Carson's book, "Silent Spring" in 1962. That book singlehandedly changed insect management forever.

The new idea of "Integrated Pest Management" started to gain momentum in the early 1960's with the publication of Silent Spring, which served as a warning in the overuse of the new miracle insecticides: DDT, other chlorinated hydrocarbon pesticides, broad spectrum insecticides in general were posing a danger to man and the ecology of the planet due to their wide usage throughout the world. This was a turning point causing agriculturists, extension specialist, chemical companies and researchers to rethink the most logical ways to move forward and utilize methods which are 'sustainable' and not to be completely dependent on chemical control.

In 1959 a landmark paper was published by Stern, Smith, van den Bosch, and Hagan that outlined the integrated control concept of combining natural and applied control measures and provided a philosophy for insect control that led directly to the current interpretation of IPM.

There are many definitions of integrated pest management of insects. The following definition covers all of the major facets and is generally accepted by most government and local agencies worldwide. *"Integrated pest management (IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and non-target organisms, and the environment". (Developed by the University of California - IPM)*

Some of the first descriptions of integrated pest management had very long and outlandish terms which made it sound extremely complicated. However, in 1972, R. L. Rabb simplified the definition as "the intelligent selection and use of pest control actions that will ensure favorable economic, ecological, and sociological consequences".

## Insect Management Strategies

Effective insect and mite management involves multiple facets, all with one common goal in mind: sustainability. Vegetable crops are attacked by an overabundance of insects and related pests which the buyers would rather avoid. Perhaps even more important is the damage caused by the insects which lowers vegetable quality. Here are a few of the facets which are considered for Georgian vegetable production. These considerations are general and apply for most pest management programs. They are not exclusive and with time will most likely be modified as they are improved on by research and experience, always seeking to find better ways to manage insect and mite problems. IPM seeks the optimal combination of tactics to reduce vegetable pest populations in order to make it economically feasible devoid of adverse effects on the farm or to the environment and always with the buying public in mind.

## Know your pests

First of all it is important to know the identity of the key pest insects and mites and beneficial organisms you are dealing with. This can be confirmed by your local extension person or by taking a few close-up pictures and send them to persons working with the crop in your area. Misidentifications can be very costly. Keep in mind that not all insects and mites are harmful. In fact, quite a few are beneficial.

Properly identifying pests is the foundation on which a good insect management program is built. If the pest is not properly identified, the chances of selecting the correct control strategies are greatly diminished. Many insects and mites can be correctly identified simply because they are encountered so often. However, it never hurts to back up your knowledge base with some reference materials. Beneficial organisms can be important components of an effective insect management program. Being able to distinguish the good guys from the bad guys may help you avoid unnecessary and possibly disruptive pesticide sprays. Some common predators that all growers should be able to identify include lady beetle larvae and adults, lacewing larvae and adults, and syrphid fly larvae. Access to the internet is very valuable in finding picture of both beneficial and pest species.

## Crop rotation

Is a systematic approach to deciding which crops to plant where in vegetable production from year to year. Crop rotation is where a certain crop can be grown only a year or a short period of years and then discontinued for a given number of years before it is planted again. Here we are concerned with insects and mites as well as nematodes and diseases which cannot generally survive without a certain group of host plants which they depend on for survival and multiplication. By rotating the crop planted it is possible to eliminate the host plant and its relatives and thus get rid of a portion of the pests in that area. Thus, here is another practice without the use of chemicals which works very well to drastically mitigate some insects and related pests.

The goal of crop rotation is to help avoid or reduce problems with soil borne organisms such as nematodes of potato and some soil-dwelling insects in addition it also helps manage soil fertility. We know for example that rotation works in Georgia for: potato rot nematode, onion thrips, and carrot rust fly. Rotating can also reduce the severity of a number of other pest problems. For example, by rotating potato fields you can greatly increase the amount of time it takes Colorado potato beetles to colonize a field, thereby reducing the time the beetles have to increase to damaging levels. Don't plant crops that are susceptible to wireworm damage in fields that were previously in sod or heavily infested with grassy weeds. In addition, it is a good idea not to plant cabbage or onions next to small grain fields, because onion thrips build up to very high levels in small grains and when they are harvested or dry down they normally move into cabbage or onions.

## Tillage

By tilling or cultivating the soil insects are greatly affected directly, by the texture of the soil and its chemical composition, the percentage of soil moisture, the temperature, and other soil organisms and, indirectly by their influence on the host plant. Tilling has a tendency to bring pupae, mature larvae and adult insects to the surface where they are dealt with by the elements and nature, such as birds, predacious insects and other natural enemies. Small rodents eat a lot of the insects that are exposed on the surface. Tillage in the fall and crop destruction reduces insect populations by crushing them or by destroying their over-wintering habitat, exposing them to harsh weather conditions. In this publication we recommend cultivation to aid in the control of insect pests for several crops. Tillage can be used to reduce Colorado potato beetles and to diminish wire worm populations.

## Preventative pest management techniques

Selecting and using preventative pest management techniques can be effective and is usually less expensive than insecticide applications. There are a number of practices that can reduce insect numbers before you actually see the insects in the field. Often, decisions about these practices must be made based on past experience with the insect rather than current knowledge of the severity of the infestation. Many of these practices are good management practices for weeds and diseases as well, so they can easily be incorporated into an overall insect management program. You will notice the number of times that it is recommended in the management of Georgian vegetable pests. It is advisable to utilize the destruction of crop residue and weed removal in order to delay and deter the build-up of noxious insect and mite pests. This is an excellent way to delay and discourage such pests. It is recognized that Insects tend to become active at specific times each year, varying the time of planting can sometimes help prevent serious insect problems.

**Host plant resistance:** Is a very important mechanism and is used a great deal today in certain types of plants where we have resistance to pest damage of major importance. Developing resistant cultivars by traditional breeding methods is generally slow and a rather inexact process. But new advances in biotechnology now make it possible to take specific genes from one organism and insert them into the cells of a completely different species leading to a plant that is resistant. In Georgia several insect resistant cultivars of vegetable plants are available. This is an ideal strategy to avoid pesticide applications. Planning for this aspect of management must start early with the choice of cultivars to be utilized.

Attractants and repellents: Are useful tools in certain situations to prevent an insect from building up to economic injury levels. In such cases over the period of only a year or so the pest population can be reduced to insignificant numbers just by trapping out. In order to get rid of the adults that are captured they need to be removed from the traps and discarded. This is a very smelly activity because they usually die in the traps. Thus, it is recommended to bury such collections.

Likewise repellants at times can be strong deterrents and actually keep a vegetable crop safe from specific insect pests. This is more commonly achieved in home gardens by planting herbs which repel insects or nematodes. A couple of examples are: basil which repels the carrot fly adults; catnip which repels the cabbage looper and the Colorado potato beetle; and chive which repels carrot fly and aphids. Many other combinations have been reported.

Trap Crops: There are a few instances where trap crops have given protection to a crop. A trap crop is a plant that attracts agricultural pests, usually insects, away from nearby crops. A trap crops can be planted around the circumference of the field to be protected, or interspersed among them. The benefits of trap cropping are: better quality of the main produce; attract beneficial organisms; enhance biodiversity; and reduce dependence on insecticides.

Another way to use a trap crop is to use the same plant cultivar as the main crop. The trap crop is planted much earlier than the main crop in order for it to serve as food for the insects. A second method is to use two entirely different species. Research has shown that early planted tomatoes can serve as trap crops for multiple pests to protect a planting of desirable tomatoes. This might be tested in your fields on a small scale to see what kind of results you can obtain.

**Monitoring the current status of insects and mites:** Vegetable growers must make insect and mite pest management decisions on an almost daily basis during the growing season. To make the best decisions, it is often useful to have information regarding the current status of a pest's population. This can be accomplished through some sort of sampling or monitoring program. There are several methods to monitor insect populations.

The most common method for monitoring insects is by scouting fields. Scouting can be formal, such as counting insects on a given number of plants throughout the field, or it can be informal, with the grower walking through the field and looking for insects on the plants. Formal scouting may be more accurate, but the most important thing is for growers to regularly walk their fields looking for insects or insect damage. Some pests, such as mites, may require the use of a hand lens in order to see them. Others may require the use of equipment such as a sweep net or a beating cloth. Most can be monitored just by close inspection of the plants. Weekly monitoring counts of given size with a set number of counts per hectare will allow growers to compare results from one week to another to make informed management decisions.

**Chemical attractants:** Are used in conjunction with simple sticky traps to monitor insect populations in relation to the economic thresholds and also to lure insects to toxic bates. Pheromone traps are often used to determine when moths are flying. This information can be used in several ways. First, catching moths in a sticky trap can alert growers to begin looking for the pest in the field. This can save time because the grower won't be looking for the pest before it is present. Second, pheromone trap catches can be used to time insecticide applications. Third, for some pests, the need to spray can be determined from the number of moths caught in the trap. Pheromones are available for a few of the moth/caterpillar pests of vegetables.

## Control by Chemicals

Selecting the proper pest control option is often dependent on the grower's knowledge of the pest complex the previous year and the insects that have been bad in previous seasons. In dealing with vegetable crops, the selection of a control options during the growing season usually means not spraying or selecting a pesticide. Although we always encourage growers to read and follow label directions, the one area where the label is not always the best source of information is concerning which insects the insecticide will control.

The insecticides recommended in this book, for control of various pests, are listed because they have been found to be effective by growers here in Georgia. Considerations that should be examined are: insecticide costs, application costs, relative effectiveness, and gain in profits that can be expected from the application, whether it will control other pests, and how it will affect predators, parasites, and pollinators. It should always be remembered that pest control materials should be selected and applied in a manner that minimizes risks to human health, beneficial and non-target organisms, and the environment.

Evaluating the effectiveness of previously used control options: Growers should always evaluate the effectiveness of a pest control action. Inspecting the field a couple of days after an insecticide is applied will help the grower determine the necessity for additional control measures in that field, as well as provide information about the insecticide's effectiveness for future reference. Growers should pay attention to whether the insecticide killed all stages of the pests or if only small larvae or nymphs were killed. They should also notice the effects on other pests in the field and on beneficial insects.

**Natural control:** Is a way of conserving natural enemies allowing them to effectively reduce pest populations and damage. This can be accomplished in several ways, but the most important is reducing the number of insecticide applications. Each time a spray is applied, more predators and parasites are killed. When deciding to use an insecticide, you should consider the impact that application will have on beneficial insects. Bacillus thuringiensis products, for example, are not known to harm beneficial insects.

**Pollination of Vegetable Crops in Georgia:** Pollination by bees is critical for the successful production of melon, watermelon and cucumbers. The common honey bee is often used effectively to pollinate these crops. However, it is important to remember the importance of our native bees. They are actually more effective than honey bees in most cases. Melons and cucumbers can be hand pollinated; however, this is tedious and time consuming.

Always try to protect your pollinators from exposure to insecticides and where possible choose pesticides that are least toxic to bees. Apply pesticides when bees are not actively foraging. Honey bees and many native bees are active primarily during the morning and early afternoon. Many pesticides can be effectively applied in the late afternoon or evening with relative safety to bees. Evening treatments are also known to aid in the control of moth pests that are actively laying eggs at night.

**Biological Control:** Deals with the introduction, encouragement and multiplication of natural enemies for the suppression or control insect pests. This form of control is also considered part of growing crops organically with little or no insecticides being allowed. It is possible, but difficult, to incorporate the introduction and multiplication of parasites, predators and diseases where chemical pesticides are being utilized. However, it is always encourage trying to protect them if they are naturally in the IPM area. This can be accomplished as with pollinators; choice of pesticide, timing of applications and application targeting techniques.

Many of the key facets of IPM have been covered here, yet there are others that have not in this brief summary. However, you are now aware of the many complex issues that are incorporated into the mammoth scope of Integrated Pest Management. To be sure, it is not a static theory. It is alive and ever changing. As new and better methods are discovered that are economically feasible they will be included under this huge umbrella. However, remember that the primary goal of IPM is that it leads us to sustainability.

# DIAGNOSTIC SYMPTOMS OF EGGPLANT DISEASES

| Causal agents | Name of disease | Basic symptoms | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Spots | | Rot | | Flake/Scurf | | Wilting | | Deformation | | Damping Off | Chlorosis |
| | | Fruit | Leaf | Fruit | Root | Fruit | Leaf | Fruit | Leaf | Fruit | Leaf | | |
| Fungal | Grey Mold | X | | X | | X | | | | | | | |
| | Phomopsis Blight and Fruit Rot | X | X | | | | | | X | X | | X | X |
| | Verticillium Wilt | | | | | | | | X | | | | X |
| | Early Blight | | X | X | | X | X | | X | | | | X |
| Virus | Cucumber Mosaic Virus (CMV) | | | | | | | | | | X | | X |
| | Stolbur | | | | | | | X | | | | | X |
| Bacterial | Bacterial Spot | | | | | | | | | | | | |

# GENERAL DIAGNOSTIC OF POTATO DISEASES

| Source of infection | Causal agents | Name of disease | Basic symptoms: Blotching – Tuber | Blotching – Leaf | Blotching – Stem | Rot – Tuber | Flake/Scurf – Tuber | Flake/Scurf – Leaf | Flake/Scurf – Stem | Necrosis | Wilting – Tuber | Wilting – Stem | Wilting – Leaf | Deformation | Warts – Tuber | Warts – Leaf | Warts – Stem | Slow Growth | chlorosis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fungal | Phytophthorainfestans | Late Blight | X | X | X | X | | | | | | | | | | | | | |
| | Fusarium solani | Fusarium Dry Rot | | | | | X | | | | X | | | | X | | | | |
| | Synchithrium endobioticum | Potato Canker | | | | X | | | | | X | X | X | | X | X | X | | |
| | Spongospora subterranea | Powdery Scab | | | | X | X | | | | | | | | X | | | | |
| | Alternaria solani. | Early Blight | X | X | | X | | | | | | | | | | | | | |
| | Cercospora concors | Cercospora Leaf Blotch | | X | | | | X | | | | | X | | | | | | |
| | Rhizoctonia solani | Rhizoctonia | X | | | X | | | X | | | | | | | | | | |
| Viirus | Potato virus X(PVX) | Mosaic | | X | | | | | | X | | | | | | | | X | X |
| | Potato virus (PAMV) | Aucuba Mosaic | X | X | | | | | | X | | | | | | | | | |
| | Potato virus S (PVS) | Potato Virus S (PVS) | | | | | | | | | | | X | X | | | | | |
| | Potato virus Y (PVY) | Potato Virus Y (PVY) | | X | X | | | | | X | X | X | | | | | | | |
| | Potato virus M (PVM). | Potato Virus M (PVM). | | | | | | | | | | | | X | | | | | |
| Bacterial | Pectobacterium phytophthorum | Black Leg | | | X | X | | | | | | | | | | | | X | X |
| | Erwinia, Corynebacterium, Bacillus and Pseudomonas spp. | Bacterial Soft Rot | | | | X | | | | | | | | | | | | | |

# DIAGNOSTIC SYMPTOMS OF CUCUMBER DISEASES

| Causal agents | Name of disease | Basic symptoms | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Spots | | | Rot | | Flake/Scurf | | | Necrosis | Dry/Fade | | | Deformation | | Growth is slowed down | chlorosis |
| | | Fruit | Leaf | Stem | Fruit | Stem | Fruit | Leaf | Stem | | Fruit | Stem | Leaf | Fruit | Leaf | | |
| Fungal | Powdery Mildew | | X | | | | | X | X | | X | | X | | | X | X |
| | Sclerotinia Rot | | X | X | X | | X | | | | X | | X | | X | | |
| | Anthracnose | X | X | X | X | | | | | | | X | X | | | | |
| | Gummy Stem Blight | | X | X | | | | | | | X | | | | | X | |
| | Cladosporium | X | X | | | | X | | | | X | | | | | | |
| | Downy Mildew | | X | | | X | | X | | | | X | X | | | | |
| | Alternaria Leaf Spot | | X | | | | | X | | X | | | | | | | |
| | Target Spot | | X | | | | | X | | X | | | | | | X | |
| | Fusarium Wilt | | | | | | | | | | | X | X | | | X | |
| | Black Root Rot | | | | | | | | | | | X | X | | | X | X |
| | Gray Mold | | X | X | | | X | X | X | | | | | | | | |
| Virus | Cucumber Mosaic Virus | | X | | | | | | | | | | | X | X | X | X |
| | Cucumber Green Mottle Mosaic Virus | | | | | | | | | X | | | | | X | | |
| Bacterial | Soft Rot and Wilt | | X | | X | | | | | X | | X | X | | | X | |
| | Bacterial Wilt (bacteriosis) | X | X | | | | | | | | | | | | | | X |

# DIAGNOSTIC SYMPTOMS OF CABBAGE DISEASES

| Source of infection | Causal agents | Name of disease | Basic symptoms | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Spots | | | Rot | | Flake/Scurf | | | Necrosis | Wilting | | | Warts | Deformation | | Growth is slowed down | Chlorosis |
| | | | Fruit | Leaf | Stem | Fruit | Leaf | Fruit | Leaf | Stem | | Fruit | Stem | Leaf | | Flower | Leaf | | |
| Fungal | Plasmodiospora brassicae. | Clubroot | | | | | | | | | | | | | X | | | X | |
| | Hyaloperonosporaparasitica | Downy Mildew | X | X | | X | X | | X | | | | | | | | | | X |
| | Alternaria brassicae | Alternaria Leaf Spot | X | X | | | | X | X | | | | | | | | | | |
| | Phoma lingam | Black Leg (Phoma Canker and Leaf Spot) | X | X | X | | | | | | | | | | | | | X | |
| | Fusarium oxysporum | Fusarium Wilt | | | | | | | | | | | X | X | | | X | | X |
| | Botrytis cinerea | Gray Mold | | | | X | | X | | | | | | | | | | | |
| | Albugo candida | White Rust | | X | | | | | | | | | | | | X | | | X |
| | Rhizoctonia solani | Rhizoctonia (rhizoctoniosis) | X | | | X | | | | | | | | | | | | | X |
| | Sclerotinia sclerotiorum | Sclerotinia White Rot | | | | X | | | X | X | | | | | | | | | |
| Virus | Cauliflower Mosaic Virus | Cauliflower Mosaic Virus | | | | | | | | | X | | | | | | X | | |
| Bacterial | Erwvinia carotovora, Erwvinia aroideae, and Pseudomonas Spp. | Bacterial Soft Rot | | X | | X | | | | | | X | | | | | | X | |
| | Xanthomonas campestris | Black Rot of Cabbage | | X | | | | | | | | | | | | | | X | X |

# DIAGNOSTIC SYMPTOMS OF TOMATO DISEASES

| Causal Organism | Causal agents | Name of disease | Basic symptoms | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Spots | | Rot | Wilting | Flake/Scurf | | Necrosis | | Deformation of leaves | Chlorosis | Stunting | Defloration |
| | | | Fruit | Leaf | | | Leaf | Fruit | Leaf | Fruit | | | | |
| | Colletotrichum coccoides | Anthracnose | X | | | | | X | | | | | | |
| | Alternaria solani | Early Blight (Alternariosis) | X | X | | | | | | | | X | | |
| | Cladosporium fulvum | Leaf Mold (Cladosporiosis) | | X | | | X | | | | | | | |
| | Sclerotinia libertiana and Sclerotium bataticola | Sclerotinia and Sclerotium Blight (Sclerotiniosis) | | | X | | | X | | | | | | |
| | Verticillium dahlia | Verticilium Wilt | | X | | X | | | | | | X | | |
| Fungal | Phytophthora infestants | Late Blight of Tomato | X | X | | | X | X | | | | | | |
| | Fusarium oxysporum f. sp. Lycopersici | Tomato Fusarium Wilt | | | | X | X | | | | | X | | |
| | Septoria lycopersici . | Septoria Leaf Spot | | X | | | | | | | | | | |
| | Leveillula taurica and Erysiphe cichoracearum | Tomato Powdery Mildew | | X | | X | X | | | | | | | X |
| | Rhizoctonia, Pythium, Phytophthora and Fusarium | Seedling Blight and Damping-Off (Black Leg) | | | | X | | | | | | | | |
| | Rhizopus nigricans. | Rhizopus Rot (Wet Rot) | X | | X | | | | | | | | | |
| | Tomato Mosaic virus (ToMv) | Tobacco (Tomato) Mosaic Virus (ToMv) | | | | | | | | | X | | | |
| Virus | Tomato Impatience Necrotic Spot Virus (INSV) | Tomato Impatience Necrotic Spot Virus (INSV) | X | | | X | | | | | | X | X | |
| | Phytoplasma | Stolbur | | | | X | | | | X | | | | |
| | Clavibacter michiganensis sub. sp. Michiganensis | Bacterial Canker | | | | X | | | X | | | | X | |
| Bacterial | Ralstonia solanacearum | Bacterial Wilt | | | | X | | | | | | | | |
| | Xanthomonas campestris pv. Vesicatoria | Bacterial Spot of Tomato | | | | | | | | | | | | X |

# DIAGNOSTIC SYMPTOMS OF CARROT DISEASES

| Source of infection | Causal Agents | Name of disease | Basic symptoms | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Spots | | | Rot | | Flake/Scurf | | | Necrosis | Wilting | | | Warts | Deformation | | Growth is slowed down | chlorosis |
| | | | Tap root | Leaf | Stem | Tap root | plant | Taproot | Leaf | Stem | | Tap root | Stem | Leaf | | Stem | Taproot | | |
| Fungal | Phoma rostrupii | Brown Rot | X | X | X | X | | X | X | X | | | X | X | | | | | |
| | Alternariara dicina | Black Rot Black Carrot Root Dieback | X | X | | | | X | | | | | | X | | | X | | |
| | Sclerotinia sclerotiorum | Cottony Rot | | | | X | | X | | | | | | | | | | | |
| | Botrytis cinerea | Gray Mold Rot | X | | | X | | X | | | | | | | | | | | |
| | Rhizoctonia carotae | Crater Rot | X | | | | | X | | | | | | | | | | | |
| | Fusariumspp | Fusarium Dry Rot | X | | | | | X | | | | X | | | | | | | |
| Virus | Parsnip Yellow Fleck Virus | Parsnip Yellow Fleck Virus | | | | | | | | | X | X | | X | | | | | X |
| | Carrot Red Leaf Virus (CtRLV) | Carrot Red Leaf Virus (CtRLV) | | | | | | | | | | | | | | | | X | X |
| Bacterial | Erwinia caratovora | Soft-Rot | X | | | X | | | | | | | | | | | | | |
| | Xanthomonascampestispv. carotae | Bacteriosis | | X | | | | | | | | | | X | | | | X | |

# DIAGNOSTIC SYMPTOMS OF PEPPER DISEASES

| Source of infection | Causal agents | Name of disease | Basic symptoms | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Spots | | | Rot | | Flake/Scurf | | | Necrosis | Dry/Fade | | | Deformation | | Growth is slowed down | chlorosis |
| | | | Fruit | Leaf | Stem | Fruit | Root | Fruit | Leaf | Stem | | Fruit | Stem | Leaf | Fruit | Leaf | | |
| Fungal | Alternaria Solani | Early Blight | X | X | | | | X | | | X | | | X | | | | |
| | Colletotrichum Capsisi | Anthracnose | X | X | | | | | | | X | | X | X | | | X | |
| | Fusarium oxysporum | Fusarium Wilt | | | X | | | | | | | | | X | | | | X |
| | Botrytis Cinerea | Gray Mold | X | X | X | X | | X | X | | | | | | | | | |
| | Didymella Lycopersici, Phoma Destructiva. Phoma Exiqua | Stem and Fruit Rot | | | X | | | | | X | X | | | | | | | |
| | Verticillium dahliae,Verticillium albo-atrum. | Verticillium Wilt | | X | | | | | | | X | | X | X | | | X | |
| | Cercospora Capsici | Cercospora Leaf Spot | | X | | | | | | | | | | X | | | | X |
| | Erysiphe Oronti | Powdery Mildew | | X | | | | | X | | | | | | | X | | X |
| | Phytophthora capsici. | Phytopthora Blight | X | X | | | | | | | | | X | X | | | | |
| Virus | phytoplasma | Stolbur | | | | | X | | | | | | X | X | | X | X | X |
| | Cucumber mosaic virus (CMV) | Cucumber Mosaic Virus (CMV) | | | | | | | | | | | X | | X | X | X | X |
| | Alfalfa mosaic virus (AMV) | Alfalfa Mosaic Virus (AMV) | | | | | | | | | | | | | X | | | X |
| Bacterial | Xanthomonas Campestrispv.Vesicatoria | Bacterial Leaf Spot | X | X | | X | | | | | X | | X | X | | | | X |
| | Clavibacterm ichiganensis | Bacterial Canker | X | X | X | | | | | | | | | | | | | |
| | Ralstonia solanacearum. | Bacterial Wilt | | | | | | | | | | | X | X | | | | X |

# DIAGNOSTIC SYMPTOMS OF ONION AND GARLIC DISEASES

| Source of infection | Causal Agents | Name of disease | Basic symptoms | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Spots | | Rot | | Flake/Scurf | | Necrosis | Wilting | | Warts | Deformation | Growth is slowed down | chlorosis |
| | | | Bulb | Stem | Bulb | Stem | Bulb | Stem | | Bulb | Stem | | Stem | | |
| | Peronospora destructor | Downy Mildew | | X | X | | | X | | | X | | X | | X |
| | Pucciniaallii | Leek Rust | | X | | | | | | | X | | | | |
| | Sclerotinia porri | Neck Rot of Garlic | X | | | | X | X | | X | | | | | X |
| | Alternaria alli | Alternaria Blight | X | X | | | X | | | | | | | | |
| Fungal | Botrytis allii | Neck Rot of Onion | | X | X | | X | X | | | | | | | |
| | Urocystisce pulae | Onion Smut | | X | | | | X | | | X | | | | |
| | Fusarium ozyspoum Fusarium moniliforme Fursarium culmorum | Fusarium Wilt and Bulb Rot | | | | | | X | X | | | | | X | X |
| | Scleriotinia cepivorum | White Rot of Onion and Garlic | | | X | X | X | | X | | X | | | X | X |
| | Aspergilus niger | Black Mold Rot of Onion Bulbs | | | | | X | | | X | | | | | |
| Virus | Onion Mosaic Virus | Onion Mosaic Virus | | X | | | | | | | X | | X | | X |
| Bacterial | Pectobacterium carotovorum and Burk holderiacepacia | Bacterial Soft Rot Bacteriosis | | | X | | | | | | | | | | |

# DIAGNOSTIC SYMPTOMS OF WATERMELON DISEASES

| Source of infection | Causal Agent | Name of disease | Basic symptoms | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Spots | Rot | Flake/Scurf | | Mosaic | Wilting | | Deformation | | Growth is slowed down |
| | | | Leaf | Fruit | Leaf | Flower | | Stem | Leaf | Fruit | Leaf | |
| Fungal | Sclerotinia sclerotiorum | White Mold (Sclerotinia rot) | | X | | X | | | | | | |
| | Colletotrichum orbiculare | Anthracnose | X | X | X | | | | | | | |
| | Pseudoperonospora cubensis | Downy Mildew | X | | X | | | | | | | X |
| | Erysiphecichoracearum, Sphaerotheca fuliginea | Powdery Mildew | X | | | | | | X | X | X | |
| Virus | Watermelon mosaic virus (WMV) | Watermelon Mosaic Virus (WMV) | X | | | | X | | | | | X |
| | Cucumber mosaic virus | Cucumber Mosaic Virus | | | | | X | | | | X | |
| Bacterial | Acidovoraxavenaesubsp.Citrulli | Bacterial Fruit Blotch | X | | | | | | X | | | |

# DIAGNOSTIC SYMPTOMS OF MELON DISEASES

| The source of infection | Causal Agents | Name of disease | Basic symptoms | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Spots | | Rot | Flake/Scurf | | Mosaic | Wilting | | Warts | Deformation | Growth is slowed down | chlorosis |
| | | | Fruit | Leaf | Fruit | Leaf | Stem | | Stem | Leaf | | Leaf | | |
| Fungal | Sphaerotheca fuliginea | Powdery Mildew | | | | X | X | | | X | | X | X | |
| | Fusarium oxysporum f. sp.melonis | Fusarium Wilt | | X | | | | | X | X | | | | X |
| | Colletotrichum orbiculare | Anthracnose | | X | | | | | X | X | X | | | |
| | Pseudoperonospora cubensis | Downy Mildew | | X | | X | | | | X | | | | |
| Virus | Cucumber mosaic virus (CMV) and Watermelon mosaic virus (WMV) | Cucumber Mosaic Virus (CMV) and Watermelon Mosaic Virus (WMV) | | | | | | X | | | | X | X | |
| Bacterial | Acidovora xavenae | Bacterial Fruit Blotch | X | X | X | | | | | X | | | | |
| | Pseudomonas syringaepv. Lachrymans | Angular Leaf Spot | X | X | X | | | | | X | | | | |

# GLOSSARY

## A

**Acervulus** - A subepidermal, saucer-shaped, asexual fruiting body producing conidia on short conidiophores.

**Aecium** - A cup-shaped fruiting body of the rust fungi which produces aeciospores.

**Anomorph** - The imperfect or asexual stage of a fungus.

**Anthracnose** - A disease that appears as black, sunken leaf, stem, or fruit lesions and caused by fungi that produce their asexual spores in an acervuli.

**Apothecium** - An open cup- or saucer-shaped ascocarp of some Ascomycetes.

**Ascocarp** - The fruiting body of Ascomycetes containing asci.

**Ascomycetes**- A group of fungi producing their sexual spores, ascospores, within asci.

**Ascospore** - A sexually produced spore borne in an ascus.

**Ascus** - A saclike cell of a hypha in which meiosis occurs and which contains the ascospores (usually eight).

**Asexual reproduction** - Any type of reproduction not involving the union of gametes or meiosis.

## B

**Bacillus** - A rod-shaped bacterium.

**Bacteriophage** - A virus that infects bacteria and usually kills them.

**Basiciomycetes** - A group of fungi producing their sexual spores, basiciospores, on basidia.

**Basidiospores** - A sexually produced spore, borne on a basidium.

**Basidium** - A structure on which basidiospores are borne.

## C

**Canker** - A necrotic, often sunken lesion on a stem, branch, or twig of a plant.

**Chlamydospore** - A thick-walled asexual spore formed by the modification of a cell of a fungus hypha.

**Chlorosis** - Yellowing of normally green tissue due to chlorophyll destruction or failure of chlorophyll formation.

**Cleistothecium** - An entirely closed ascocarp.

**Conidiophore** - A specialized hypha on which one or more conidia are produced.

**Conidium** - An asexual fungus spore formed from the end of a conidiophore.

**Culture** - Artificially grown microorganisms on a prepared food material.

**Cyst** - An encysted zoospore (fungi); in nematodes, the carcass of dead adult females of the genera Heterodera or Globodera which usually contain eggs.

## D

**Dikaryotic** - Mycelium or spores containing two sexually compatible nuclei per cell - common in basidiomycetes.

**Disease cycle** - The chain of events involved in disease development, including the stages of development of the pathogen and the effect of the disease on the host.

## E

**Ectoparasite** - A parasite feeding on a host from the exterior.

**Enation** - Tissue malformation or overgrowth induced by certain virus infections.

**Endoparasite** - A parasite which enters a host and feeds from within the host.

**Flagellum** - A whip-like structure projecting from a bacterium or zoospore and functioning as an organ of locomotion.

## G

**Gum** - Complex polysaccharidal substances formed by cells in reaction to wounding or infection.

## H

**Haustorium** - A simple or branched projection of hyphae into host cells which acts as an absorbing organ.

**Host** - A plant that is invaded by a parasite and from which the parasite obtains its nutrients.

**Host range** - The various kinds of host plants that are attacked by a parasite.

**Hyaline** - Colorless transparent.

**Hyperplasia** - A plant overgrowth due to increased cell division.

**Hypertrophy** - A plant overgrowth due to abnormal cell enlargement.

**Hypha** - A single branch of a mycelium.

## I

**Imperfect fungus** - A fungus that is not known to produce sexual spores.

**Imperfect stage** - The part of the life cycle of a fungus in which no sexual spores are produced. The anamorph stage.

**Indicator** - A plant that reacts to certain viruses or environmental factors with production of specific symptoms and is used for detection and identification of these factors.

## J

**Juvenile** - The life stage of a nematode between the embryo and the adult; an immature nematode.

## L

**Local lesion** - A localized spot produced on a leaf upon mechanical inoculation with a virus.

## M

**Mummy** - A dried, shriveled fruit.

**Mycelium** - The hypha or mass of hyphae that make up the body of a fungus.

## N

**Noninfectious disease** - A disease that is caused by an abiotic agent, that is, by an environmental factor, not by a pathogen.

## O

**Obligate parasite** - A parasite that in nature can grow and multiply only on or in living organism.

**Oomycete** - A fungal-like chromistan that produces oospores.

**Oospore** - A sexual spore produced by the union of two morphologically different gametangia (oogonium and antheridium).

## P

**Parasite** - An organism living on or in another living organism (host) and obtaining its food from the latter.

**Pathogen** - An entity, usually a microorganism that can incite disease.

**Pathovar** - In bacteria, a subspecies or group of stains that can infect only plants within a certain genus or species.

**Perfect stage** - The sexual stage in the life cycle of a fungus.

**Phytoplasma** - Mollicutes that infect plants and cannot yet be grown in culture.

**Primary infection** - The first infection of a plant by the overwintering or oversummering pathogen.

**Prokaryate** - A microorganism whose genetic material is not organized into a membrane-bound nucleus, for example bacteria and mollicutes.

**Pustule** - Small blister like elevation of epidermis created as spore form underneath and push outward.

**Pycnium** - Also called spermagonium. In some basidiomycetes, it contains the spermatia and receptive hyphae.

**Pycnidium** - An asexual, spherical, or flask-shaped fruiting body lined inside with conidiophores producing conidia.

**Pycniospore** - Also called spermatium. A spore produced in a pycnium.

## R

**Ringspot** - A circular area of chlorosis with a green center; a symptom of many virus diseases.

## S

**Saprophyte** - An organism that uses dead organic material for food.

**Sclerotium** - A compact mass of hyphae with or without host tissue, usually with a darkened rind, and capable of surviving under unfavorable environmental conditions.

**Sexual** - Participating in or produced as a result of a union of nuclei in which meiosis takes place.

**Spiroplasmas** - Pleomorphic, wall-less microorganisms that are present in the phloem of diseased plants. They are often helical.

**Sporangium** - A container or case of asexual spores. In some cases it functions as a single spore.

**Spore** - The reproductive unit of fungi consisting of one or more cells; it is analogous to the seed of green plants.

**Sporadochium** - A fruiting structure consisting of a cluster of conidiophores woven together on a mass of hyphae.

**Stylet** - A long, slender, hollow feeding structure of nematodes and some insects.

**Systemic** - Spreading internally throughout the plant body.

## T

**Telemorph** - The sexual or so-called perfect growth stage or phase in fungi.

**Teliospore** - The sexual, thick-walled resting spore of the rust and smut fungi.

**Telium** - The fruiting structure in which rust teliospores are produced.

## V

**Viroid** - Small, low-molecular-weight ribonucleic acid (RNA) that can infect plant cells, replicate themselves, and cause disease.

**Virus** - A submicroscopic, obligate parasite consisting of nucleic acid and protein.

## Z

**Zoospore** - A spore bearing flagella and capable of moving in water.

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