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Pest Management Guide for Sweet Pepper




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All photos in this manual were taken by the authors (Dr. Ken Okwae Fening, Dr. Francis Collison Brentu and Mr. Paul Muteru) and the others have been duly acknowledged.

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Acronyms

AEAs . . . . . .Agricultural Extension Agents

Bt . . . . . .*Bacillus thuringiensis*

Biocontrol. . . . .Biological control

Biopesticide . . .Biological pesticide

CSIR . . . . . .Council for Scientific and Industrial Research

IGRs . . . . . .Insect Growth Regulators

IPM. . . . . .Integrated Pest Management

MoFA . . . . . .Ministry of Food and Agriculture

NPPO . . . . . .National Plant Protection Organization

PPRSD. . . . . .Plant Protection and Regulatory Services Directorate

PHI . . . . . .Pre-harvest interval

REI . . . . . .Re-entry interval

1. Introduction

Sweet pepper (*Capsicum annuum*) is the most consumed spice in Ghana and remains the common household ingredient in various soups, stews, and sauces. The fresh and processed pepper products are valued for pungency, flavor, vitamin A and B, antioxidant, and appetite-stimulating effect (Saleh et al., 2018).

In Ghana, sweet pepper is a major cash crop cultivated, usually in the open field by small- and large-scale farmers. However, greenhouse or screenhouse production has developed rapidly in the last decade due to pest or disease problems mostly associated with open field cultivation. Compared to open-field production, greenhouse production systems use the integrated pest management (IPM) strategy of "physical barrier" in a greenhouse. This management tactic eliminates many open-field pests and diseases, resulting in greatly increased pepper yields.

However, greenhouse pepper crops still suffer significant losses from certain pests and diseases, including aphids, fruit borers, damping-off, root rots, etc. Frequent pest and disease outbreaks occur due to poor management practices and hygiene/sanitation. This situation is likely to change as the industry identifies and develops appropriate pest management strategies for farmer adoption.

This manual describes using the relevant pictures and illustrations, the pest and disease problems encountered by farmers during sweet pepper production from the nursery establishment to harvesting, especially under greenhouse or screenhouse conditions. Only pests and diseases that affect greenhouse/open field cultivation of sweet pepper in Ghana have been considered.

It also briefly explains with pictures the life cycle of the expected pests and diseases and highlights their destructive stages and how farmers can control the pest at any stage of the life cycle, taking advantage of the most vulnerable stage of the pest or early stages of disease manifestation. A combination of appropriate and compatible pest management strategies (cultural, physical/mechanical, biological, host plant resistance, etc.) is recommended, with the use of pesticides (chemical control), preferably the environmentally friendly and less toxic pesticides, as a last resort, when other control measures fail to offer effective protection against pests and diseases, as embodied in IPM. It is advisable to rotate different Mode of Action (MoA) class of pesticides to delay the development of resistance. Also the use of the less hazardous synthetic pesticides should be restricted to the seedling, vegetative and pre-flowering stages of the crop and complemented with the biological pesticides during flowering and fruiting stages of the crop to ensure food and environmental safety, and help promote the activities of beneficial insects (e.g. natural enemies and pollinators).

The IPM approach will allow the farmer to put in place measures to prevent and monitor pests and diseases and their timely control or management to ensure significant damage and yield losses do not occur. This will improve the yield of sweet pepper and promote food and environmental safety.

As an appendix to this document is a tracking sheet/scouting guide that can be used by farmers and growers to monitor pests and diseases for timely implementation of control measures. There is the need for regular (twice a week) scouting, by inspecting plant parts (leaves, stem, fruits, etc), depending on the growth stage of crop and the type of pests, for the presence of the pest or its damage to establish their infestation and damage early enough (action threshold), to ensure a decision is made to control to prevent irreversible damage from occuring (economic damage).

Scouting can also be done by monitoring catches of pest numbers from traps set in the vicinity of the crop for informed decision making. Taking a decision to control based on the combination of pest thresholds from sampling from the crop and also estimates from trap catches could offer a more precise information, than when they are utilised independently. This regular scouting will support farmers and growers to document pest and disease incidence on the crop and also record information on the control method employed such as the type of pesticides applied, the rate and frequency of application, among others.

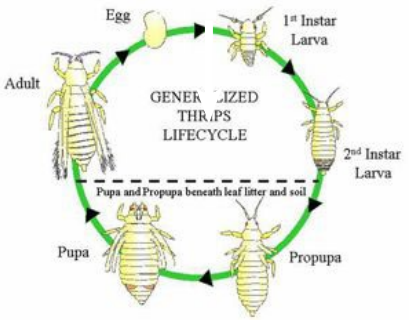
Please note that use of pesticides should only be with EPA approved pesticides and follow the label recommendation as can be found on the packaging.

The pesticides listed in this guide are given as active ingredients, not the registered trade names.

Where applicable biocontrol options are given, however, not all are currently available in Ghana. We hope that by mentioning them this will increase the use and application of biological control agents in the future.

2. Insect pests of sweet pepper and their management

Greenhouse-grown sweet pepper (*Capsicum annum*) plants are susceptible to attack by insects and mite pests, including flower thrips, whiteflies, aphids, fruit borers, cutworms, mealybugs, broad mites, and two-spotted spider mites. These insects and mites cause direct damage by feeding on flowers, fruits, leaves, stem, and other plant parts and indirect damage by serving as vectors of plant diseases (viruses). These direct and indirect damage result in reduced plant growth, leading to both quantitative and qualitative yield losses. Below you will find information about these pests and how to sustainably manage them.



Generalised life cycle of thrips. (Photo courtesy of UC Statewide Integrated Pest Management Program) (https://cisr.ucr.edu/invasive-species/avocado-thrips).

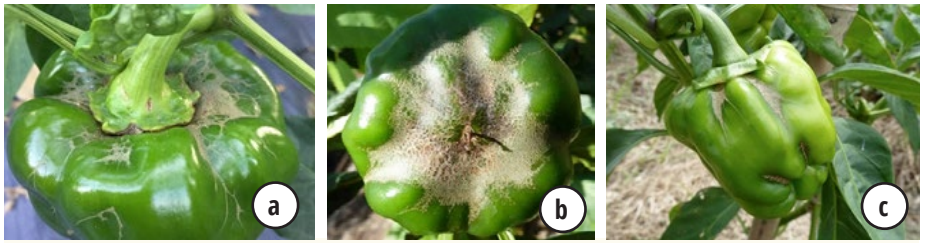
2.1 Thrips

Scientific name: *Thrips* spp., *Megalurothrips sjostedti*
Distribution: Widespread
Stage of crop attacked: Seedling and reproductive stages

Main damage symptoms:

- Both the adults and larvae suck the plant's outermost layer and cause "flecking" or scars.
- Feeding results in distorted and stunted growth, and sunken tissues on the underside of the leaves and scars on fruits.
- May spread viral diseases (e.g., Tomato spotted wilt virus) during their feeding activities.

Sweet pepper with Tomato spotted wilt viral disease. (Photo by Stuart Reitz Oregon State University).



Scaring caused by thrips on fruit of sweet pepper. (Photos by Suzanne Neave & Grahame Jackson Information from Thrips (2021) Wikipedia. (https://en.wikipedia.org/wiki/Thrips)' and J. Bethke JA (2014) Thrips. How to manage pests in gardens and landscapes. UC/IPM. (http://ipm.ucanr.edu/PMG/PESTNOTES/pn7429.html); Mani Mua, SPC, Sigatoka Research Station, Fiji.

Prevention

- Undertake pre-planting and post-harvest sanitation
  - Remove or destroy volunteer plants and debris.
  - Plant residues left on the soil surface can harbour thrips to survive and spread the next season.
  - Implement good cultural practices to increase sweet pepper plant tolerance and reduce attractiveness to thrips.
  - Effects of mulch on thrips may include increased biological control through enhancement of predator populations, creation of a barrier for pre-pupae and pupae (resting life stages) to access soil, and reduced temperatures, which slow thrips development and population increase.
- Use trap crops, inter-cropping, and crop rotation
  - Intercrop or rotate sweet pepper with trap crops that are highly attractive to thrips such as carrots, crucifers, cucurbits, and some flowers.
  - Using a trap crop involves planting small strips or patches of the alternative crop within a sweet pepper field to attract thrips.
  - The trap crop is sprayed with an insecticide when thrips populations increase.
  - Inter-cropping, or mixed planting, of carrots and sweet pepper has been shown to reduce thrips populations on pepper by attracting them to the carrots.
  - Thrips injury to carrots is not as economically damaging as injury to.
- Apply sprinkler irrigation when possible
  - Use overhead sprinkler irrigation to reduce thrips population on crop.
  - The physical action of water washing thrips from plants and water droplets standing on leaf surfaces are inhibitory to thrips.
  - Thrips prefer warm and dry conditions.
  - In addition, water applied through sprinklers may cause a crust to form on the soil surface and reduce the ability of pre-pupae and pupae to seek shelter in the soil.

Ripened sweet pepper fruit with flicking (scars) caused by thrips. (Photo by Stuart Reitz Oregon State University)

- Select resistant or tolerant sweet pepper varieties
  - Some varieties can tolerate effects of thrips feeding with only mild yield loss.
  - Varieties with tolerance to thrips require fewer insecticide applications.
  - Reduced insecticide use lowers control costs and slows development of resistance to insecticides in the thrips population and may encourage biological control through preservation of natural enemies.

Monitoring

- Inspect plants
  - Flower thrips adults and larvae can be visually identified and counted.
  - The use of magnifying hand lens will also enhance visibility.
  - Thrips sampling is important to optimise management strategies and to inform the grower about thrips population pressure over time.
  - It is recommended you sample 5 plants each in about 5 different areas, making a total of 25 plants per greenhouse.
  - Monitor plants for adult and larvae, and only treat when you see more than two larvae or adults per small fruit, or more than six adults per flower.
  - Thrips numbers tend to be higher near field borders where adults infest first
- Alternatively, use blue or yellow sticky traps to monitor adult thrips population.

Control

- Management of thrips involves the combination of cultural, chemical control measures and use of resistant and tolerant varieties (if available) that suppress thrips populations and reduce their feeding damage
- Use of ultra-violet reflective mulches can control thrips- an effective integrated pest management programme employs reduced-risk insecticides, natural infestations of minute pirate bugs (*Orius* spp.) (biological control) and cultural tactics including ultraviolet-reflective mulch (Reitz et al., 2003).

Biopesticides

- Spinetoram
- Spinosad
- Pyrethrum/ Pyrethrins
- Neem seed extract: 750 g/15 l
- Neem oil (0.3 % Azadirachtin): 60 ml/l
- Neem oil (1% Azadirachtin): 30 ml/l
- *Metarhizium anisoplae* (ICIPE 69)

Synthetic insecticides

Placing pepper flowers in vials with 70% alcohol. (Photo by Stuart Reitz Oregon State University)

Yellow sticky traps for monitoring thrips and whiteflies in greenhouse-grown sweet pepper. (Photo by Biobest Group NV)

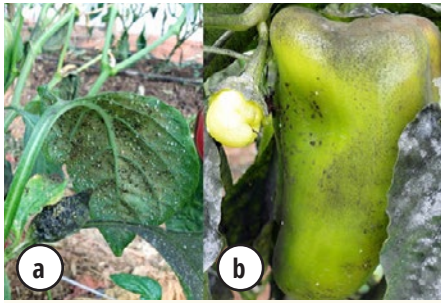
Active ingredient	PHI	Remarks
Imidacloprid or Imidacloprid + Emamectin benzoate	2 weeks	Spray in two weeks intervals to control thrips. Rotate this active ingredient with other recommended insecticides to prevent resistance development.
Pymetrozine (500 g/kg)	2 weeks	Spray in rotation with other insecticides to control thrips
Fipronil (50 g/l)	2 weeks	Spray in rotation with other insecticides to control thrips
Thiamethoxam (350 g/l) or Thiamethoxam (141 g/l) + Lambdacyhalothrin (106 g/l)	2 weeks	Spray in rotation with other insecticides to control thrips
Acetamiprid (16 g/l) + Indoxacarb (30 g/l)	2 weeks	Spray in rotation with other insecticides to control thrips
Spirotetramat (100 g/l)	1 week	Spray in rotation with other insecticides to control thrips
Deltamethrin (12.5 g/l)	3 days	Spray in rotation with other insecticides to control thrips
Chlorfenapyr (24%)	2 weeks	Spray in rotation with other insecticides to control thrips
Lambda cyhalothrin (25 g/l)	3 days	Spray in rotation with other insecticides to control thrips
Novaluron (100 g/l)	1 day	Apply when the majority of the pest population is at egg hatch to early instars
Biological pesticides	0–3 days	Biopesticide used in rotation with other synthetic insecticides. Much preferred during flowering and fluiting stages.

2.2 Whiteflies

Common name: Sweet potato whitefly
Scientific name: *Bemisia tabaci*
Distribution: Widespread
Stage of crop attacked: Seedling and vegetative stages

Main damage symptoms:

Whiteflies suck sap of plant, causing distortion of the leaf e.g., leaf curl. Transmission of viral diseases. They excrete honeydew which encourage growth of black sooty mould that interferes with photosynthesis and could reduce fruit quality, making it unattractive and unmarketable.

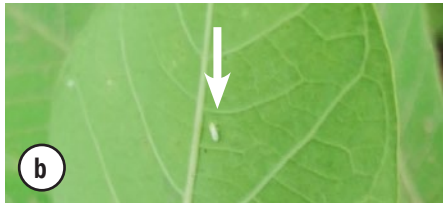


Sweet pepper leaves (a) and fruits (b) infested with Bemisia tabaci *(nymphs and adults) and sooty moulds deposited on leaves and fruits. (Photo adopted from Bello et al., 2020).*

The adult of the of the sweet potato whitefly (*Bemisia tabaci*) closely resembles the greenhouse whitefly (*Trialeurodes vaporariorum*) but is slightly smaller and yellower. More distinctively, the wings of B. tabaci are held vertical and parallel along the body.

The greenhouse whitefly is known to occur in many continents, including some countries in north, east and southern Africa (CABI 2021).

B. *tabaci* and *Trialeurodes* are the vector for several viral diseases. Since viral diseases have no cure, management intervention should focus on early detection of vector and its control.



Nymphs and adults of sweet potato whitefly, Bemisia tabaci. *(Adult B.* tabaci *photo (c) is from Public Domain – Released by the USDA-ARS/original image by Stephen Ausmus.*

Adults and of the greenhouse whitefly, Trialeurodes vaporariorum. *(Unlike, B.* tabaci, *the fourth-instar nymphs have very long waxy filaments and a marginal fringe). (See photo above). Photo ©University of California.*

Prevention

- Implement good farm sanitation practices by regular weeding of weeds in the greenhouse.
- Cover seedlings with a fine mosquito net or mesh to prevent whiteflies attack at nursery stage.

Monitoring

- Use yellow sticky traps to monitor adult whiteflies population.
- Look at the underside of leaves for the presence of the nymphs and adult whiteflies early morning (6-7am), where they are still inactive.
- The action threshold is about 4 adults per leaf in a random 30-leaf sample of healthy leaves.

Control

Biological control

- Conserve local natural enemies' population by minimising the use of synthetic insecticides.
- If encouraged natural enemies could bring the whitefly menace to a minimum level.

Examples of whitefly predators:
- Mirid bug, *Nesidiocoris tenuis*
- lacewings
- predatory bugs
- ladybird beetles
- predatory mites

Examples of whitefly parasitoids:
- Parasitoid wasps e.g. *Encarsia* spp.

Example of beneficial fungi:
- *Metarhizium anisopliae*

- Biopesticides (for effective control, weekly application is preferable)
  - Spinosad
  - Neem oil (Azadirachtin 0.3 %): 60 ml/15 l
  - Neem oil (Azadirachtin 1%): 30 ml/15 l
  - Neem seed extract: 750 g/15 l of water
  - potassic soap solution *alata samina*: 75 g/ 15 l
  - pyrethrum at the recommended label application rate
  - maltodextrin: 150–225 ml/15 l
  - *Metarhizium anisopliae*
  - *Beauveria bassiana*
  - Oxymatrine

Synthetic insecticides

Active ingredient	PHI	Remarks
Imidacloprid or Imidacloprid + Emamectin benzoate	2 weeks	Spray in two weeks intervals to control whiteflies. Rotate this active ingredient with other recommended insecticides to prevent resistance development.
Pymetrozine (500 g/kg)	2 weeks	Spray in rotation with other insecticides to control whiteflies
Acetamiprid (16 g/l) + Indoxacarb (30 g/l)	2 weeks	Spray in rotation with other insecticides to control whiteflies
Spirotetramat (100 g/l)	1 week	Spray in rotation with other insecticides to control whiteflies
Deltamethrin (12.5 g/l)	3 days	Spray in rotation with other insecticides to control whiteflies
Chlorfenapyr (24%)	2 weeks	Spray in rotation with other insecticides to control whiteflies
Lambda cyhalothrin (25 g/l)	3 days	Spray in rotation with other insecticides to control whiteflies
Novaluron (100 g/l)	1 day	Apply when the majority of the pest population is at egg hatch to early instars
Biological pesticides	0–3 days	Biopesticide used in rotation with other synthetic insecticides. Much preferred during flowering and fluiting stages.

2.3 Aphids

Common name: Green peach aphid (local name: nkokodwee)
Scientific name: *Myzus persicae*
Distribution: Widespread
Stage of crop attacked: Seedling, vegetative and reproductive stages

Main damage symptoms:

- Suck plant sap leading to stunted growth, leaf curl, yellowing of leaves, wilting, sooty mould and transmission of viruses.

White spots on sweet pepper fruit caused by aphids feeding on the fruit bud when it was still young. (Photo from https://www.alberta.ca/pests-of-greenhouse-sweet-bell-peppers-and-their-biological-control.aspx).

*(a) Aphids (*Myzus persicae*) underneath the leaves of a sweet pepper (Photo from Insectekpest.com).*
*(b) Greenhouse-grown sweet pepper heavily infested with aphids (*M. persicae*) and showing the characteristic symptoms (leaf curl, yellowing, sooty mould, etc. (www.shutterstock.com).*

Prevention

- Before planting, check surrounding areas for sources of aphids and remove these sources.
- Some aphids build-up on weeds, moving onto related crop seedlings after they emerge.
- On the other hand, the aphid-infested weeds can sometimes provide an early source of aphid natural enemies.
- Always check transplants for aphids and remove them before planting.

Monitoring

- Monitor their population using yellow water bowl or sticky trap for the winged adult population.
- Alternatively, inspect the underside of leaves for their presence or symptoms such as leave curl, sooty mould, wilting or stunted growth.
- Action thresholds range from "50% or more of the leaves infested" to "three to four aphids per plant".

Control

Biological control

- Natural enemies attacking aphids in the field include parasitoids or parasitic wasp (*Aphidius* spp.) and several predators, mainly spiders, midges, hoverflies, ladybird, lacewings, and predatory bugs.
- Biopesticides:
  - Neem oil (Azadirachtin 0.3 %): 60 ml/15 l
  - Neem oil (Azadirachtin 1%): 30 ml/15 l
  - Neem seed extract: 750 g/15 l of water,
  - Insecticidal soaps – *alata samina* applied at 75 g/15 l
  - petroleum-based horticultural oils or
  - plant-derived oils, e.g., canola oil

Synthetic insecticides

- Etofenprox
- Pymetrozine
- Spirotetramat
- Oxymatrine
- Profenofos + cypermethrin
- Profenofos + lambda cyhalothrin

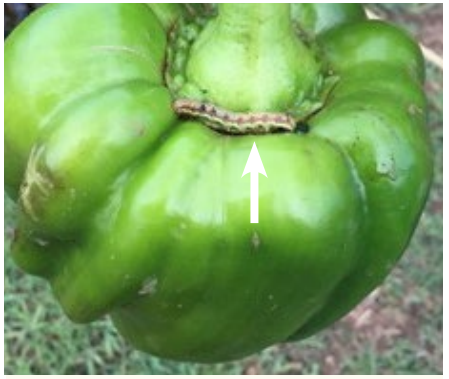
Active ingredient	PHI	Remarks
Profenofos (300 g/l) + Lambda-cyhalothrin (15 g/l) or Profenofos (40%) + Cypermethrin (4%)	2 weeks	Spray in rotation with other insecticides to control aphids
Imidacloprid or Imidacloprid + Emamectin benzoate	2 weeks	Spray in two weeks intervals to control aphids. Rotate this active ingredient with other recommended insecticides to prevent resistance development.
Pymetrozine (500 g/kg)	2 weeks	Spray in rotation with other insecticides to control aphids
Fipronil (50 g/l)	2 weeks	Spray in rotation with other insecticides to control aphids
Thiamethoxam (350 g/l) or Thiamethoxam (141 g/l) + Lambdacyhalothrin (106 g/l)	2 weeks	Spray in rotation with other insecticides to control aphids
Acetamiprid (16 g/l) + Indoxacarb (30 g/l)	2 weeks	Spray in rotation with other insecticides to control aphids
Spirotetramat (100 g/l)	1 week	Spray in rotation with other insecticides to control aphids
Deltamethrin (12.5 g/l)	3 days	Spray in rotation with other insecticides to control aphids
Chlorfenapyr (24%)	2 weeks	Spray in rotation with other insecticides to control aphids
Lambda cyhalothrin (25 g/l)	3 days	Spray in rotation with other insecticides to control aphids
Biological pesticides	0–3 days	Biopesticide used in rotation with other synthetic insecticides. Much preferred during flowering and fluiting stages.

2.4 Fruit borers

Common names: False codling moth (FCM), Cotton leafworm, Bollworm, cabbage looper
Scientific names: *Thaumatotibia leucotreta, Helicoverpa* spp., *Spodoptera* spp., *Trichoplusiani, Tuta absoluta* (as a minor pest)
Distribution: Widespread
Stage of crop attacked: Fruits

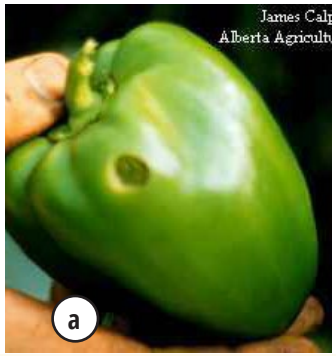
Main damage symptoms:

- Bores into fruit, making it unmarketable.



The cotton bollworm, Helicoverpa armigera *larva boring into sweet pepper fruit (Photo from Pacific Pests, Pathogens & Weeds – Fact Sheets).*

False codling moth (Thaumatotibia leucotreta) *larvae attacking sweet pepper fruit. (Photo by Adom Medetissi, ARPPIS University of Ghana)*



Looper damage on sweet pepper fruits and leaves. (Photo from https://www.alberta.ca/pests-of-greenhouse-sweet-bell-peppers-and-their-biological-control.aspx).

Prevention

- Sweet pepper should be kept clean from weeds.
- Field should be free of any crop residue that may harbour the pest.

Monitoring

- Use pheromone traps or lures for H. *armigera, Thaumatotibia leucotreta*, or sample fruits and look for exit holes of caterpillar, frass, damage symptoms, etc.
- Action threshold: One (1) larva per fruit is recommended for implementation of control measures.

Control

Physical control

- Mass trap adult males using pheromone traps to reduce the pest population.

Biological control

- Natural enemies will rarely eradicate all eggs or larvae but may reduce infestations to below economic threshold if predators and parasitoids are not disrupted by broad-spectrum insecticides.
- The most common *Helicoverpa* predators in field crops are predatory bugs, predatory beetles, spiders, lacewings, and ants.

Spodoptera *spp. damage on sweet pepper fruit.(Photo from http://veggiescout.ca.uky.edu/beetarmyworm)*

Biopesticides:

- Neem oil (Azadirachtin 0.3 %): 60 ml/15 l
- Neem oil (Azadirachtin 1%): 30 ml/15 l
- Neem seed extract: 750 g/15 l of water
- *Bacillus thuriengiensis* (Bt)
- *Metarhizium anisopliae*
- *Beauveria bassiana*

Synthetic insecticides (indication of translaminar [TL] or systemic [S])

Active ingredient	PHI	Remarks
Emamectin Benzoate (TL)		
Emamectin Benzoate (40 g/l) (TL) + Lufenuron(50 g/l) (TL)	1 week	Spray in two weeks intervals to control fruit borers. Rotate this active ingredient with other recommended insecticides to prevent resistance development.
Imidacloprid (50 g/l) (S) + Emamectin benzoate (12 g/l) (TL)		
Acetamiprid (16 g/l) (S) + Indoxacarb (30 g/l) (S +TL)	2 weeks	Spray in rotation with other insecticides to control fruit borers
Spinosad (0.24 g/l)	1 day	Spray in rotation with other insecticides to control fruit borers
Tebufenozide (TL) (50 g/l) + Emamectin benzoate (10 g/l) (TL)	1 week	Spray in rotation with other insecticides to control fruit borers
Chlorfenapyr (24%) (TL)	2 weeks	Spray in rotation with other insecticides to contro fruit borers
Novaluron (100 g/l)	1 day	Spray in rotation with other insecticides to contro fruit borers
Biological pesticides	0–3 days	Biopesticide used in rotation with other synthetic insecticides. Much preferred during flowering and fluiting stages.

2.5 Two spotted mites

Common names: Two spotted spider mites
Scientific name: *Tetranychus urticae*
Distribution: Widespread
Stage of crop attacked: Vegetative to reproductive stages

Main damage symptoms:

- Speckling of leaves and fine webbing on the underside of affected leaves. Leaves may turn yellow and dry up, and plants may lose vigour and die when infestations are severe.

Characteristic webbing and yellowing/browning caused by two-spotted spider mites on pepper leaf. (Photo by Sharma, O.P. Bugwood.org)

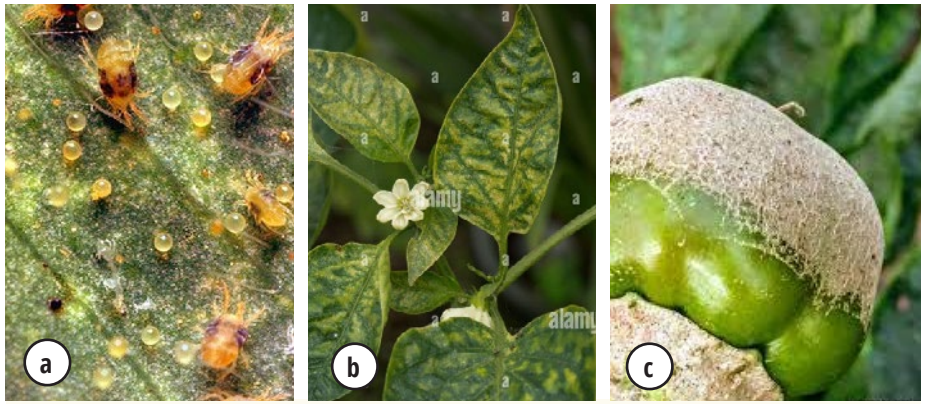
Prevention

Cultural and mechanical practices:

- Timely irrigation and nutrient management are effective preventive tactics.
- Weed control around cropping areas will reduce movement of spider mites and prevent early infestations.

Monitoring

- Mites are very tiny and difficult to see with the naked eye.
- Observe mites closely or aided by a magnifying hand lens.
- Monitor for early symptoms of infestation in the field (e.g., webbing, yellow discolouration, yellow spot or stippling on leaves, mottled leaves, etc.) or their presence.
- Action threshold is 8–14 spider mites/leaf to implement control measures.



Images of the two-spotted spider mites and their characteristic symptoms on sweet pepper fruit and leaves. (a. Photo by Sharma, O.P. Bugwood.org). b. Photo by Nigel Cattlin / Alamy Stock Photo. c. Photo by Ken Gray Insect Image Collection)

Control

Biological control

- In screenhouse or greenhouse environments, predatory mites are excellent choices for where spot-treatment may be adequate instead of area-wide release.
- The trick to success is to release them soon after pest detection to suppress the population.
- Potential biocontrol agents include:
  - *Phytoseiulus persimilis* (good against two spotted spider mites in humid environments)
  - *Amblyseius andersoni* (a native predatory species)
  - *Orius insidiosus* (Pirate bug)
  - *Stethorus* (lady beetles that attack spider mites)
  - *Chrysopa* (green lacewings)

Biopesticides:

- Neem oil (Azadirachtin 0.3 %): 60 ml/15 l
- Neem oil (Azadirachtin 1%): 30 ml/15 l
- Neem seed extract: 750 g/15 l of water,
- horticultural/mineral oils
- paraffinic oils
- other natural oil blends
- Insecticidal soaps – '*alata samina*' (75–120/15 l of water)
- Oxymatrine
- *Metarhizium anisopliae*

Synthetic insecticides

Active ingredient	PHI	Remarks
Abamectin	2 weeks	Spray in rotation with other insecticides to control spider mites
Sulphur (50%) + Copper (8%)	2 weeks	Spray in rotation with other insecticides to control spider mites
Spirotetramat (100 g/l)	1 week	Spray in rotation with other insecticides to control spider mites
Chlorfenapyr (24%)	2 weeks	Spray in rotation with other insecticides to control spider mites
Biological pesticides	0–3 days	Biopesticide used in rotation with other synthetic insecticides. Much preferred during flowering and fluiting stages.

NB: Control mites using miticides or acaricides.

2.6 Broad mites

Common names: Broad mites
Scientific name: *Polyphagotarsonemus latus*
Distribution: Widespread
Stage of crop attacked: Vegetative to reproductive stages

Main damage symptoms:

- Broad mites feed in groups, primarily on the underside of young leaves where females lay eggs. They are cell-feeders using their piercing-sucking mouthparts to feed on the epidermis of leaves.
- This causes leaf margins to curl downward, and leaves may become hardened, brittle, puckered, and/or shrivelled (see photo below).
- Fruit can be misshapen, with blisters and/or cracked.

Prevention

- Weeds within and around greenhouses should be cleared.
- The movement of people or equipment from infested to uninfested areas should be avoided.
- Female broad mites have been known to attach to the legs and antennae of adult greenhouse whitefly (*Trialeurodes vaporariorum*) and/or sweet potato whitefly B-biotype (*Bemisia tabaci*), resulting in another means of dispersal.
- Thus, effective control of whiteflies in the greenhouse will minimise the dispersal of broad mites by them.

Monitoring

- Mites attacks young, growing plant parts, and are very tiny and difficult to detect.
- They usually feed on the lower leaf surface and causes leaf edges to become rigid and roll under and causes distortion and/or discoloration of flowers, aborted buds, malformed/blistering of fruits and stunted growth.
- Sweet pepper has a particularly low tolerance for the broad mites.
- Monitor plants parts regularly, especially the growing points (meristematic region) for the above symptoms/ and presence of broad mites using a magnifying hand lens.
- Although no threshold has been developed, less than five mites on a young pepper plant can cause severe damage resulting in significantly fewer fruit per plant and lower fruit weight (Cho et al., 1996).

Broad mites damage on sweet pepper and female broad mite. (a. Photo credit: Becky Sideman, b. Photograph by D. Riley, University of Georgia, c. electron microscope photograph by Eric Erbe; digital colorisation by Chris Pooley, USDA.)

Control

Physical control

- Hot water treatments may be used to control the mites without injuring the plants. This involves lowering the plant into water held at 43°C to 49°C for 15 minutes (Fasulo, 2019).

Biological control

- Predatory mites and pathogenic fungi are the major natural enemies of broad mites.
- Inoculative releases of the predatory mites *Neoseiulus (Amblyseius) californicus* and *N. barkeri* may be used for biological control, especially in greenhouses.

Biopesticides

- Neem oil (Azadirachtin 0.3%): 60 ml/15 l
- Neem oil (Azadirachtin 1%): 30 ml/15 l
- Neem seed extract: 750 g/15 l of water,
- horticultural/mineral oils
- paraffinic oils
- other natural oil blends
- Insecticidal soaps – '*alata samind*' (75–120/15 l of water)
- Pathogenic fungus, *Metarhizium anisopliae*
- Oxymatrine

Synthetic insecticides

Active ingredient	PHI	Remarks
Abamectin	2 weeks	Spray in rotation with other insecticides to control broad mites
Chlorfenapyr (24%)	2 weeks	Spray in rotation with other insecticides to control broad mites
Spirotetramat (100 g/l)	1 week	Spray in rotation with other insecticides to control broad mites
Biological pesticides	0–3 days	Biopesticide used in rotation with other synthetic insecticides. Much preferred during flowering and fluiting stages.

NB: Control mites using miticides or acaricides. However, broad mite populations may be difficult to suppress with contact miticides because the mites are in the meristematic tissues. Those indicate in the above table are okay.

2.7 Cutworms

Common names: Cutworms
Scientific name: e.g. *Agrotis* spp.
Distribution: Widespread
Stage of crop attacked: Young seedlings

Main damage symptoms:

- They destroy young plants by eating the stems at or near ground level and cutting the seedling down.

Prevention

- The earlier you discover the pests; the easier control of cutworms becomes since it's easier to kill cutworm pests when they are under ½ inch (1.25 cm) long.
- Taking out weeds and early planting also help to prevent cutworm infestations. Picking up plant detritus is another good option since the eggs that hatch into cutworms are laid on dead plant material.
- And when you remove plant debris and destroy it, you will also remove and destroy any cutworm eggs laid there.

Monitoring

- Cutworms aren't that easy to spot anyway since they hide during the day in the soil.
- At night, they come out and feed on the base of plants (young seedlings).
- Some types of cutworms climb up to feed higher on plant stems and the damage will be higher.
- In all cases, the largest larvae do the most cutworm damage.

Cutworms attacking a young seedling stem by cutting it. (Photo by Clemson University-USDA Extension slides)

- Under a freshly cut seedling, you can often find a cutworm larva in the soil.
- Action threshold: One (1) larva per 100 plants and the presence of cut plants indicate that control is necessary.

Control

Cutworms rarely cause economic damage. Apply an approved insecticide late in the afternoon for best control.

Biological pesticide

- Neem based insecticides – Neem cake (1 kg per 10 m²/1 t/ha).
- *Bacillus thuringiensis*

Synthetic insecticides:

Active ingredient	PHI	Remarks
Profenofos (300 g/l) + Lambda-cyhalothrin (15 g/l) or Profenofos (40%) + Cypermethrin (4%)	2 weeks	Spray in rotation with other insecticides to control the cutworm
Imidacloprid or Imidacloprid + Emamectin benzoate	2 weeks	Spray in two weeks intervals to control aphids. Rotate this active ingredient with other recommended insecticides to prevent resistance development.
Fipronil (50 g/l)	2 weeks	Spray in rotation with other insecticides to control cutworms
Thiamethoxam (350 g/l) or Thiamethoxam (141 g/l) + Lambdacyhalothrin (106 g/l)	2 weeks	Spray in rotation with other insecticides to control cutworms
Acetamiprid (16 g/l) + Indoxacarb (30 g/l)	2 weeks	Spray in rotation with other insecticides to control cutworms
Spirotetramat (100 g/l)	1 week	Spray in rotation with other insecticides to control cutworms
Deltamethrin (12.5 g/l)	3 days	Spray in rotation with other insecticides to control cutworms
Chlorfenapyr (24%)	2 weeks	Spray in rotation with other insecticides to control cutworms
Lambda cyhalothrin (25 g/l)	3 days	Spray in rotation with other insecticides to control cutworms
Biological pesticides	0–3 days	Biopesticide used in rotation with other synthetic insecticides. Much preferred during flowering and fluiting stages.

2.8 Mealybugs

Common names: Mealybugs
Scientific names: *Dysmicoccus brevipes, Phenacoccus spp.*
Distribution: Widespread but sporadic
Stage of crop attacked: Vegetative stage

Main damage symptoms:

- Is characterised by a reduction in photosynthesis and growth of plant, due to sap feeding and because of honeydew excretion, sooty mould formation and sometimes virus transmission.

Prevention

- Keep farm and its surroundings free from weeds that harbour mealybugs and ants that tender them.
- Inspect any new plants thoroughly for mealybugs before bringing them to your greenhouse or before planting them.
- If you can't remove all the mealybugs present, discard and destroy the plant.

Monitoring

- They are most often a pest in greenhouses as predators usually keep them under control outdoors.
- They can usually be identified by the fluffy white egg masses.
- Mealybugs usually enter a greenhouse on infested plant material.

Mealybugs attack on pepper leaf. (Image: Sally Tucker, Bugwood.org)

- Mealybugs use their piercing-sucking mouth-parts to withdraw plant fluids.
- Both nymphs (referred to as crawlers) and adults feed on plants and cause stunting, leaf yellowing, and distortion of plant parts.
- Monitor visually observing plant parts (stems, leaves and fruits) for the presence of mealybugs or their damage symptoms (stunted growth, sooty moulds, deformation and yellowing of leaves, sometimes defoliation) to detect early infestation to initiate control measures on time.
- The honeydew produced by mealybugs is often collected by ants which in turn protect the mealybugs against natural enemies.
- Action threshold: Initiate control measures when about 2% of fruits is infested with mealybugs.

Control

Physical control

- Physically remove mealybugs by handpicking or prune them out.

Biological control

- Look for parasite pupae within mealybug colonies, or emergence holes in mummified mealybugs.
- Naturally occurring predators of mealybugs include ladybird beetles, green and brown lacewings, spiders, minute pirate bugs, and larvae of predaceous midges.

Biological pesticides:

- Insecticidal soaps, horticultural oil and neem oil insecticides applied directly on mealybugs can provide some suppression, especially against younger nymphs that have less wax accumulation.
- Insecticides are generally not very effective for mealybugs.

Synthetic insecticides

Active ingredient	PHI	Remarks
Profenofos (40%) + Cypermethrin (4%)	2 weeks	Spray in rotation with insecticidal soaps,horticultural oils or neem oil to control mealybugs
Spirotetramat (100 g/l)	1 week	Spray in rotation with insecticidal soaps,horticultural oils or neem oil to control mealybugs
Biological pesticides	0–3 days	Much preferred during flowering and fluiting stages

NB: Insecticides are generally not very effective for mealybugs. The mealybugs' waxy coating repels most contact insecticides, and their habit of aggregating in hidden locations makes them hard to reach.

3. Diseases of sweet pepper and their management

3.1 Bacterial diseases

3.1.1 Bacterial wilt of pepper

Scientific name of causal organism: *Ralstonia solanacearum*
Distribution: Worldwide
Stage of crop attacked: Seedling, vegetative, or fruiting stage

Description of main symptoms:

- Initial wilt symptoms occur in younger leaves and slight yellowing of older leaves.
- The wilted leaves maintain their green colour and do not fall off as disease progresses.
- Under conditions favourable to the disease, complete wilt occurs.
- The wilting and death of the plant are accompanied by dark brown discoloration of the vascular elements.
- White, milky strand of bacterial ooze flows out when a freshly cut section of infected stem base is placed in water.

Bacterial wilt of pepper. (Source: http://people.umass.edu/)

Prevention

- Quarantine regulations must be enforced to prevent the introduction of exotic pathogen strains that may attack pepper.
- Use disease-free seeds for planting.
- Use disease-resistant varieties/cultivars if available.
- Burn or plough residual crop debris on the field deep into the soil before transplanting.

Monitoring

- Monitor the field for symptoms described above and take appropriate actions.

Cultural control

- Practice farm sanitation to reduce conditions favouring the development and spread of the disease.
- Use soil an amendment containing inorganic and organic mixtures; it can reduce wilt incidence.
- Remove wilted plants with roots as soon as symptoms are observed to minimise the spread of disease from plant to plant.
- Bacterial wilt is very difficult to control once established in a field; hence practice crop rotation using maise-sorghum or maise-onion or garlic and rice to reduce pathogen inoculum.
- Eradicate weeds that may harbour bacteria to reduce the source of inoculum in the field.
- Avoid working or harvesting fields while the foliage is wet. Mechanical spread of the bacterial pathogen is likely.
- Fields should not be irrigated excessively because excess soil moisture favours inoculum build-up.

Physical control

- Soil solarisation upto 2–3 weeks before transplanting can help reduce inoculum in an infected planting medium.
- Use heat sterilisation treatments (steam at 81°C for 30 mins) to control the bacteria in nursery soil before planting.

Synthetic antibiotics

- It is not recommended to use antibiotics used to treat human diseases. This is to prevent cross-resistance. In addition, it is not allowed and is not registered for this use!

3.1.2 Bacterial spot of pepper

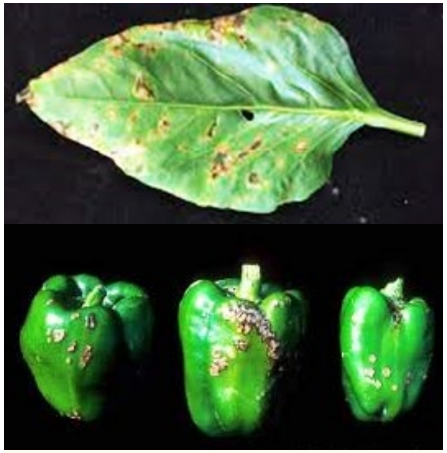
Scientific name of causal organism: *Xanthomonas campestris pv. vesicatoria*
Distribution: Worldwide
Stage of crop attacked: Seedling, vegetative, or fruiting stage

Description of main symptoms:

- Symptoms begin as small, yellow-green circular lesions surrounded by a chlorotic halo on leaves.
- These spots appear water-soaked under wet conditions. As the lesions mature, the chlorosis extends from the area around the lesions on diseased leaves, while the centre of the spots becomes brown to black and sunken.
- Tissues in the centre of the lesion often dry up and break away, giving a 'shot-hole' appearance to the leaf.
- When spots are numerous, they may join together and form irregular discoloured streaks along the veins and leaf margins.
- Edges and tips of leaves may die, then dry and break away, causing leaves to appear ragged.
- Severely spotted leaves turn yellow or brown and fall from the plant; young leaves can be distorted.
- Fruit spots begin as green, circular, slightly raised lesions which eventually become brown or dark, raised, and about ⅛ inch in diameter. Centres of the spots become necrotic, corky, and scab-like.

Prevention

- Use pathogen-free seeds and transplants.
- Use fungicide-coated seeds for planting.
- Use disease-resistant varieties.
- Surface sterilise previously untreated seeds in 2% sodium hypochlorite solution for 3 mins and rinse thoroughly with three changes of sterile water to kill bacterial populations.
- Beetles and other insects spread the bacterium. Use a screen net to protect nursed seedlings from insects that spread the bacterial inoculum.
- Deep plough to bury infected crop debris four weeks before planting.



Bacterial spot symptoms on pepper leaf and fruit. (Source: www.hortnews.extension.iastate.edu and www.vegetablemdonline.ppath.cornell.edu)

Monitoring

- Constantly monitor the crops to identify spotted and striped beetles and other insects or any possible sources of infection for proper action.

Cultural control

- Eliminate wild host plants such as nightshade and ground cherry in and around the field.
- Cull infected plants when observed.
- Practice crop rotation with non-host plants such as baby corn and soybean so that peppers are grown only every 3 to 4 years. However, do not use soybeans in the rotation if white mould (*Sclerotinia sclerotiorum*) has been a problem.
- Avoid working in the field when foliage is wet.
- Use traps like light, sticky traps, and baits to control insects that spread the bacterial inoculum.

Synthetic fungicides

- Spray Copper-based chemicals to protect the plant surfaces from infection.
- Follow chemical labels direction for use.

Synthetic insecticides

- Use Attack 1.9 EC [Emamectin-benzoate (1.9%)] to provide season-long control of spotted and striped beetles, grasshoppers, squash bugs and other insects that spread the pathogen.
- Start insecticide applications soon after trans-planting, even if no beetles are evident.

Active ingredient	PHI	Remarks
Copper hydroxide (770 g/kg)	2 weeks	Apply as a protectant at 5–7 days intervals
Copper oxychloride (35%)	2 weeks	Apply as a protectant at 5–7 days intervals

3.2 Fungal diseases of sweet pepper

3.2.1 Anthracnose of pepper

Scientific name of causal organism: *Colletotrichum capsici*
Distribution: Worldwide
Stage of crop attacked: Fruit

Description of main symptoms:

- Dark brown or black circular depressed lesions develop on any size fruit. Often multiple lesions form on individual fruit.
- When the disease is severe, lesions may coalesce to cover a large fruit area. Often pink to orange masses of fungal spores form in concentric rings on the surface of the lesions.
- In older lesions, black structures called acervuli may be observed. When observed with a hand lens, these black structures look like tiny black dots; they look like tufts of tiny black hairs under a microscope.
- The pathogen sporulates quickly and profusely and can spread rapidly throughout a pepper crop resulting in up to 100% yield loss.
- Lesions may also appear on stems and leaves as irregularly shaped brown spots with dark brown edges.

Anthracnose spots on sweet pepper fruits. (Source: www.apps.lucidcentral.org)

Prevention

- Sow disease-free seeds or fungicide-treated seeds to reduce fungal contamination.
- Seed can also be disinfected by soaking in hot water at 52°C for 30-minutes.
- Use healthy seedlings for transplanting.
- In areas where market constraints and other diseases do not limit the choice of cultivar, cultivars demonstrating a moderate level of resistance (e.g., Colossal, Brigadier, and Paladin) should be chosen for planting.
- Incorporate crop debris into the soil soon after harvest to clean the farm of the previous season's inoculum. Burn the crops residues as an alternative to ploughing.

Monitoring

- Monitor the field for symptoms described above and take appropriate actions.

Cultural control

- Rogue and destroy infected seedlings and transplants by burning them immediately after identifying them.
- Do not use overhead irrigation or apply overhead irrigation during the early part of the day so that plants can dry before sundown.
- Practice farm sanitation to eliminate weeds serving as an alternate host.
- Avoid dense plant stands and prune excess branches to improve air circulation in and around plants.
- The disease can spread in stored fruits; hence infected fruit must be culled during harvesting.
- Fields designated for crop rotation should be planted with non-host crops, e.g., maise and garlic.

Synthetic fungicides

- Fungicides can protect only healthy tissue and don't eradicate existing infections. Complete spray coverage and timing are crucial in preventing the disease.
- Thoroughly spray all new growth as buds begin to open with a protectant fungicide.
- Apply pesticides before rainy periods. If no rains are predicted, you can delay this application. If moist weather prevails, additional applications may be required to protect new growth.

Active ingredient	PHI	Remarks
Mancozeb (800 g/kg)	2 weeks	Apply as a protectant or cure at two weeks intervals
Azoxystrobin (200 g/l) + Difenoconazole (125 g/l)	3 weeks	No more than two applications per season. It can be tank-mixed with a protectant fungicide.
Thiophanate-methyl (70%)	3 weeks	Apply as a cure or when the disease has already occurred. A mixture of chlorothalonil and thiophanate-methyl offers an excellent control.

3.2.2 Cercospora leaf spot

Scientific name of causal organism: *Cercospora capsici*
Distribution: Worldwide
Stage of crop attacked: All developing stages of the fruit

Description of main symptoms:

- Circular leaf spots appear with a light grey centre and a reddish-brown margin, reaching 1 cm in diameter.
- Spots later become tan with a dark ring and a yellowish halo around the ring, resulting in a "frog-eye" appearance.
- Under high humidity conditions and using a good high magnification hand lens, thin, needle-like spores may be seen in the centre of the spots arising from small black fungal tissue.
- The affected centres of lesions dry and often drop out as they age.
- When numerous spots occur on the foliage, the leaves turn yellow and drop or wilt.
- Defoliation is often severe, exposing fruits to sunscald.

Prevention

- Use pathogen-free seeds and seedlings.
- Use disease-resistant cultivars if available.
- Use certified or fungicide-treated seeds to prevent seedling infection.
- Seed soaking in hot water at 52°C for 30-minutes can help reduce the fungus on seeds.
- Planting pathogen-free seed and crop rotation are the most effective prevention strategy.
- Deep ploughing and removal of previous season's crop residues from the field can also be used to prevent the introduction of the pathogen.

Frog-eye spots on pepper. (Source: https://plantix.net/en)

Monitoring

- Constantly monitor the crops to identify any possible sources of infection.

Cultural control

- Avoid overhead irrigation or prolonged moisture to minimise disease severity.
- Avoid working on the field when the leaves are wet.
- Staking increases air movement and may help reduce infection in the field.
- Remove and destroy infected pepper plants immediately after harvest.
- Practising crop rotation for two years may help reduce inoculum in the soil.
- Remove and destroy infected plants/fruits as soon as symptoms are observed to minimise the spread of disease.

Synthetic fungicides

- Follow chemical labels direction for use.

Active ingredient	PHI	Remarks
Mancozeb (800 g/kg)	2 weeks	Apply as a protectant at 5–7 days intervals
Copper hydroxide (770 g/kg)	2 weeks	Use as a protectant; apply 5–7 days interval
Copper oxychloride (35%)	2 weeks	Use as a protectant; apply 5–7 days interval

3.2.3 Choanephora blight (Wet rot)

Scientific name of causal organism: *Choanephora cucurbitarum*
Distribution: Worldwide
Stage of crop attacked: Seed, seedling, vegetative, or fruiting stage

Description of main symptoms:

- Water-soaked lesions appear on the leaves and the margins of the leaves. Leaf tips show blight symptoms.
- Older lesions turn necrotic and appear dried out. The entire plant may wilt.
- Flowers and flower buds turn dark and wilt. Young fruits can be infected.
- Whiskers of the fungus, which are fungal strands with dark-coloured, knobby sporangiola, can be seen with a hand lens on affected plant parts.
- Deep ploughing of the previous season's crop residues from the field can help prevent pathogen introduction.

Prevention

- Use disease-free seeds to establish seedlings.
- Proper trellising – staking in combination with an optimum plant density that increases air movement and can help prevent disease incidence.
- Remove and destroy infected pepper fruits immediately after harvest to prevent the disease from affecting fruits in storage.

Monitoring

- Monitor the field for symptoms described above and take appropriate actions.

Shoot blight (top) and whisker of sporulating fungus (bottom). (Source: https://thefarmertimes.wordpress.com and http//plantpath.ifas.ufl.edu)

Cultural control

- Ensure adequate drainage in fields.
- Avoid overhead irrigation or prolonged moisture to minimise disease severity.
- Avoid excess fertilisation, which creates a dense canopy.
- Remove and destroy infected plants/fruits as soon as symptoms are observed to minimise the spread of disease.
- Remove the spent corolla after fruit set.
- Avoid working on the field when the leaves are wet.

Synthetic fungicides

- Follow chemical labels direction for use.

Active ingredient	PHI	Remarks
Chlorothalonil (400 g/l) + Dimethomorph (80 g/l)	2 weeks	Use as a protectant; apply 5–7 days interval
Mancozeb (800 g/kg)	2 weeks	Apply as a protectant at 5–7 days intervals

3.2.4 Fusarium wilt of pepper

Scientific name of causal organism: *Fusarium oxysporum f.sp capsici*
Distribution: Worldwide
Stage of crop attacked: Seedling, vegetative, or fruiting stage

Description of main symptoms:

- Infected plants display chlorosis and wilting of upper leaves.
- As wilting progress, leaves may turn dull green to brown and remain attached to the plant.
- In severe cases, the entire plant wilts while it is green.
- When the stem and roots are cut diagonally, reddish-brown streaks are visible in the vascular tissues.

Prevention

- Thoroughly disinfect equipment before moving from infected to clean fields.
- Change the position of the nursery every season.
- Remove and burn plant debris from the previous harvest before planting in the field.
- Expose loose dug-out nursery soil to sunlight for four or more weeks before planting. This improves soil aeration and kills pathogens.
- Use fungicide-treated seeds to raise seedlings.
- Plant varieties that are resistant or tolerant to the disease.
- Avoid keeping un-transplanted seedlings at the nursery to grow.

Monitoring

- Constantly monitor the crops to identify any possible source of infection.

Cultural control

- Use clean irrigation water free of fungal and bacteria spores.
- Use raised bed to prevent waterlogging; water spreads the inoculum of *Fusarium*.
- Raising the soil pH reduces the development of this disease.
- Cull infected plants and place them in sealed plastic bags or burn them.

Wilted pepper plant. (Source: http//plantpath.ifas.ufl.edu)

- Enhance farm sanitation and drainage in areas where the pathogen is present.
- Practice crop rotation non-host plants for 2–3 years to reduce pathogen inoculum in endemic areas.

Physical control

Soil treatments:

- Burn dry grass over the nursery soil before forming the beds.
- Practice solar or heat sterilisation in the sunny months by covering the soil with black polythene (250-gauge type) for two or more weeks before planting.
- Disinfect growing media using steam at 81°C for 30 mins.

Biological control

- Use competitor moulds such as *T. harzianum* to inhibit the growth of the pathogen in the growing medium. Apply to growing medium soon after transplanting; after that, repeat once in 20 days.

Synthetic fungicides

- Note that fungicides will not result in very effective control of fusarium wilt in many cases.
- Fungicides containing metalaxyl are mostly preferred for controlling soilborne pathogens.
- Follow chemical labels direction for use.

Active ingredient	PHI	Remarks
Copper oxychloride (350 g/kg) + Metalaxyl (150 g/kg)	3 weeks	Use for drenching the soil; drenching is not feasible for large-scale application
Mancozeb (640 g/kg) + Metalaxyl (80 g/kg)	3 weeks	Use for drenching the soil; drenching is not feasible for large-scale application
Metalaxyl-M (37.5 g/kg) + Chlorothalonil (400 g/kg)	3 weeks	Use for drenching the soil; drenching is not feasible for large-scale application
Chlorothalonil (400 g/l) + Dimethomorph (80 g/l)	3 weeks	Use for drenching the soil and on plant parts close to the ground

3.2.5 Fusarium stem and fruit rot

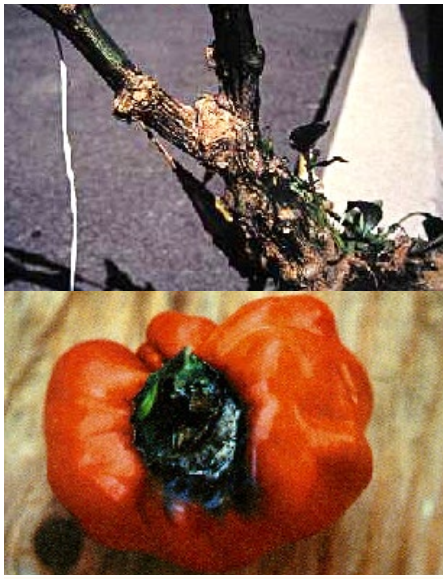
Scientific name of causal organism: *Fusarium solani*

Distribution: Worldwide

Stage of crop attacked: Seedling, vegetative, fruiting stage

Description of main symptoms:

- Black cancers develop on the nodes around prunned parts of the stem or around the places where fruits have been harvested.
- The canker increases in length and width until it girdles the stem.
- The girdling limits water flow to the shoots, causing the above plant parts to wilt and die. Leaves below the lesion do not wilt.
- Plant infected early in the production season produces lesions at the base of the stem.
- Those infected later in the season are more likely to have a lesion at the upper nodes.
- Under humid conditions, orange flask-shaped fruiting bodies develop around the diseased areas.
- Infected fruits develop black, water-soaked lesions around the calyx; lesions spread and advance-drown the side of the fruit.



Black canker and black lesions on the stem and fruit of pepper. (Source: http://www.omafra.gov.on.ca)

Prevention

- Use fungicide-treated seeds to raise seedlings.
- Maintaining a clean seedling production area is paramount in obtaining disease-free seedlings.
- Remove and dispose of previous cropping season's infected plants and other debris before transplanting.
- Remove and discard strings that may harbour spores from infected plants.
- Greenhouses should be thoroughly cleaned between crops to eliminate or reduce the previous season's inoculum in the greenhouse.
- Discard slabs, bags, cubes, pots, and other materials that had infected plants growing in them previously or sterilise them in 2% bleach solution before use.
- Discard previous season's growing media that had infected plants far away from the greenhouse or bury it. This ensures that the fungus inoculum or subsequent overwintering spore inoculum is not carried back into greenhouses by workers, wind, tires, or insects such as shore flies and fungus gnats.
- Do not replant into the same growing material unless it has been steam-sterilised.

Monitoring

- Constantly monitor the crops to identify any possible sources of infection.

Cultural control

- Use a sharp knife for pruning and harvesting. It prevents infection by promoting rapid healing of wounds.
- Environmental control using ventilation to reduce the air temperature and increase air movement through the crop also reduce the incidence and severity of stem rot.
- Always work in the affected areas of the greenhouse last.
- Avoid handling diseased plants and fruits.
- Remove diseased plants /fruits from the greenhouse carefully, taking care not to allow contact of affected portions of plants with adjacent plants, and place them in a plastic bag. Rogueing disease plants help reduce inoculum levels in the greenhouse and prevent disease spread.
- Additionally, remove about 1–2 plants on either side of the plant(s) exhibiting symptoms and place them in garbage bags.
- Maintain farm hygiene in and around the farm; sanitation measures offer the best control of *Fusarium* stem rot.
- Practice crop rotation with non-host plants for 2–3 years to reduce pathogen inoculum in areas where the disease is prevalent.

Physical control

- Disinfect seedling beds using steam or solar radiation before planting.

Synthetic fungicides

- Fungicides can protect only healthy tissue and don't eradicate existing infections. Complete spray coverage and timing are crucial in preventing disease development and subsequent spread. Spray all new growth, such as buds, young leaves, flowers, and fruits with protectant fungicides.
- Follow chemical labels direction for use.

Active ingredient	PHI	Remarks
Mancozeb (640 g/kg) + Metalaxyl (80 g/kg)	3 weeks	Apply as a protectant, 10–14 days interval
Mancozeb (800 g/kg)	2 weeks	Apply as a protectant at 5–7 days intervals
Copper oxychloride (350 g/kg) + Metalaxyl (150 g/kg)	3 weeks	Apply as a protectant at 10–14 days interval

3.2.6 Gray leaf spot of pepper

Scientific name of causal organism: *Stemphylium solani*
Distribution: Worldwide
Stage of crop attacked: All stages of growth

Description of main symptoms:

- Small necrotic spots develop on pepper leaves, petioles, stems, fruit peduncles, and calyx.
- Young seedlings are most susceptible.
- Infection begins as tiny red to brown spots that later expand into large lesions with white to grey centres and red to brown margins.
- When numerous lesions develop, leaves turn yellow and drop quickly.
- Gray leaf spot does not affect fruit, but excessive defoliation reduces fruit yield.

Prevention

- Use fungicide-treated seeds for raising seedlings.
- Plant high-quality transplants free from gray leaf spots.
- Provide adequate drainage for seedling beds and treat seedlings with fungicides to prevent disease incidence.

Monitoring

- Monitor the field for symptoms described above and take appropriate actions.

Gray leaf spot symptoms on pepper. (Source: https://www.peppergeek.com)

Cultural control

- Practice a three-year or longer crop rotation with non-host crops such as small grains.
- Eliminate crop debris, volunteers, and weeds that can serve as alternate hosts.
- Reduce periods of leaf wetness by avoiding overhead irrigation and dense plantings.
- Orientating rows parallel to the prevailing wind direction can promote rapid leaf drying and help reduce periods of extended leaf wetness.
- Plant beds should be well-drained to avoid excess moisture and promote rapid drying of the foliage after watering.

Synthetic fungicides

- Follow chemical labels direction for use.

Active ingredient	PHI	Remarks
Mancozeb (800 g/kg)	2 weeks	Apply as a protectant at 5–7 days intervals
Chlorothalonil (400 g/l) + Dimethomorph (80 g/l)	2 weeks	Use as a protectant; apply at 10–14 days intervals

3.2.7 Gray mould of pepper

Scientific name of causal organism: *Botrytis cinerea*
Distribution: Worldwide
Stage of crop attacked: Seedling, vegetative, or fruiting stage

Description of main symptoms:

- Symptoms and signs of infection appear first on flower petals, at injury sites, or on senescent tissues.
- Fruits symptoms begin as water-soaked spots that expand rapidly into large, light-coloured lesions.
- The lesions give rise to numerous long conidiophores and can easily be seen with the unaided eye.
- Individual conidiophores on flowers and stems of young seedlings can be seen protruding from lesions, giving the affected plant parts a spiny appearance.
- Young seedlings affected by gray mould are at risk of dumping off due to stem lesions originating at the node of the cotyledon or extending below it. Seedlings may also exhibit tip dieback as they grow older.
- Lesions on fruits, stems, and leaves of older plants are covered with thick, matted masses of grey to brown conidiophores and conidia, which are velvet-like in appearance.

Prevention

- The control of gray mould in plant beds and greenhouses starts with sanitation. Before seed sowing or transplanting seedlings, all plant debris that could serve as a substrate for the pathogen should be removed or incorporated deep into the soil. This will clean the farm of the previous season's inoculum.
- Burn the plant residues as an alternative to ploughing.
- Green manure should be incorporated into the soil and allowed to decompose well before establishing a new crop to minimise the substrate available to B. cinerea in the field.

Gray mould of pepper. (https://www.pnwhandbooks.org)

- Select cultivars resistant or tolerant to the disease.
- Use pathogen-free seeds or fungicide-treated seeds for planting.

Monitoring

- Monitor the field for symptoms described above and take appropriate actions.

Cultural control

- Prune plants to promote adequate ventilation and apply fungicides to the pruning wounds to help reduce losses from this disease.
- Carefully manage irrigation and air circulation to avoid long periods of high relative humidity in greenhouses.
- At night maintain the greenhouse temperature higher than outdoors to prevent water condensation on leaves.
- Enhance farm sanitation to eliminate alternate host weeds.
- Remove and destroy infected plant tissues once spotted on the farm.
- Rotate pepper with non-host crops such as cereals or legumes for 2–3 years to reduce inoculum in areas where the disease is widespread.

Synthetic fungicides

- Spray all new growth, such as buds, young leaves, flowers, and fruits with fungicides to protect healthy tissues.
- Follow chemical labels direction for use.

Active ingredient	PHI	Remarks
Copper hydroxide (770 g/kg)	2 weeks	Apply as a protectant at 5–7 days intervals
Chlorothalonil (400 g/l) + Dimethomorph (80 g/l)	2 weeks	Apply as a protectant at 2 weeks interval
Azoxystrobin (200 g/l) + Difenoconazole (125 g/l)	3 weeks	Apply the chemical as a cure. No more than two applications per season.

3.2.8 Phytophthora blight

Scientific name of causal organism: *Phytophthora capsici*
Distribution: Worldwide
Stage of crop attacked: Seedling, vegetative, or fruiting stage

Description of main symptoms:

- *P. capsici* causes root and crown rot of pepper and distinctive black lesions on stems.
- Root infections typically lead to wilting of the plant.
- The pathogen can also infect leaves, causing circular, greyish brown, water-soaked lesions.
- Leaf lesions and stem lesions are common when inoculum is dispersed from the soil to the lower portion of the plant.
- *P. capsici* can also infect fruit, causing lesions that are typically covered with white sporangia, a sign of the fungus.

Prevention

- Use fungicide treated seeds for planting.
- Select pepper cultivars that are resistant to the disease.
- Remove and burn previous cropping season's infected plants and other debris before transplanting.
- Transplant only healthy seedlings.
- Avoid poorly drained soils and low-lying areas when selecting a site for planting.

Monitoring

- Monitor the field for symptoms described above and apply control actions.
- Survey the field for areas with waterlogging and then manage it. Management of soil moisture reduces the conditions needed for the growth of *Phytophthora*.

Leaf blight of pepper caused by P. capsci. *(Source: https://www.u.osu.edu)*

Cultural control

- Always plant peppers on dome-shaped ridges or well-drained sites to reduce disease incidence.
- Avoid overhead irrigation.
- Do not work on the field when the leaves are wet.
- Enter infested greenhouses and fields last and clean equipment before moving to others.
- Removed and destroy infected plant tissues.
- Eliminate crop debris, volunteers, and weeds that may serve as alternate hosts.
- Rotate pepper with non-susceptible host crops for a minimum of two years, preferably four years. Grain crops are the most suitable (e.g., corn and small grains), but crucifers are an excellent option.

Synthetic fungicides

- Spray all new growth, such as buds, young leaves, flowers, and fruits with fungicides to protect healthy tissues.
- Follow chemical labels direction for use.

Active ingredient	PHI	Remarks
Mancozeb (640 g/kg) + Metalaxyl (80 g/kg)	3 weeks	Apply as a protectant at 2 weeks interval
Metalaxyl-M (37.5 g/kg) + Chlorothalonil (400 g/kg)	3 weeks	Apply as a protectant at 2 weeks interval
Chlorothalonil (400 g/l) + Dimethomorph (80 g/l)	2 weeks	Apply as a protectant at 2 weeks interval

3.2.9 Powdery mildew of pepper

Scientific name of causal organism: *Leveillula taurica*
Distribution: Worldwide
Stage of crop attacked: Any growth stage

Description of main symptoms:

- The fungus only infects the leaves, not the fruit or stems of pepper plants.
- Check for pepper powdery mildew by closely inspecting the underside of older leaves for the first signs of the disease.
- Look for fluffy, white patches of powdery mildew on the underside of leaves. With time, these patches may turn brown rather than remain white.
- The upper surface of the leaf may appear normal or have diffuse, yellow patches which correspond to the mildew colonies on the lower surface.
- Early powdery mildew infections can be seen easily by holding the leaf up to a light and looking for developing mildew colonies.
- Severely infected leaves wither and drop off, causing plants to die.

Prevention

- Follow strict greenhouse hygiene throughout the growing season. Conduct a thorough year-end clean-up and dispose of all crop debris offsite or by burning or burying in a landfill site. This helps to get rid of the primary inoculum.
- Keep ornamentals and imported tropical plants out of the greenhouse and immediate area.
- Use resistant cultivars when possible.
- Use fungicide-treated seeds for planting.
- Avoid the establishment of plants in areas shaded by tall plants or structures.

Powdery mildew symptoms on pepper leaves. (Source: https://www.ppath.cornell.edu)

Monitoring

- Frequent field monitoring for the above symptoms gives a head start for control.

Cultural control

- Restrict visitors' access to the greenhouse.
- Avoid overhead irrigation, and dense plant stands.
- Do not work in the field when the leaf surfaces are wet.
- Rogue infected plants as soon as they are spotted.
- When working in the greenhouse/field, work last at the infected areas.
- Control outdoor weeds surrounding the greenhouse.
- Improve greenhouse climate to reduce relative humidity and increase air circulation.
- Clean equipment used in infested greenhouses before moving to others.
- A 2-year rotation with non-host crops is beneficial in reducing pathogen inoculum.
- Plant trap crops around the field to reduce inoculum reaching the field from neighbouring farms.

Synthetic fungicides

- Follow chemical labels direction for use.

Active ingredient	PHI	Remarks
Sulphur (80%)	2 weeks	Use as a protectant; apply at 7 days intervals. It should not be used at the flowering stage. It has a negative impact on beneficial organisms.
Azoxystrobin (500 g/kg)	3 weeks	No more than two applications per season. It can be tank-mixed with a protectant fungicide.
Tebuconazole	2 weeks	For suppression only; apply 10–14 days interval.

3.2.10 Southern blight of pepper

Scientific name of causal organism: *Sclerotium rolfsii*
Distribution: Worldwide
Stage of crop attacked: Any growth stage

Description of main symptoms:

- The pathogen attacks the stem of the pepper plant near the ground, causing the plant to turn yellow and wilt.
- The plant's stem turns brown and decays above and below the soil line.
- The lower part of an infected stem remains intact, and the rest of the plant wilts and turns brown.
- The fungus is often evident as a white mycelial mat that grows on the stem and the surrounding soil.
- Lesions on fruit are water-soaked and filled with mycelia and sclerotia.

Prevention

- Selecting a field that is free of *S. rolfsii* is the most successful method of control.
- Disease seedlings should not be introduced into the field.
- Choosing a planting date that avoids a wet, warm period prevents disease incidence.
- The fungus is highly aerobic, hence burying infected plant debris and sclerotia by deep ploughing (at least 20 cm deep) with a mouldboard extension that inverts soil helps kill the fungus inoculum.
- Buried soil must not be brought back to the surface during the growing season.
- Discard slabs, bags, cubes, pots, and other materials that had infected plants growing in them previously or sterilise them in 2% bleach solution before use.
- Do not replant into a growing medium that had infected plants in them previously unless it has been steam-sterilised.

Monitoring

- Monitor the field for symptoms described above and take appropriate actions.

Southern blight of pepper. (Source: https://www.ppath.cornell.edu)

Cultural control

- Visit farm regularly to rogue diseased plants.
- Plants should not be injured during cultivation.
- A wide plant spacing helps to lower disease incidence.
- Raising the soil pH through liming can help manage the disease to some extent.
- Practice crop sanitation and hygiene by regularly weeding and removing plant debris around the plants to limit southern blight incidence and severity.
- Use a two to three-year crop rotation program with non-host crops to break the disease cycle in areas where the disease is a problem.

Physical control

- Sterilise soil by covering it with a black polyethene sheet for two or more weeks during the sunny months before planting. This traps heat to kill sclerotia in the top soil.
- Disinfect growing media using steam at 81°C for 30 mins.

Biological control

- Use competitor moulds such as *T. harzianum* to inhibit pathogen growth in the planting medium. Apply mould to growing medium soon after transplanting; after that, repeat once in 20 days.

Synthetic fungicides

- Follow chemical labels direction for use.

Active ingredient	PHI	Remarks
Azoxystrobin (200 g/l) + Difenoconazole (125 g/l)	3 weeks	No more than two applications per season. It can be tank-mixed with a protectant fungicide.

3.2.11 Verticillium wilt of pepper

Scientific name of causal organism: *Verticillium dahliae*
Distribution: Worldwide
Stage of crop attacked: At any stage of growth

Description of main symptoms:

- Symptoms include yellowing and defoliation on a few branches or the entire plant.
- The edges of the leaves roll inward on infected plants, and foliar wilting ensues. The foliage of severely infected plants turns brown and dry.
- The growth of pepper plants infected by aggressive strains of *V. dahliae* early in the season under field conditions is severely stunted with small leaves that turn yellow-green.
- Subsequently, the dried leaves and shrivelled fruits remain attached to plants that die.
- Brown discolouration of the vascular tissue is visible when a wilted plant's roots and lower stem are cut longitudinally.

Prevention

- Use resistant/tolerant cultivars if available.
- Use certified disease-free seeds for planting.
- Follow a strict greenhouse sanitation program throughout the year.
- Use sterile soil for raising seedlings.
- Plant early to escape periods of prolonged wetness.
- Avoid planting in media that had infected plants growing in them previously unless it has been sterilised.
- Select sites that are free from the disease for planting.

Monitoring

- Frequently scout and monitor plants for the above symptom and take appropriate action.

Cultural control

- Remove infected plants as soon as they are spotted.
- Additionally, remove about 1–2 plants on either side of the plant(s) exhibiting symptoms and place them in garbage bags.

Verticillum wilt infected pepper (top) and vascular discolouration within plant (bottom). (Source: http://www.omafra.gov.on.ca)

- Create good drainage to avoid excess water on the field.
- Maintain fields clean of weeds that may serve alternate hosts.
- Disinfect all tools used in pruning to prevent spreading disease from infected to healthy individuals.
- Crop rotation for three to four years with non-host crops is recommended to reduce inoculum and subsequent plant infection.

Physical Control

- Soil fumigants containing Chloropicrin can effectively control Verticillium wilt in many crops.
- Fumigation together with soil steaming and solarisation methods, increases the rate of propagule death, resulting in a reduced pathogen population.

Synthetic fungicides

- In most cases, fungicides may not cure existing infections. Hence apply fungicide treatments to protect the plants, starting from the seedling stage.
- Follow chemical labels direction for use.

Active ingredient	PHI	Remarks
Chlorothalonil (400 g/l) + Dimethomorph (80 g/l)	2 weeks	Use as a protectant; apply by drenching the soil, 5–7 days interval
Azoxystrobin (200 g/l) + Difenoconazole (125 g/l)	3 weeks	No more than two applications per season. It can be tank-mixed with a protectant fungicide.
1, 3-Dichloropropene (60.8%) + Chloropicrin (33.3%)		Use as a pre-plant soil disinfectant (fumigant). Apply to soil 2–4 weeks before planting.

3.2.12 White mould of pepper

Scientific name of causal organism: *Sclerotinia sclerotium*
Distribution: Worldwide
Stage of crop attacked: Any of the growth stages

Description of main symptoms:

- The first symptoms of white mould are dark-green, water-soaked lesions that develop on foliage, stems, and fruit.
- Occasionally, the host may exhibit dry lesions on the stalk, stem, or branches with a well-defined border between healthy and diseased tissues.
- Stem infections frequently encircle the stem at the soil line, causing plants to wilt and die.
- Petiole or bud infections proceed downward in the plant rapidly.
- Fruit infected directly from the soil surface or through the peduncle rot quickly into a watery mass.
- In advanced stages, white, cottony mycelium blankets affected tissue, and sclerotia form on the surface.
- Sclerotia also may form within the stem pith and fruit cavities, becoming black and hard as they mature.

White mould infection on stem and fruit of sweet pepper (Source: https://pnwhandbooks.org)

Prevention

- Use certified disease-free seeds for planting.
- Use sterile soil for raising seedlings.
- Manure and plant mulches suspected to come from infected locations should not be used for planting.
- Follow a strict greenhouse sanitation program throughout the year.
- Remove all plant debris from previous crops and burn them.
- Plant early to escape periods of prolonged wetness.

Monitoring

- Observe plants daily and take appropriate measures if symptoms are detected.

Cultural control

- Maintain fields clean of weeds that may serve alternate hosts.
- Greenhouses should be well ventilated to reduce disease incidence.
- Plant in well-drained soil, use wide row spacing and water early in the day.
- Crop growth should be monitored to avoid a dense canopy that encourages mould growth.
- Establish a crop rotation program with non-host crops such as corn, small grains, and grasses to reduce inoculum and subsequent plant infection.
- Cull infected plants as soon as symptoms are observed.

Physical control

- Soil fumigation with Chloropicrin can be effective at reducing soilborne inoculum.
- Soil solarisation and heat sterilisation methods can also kill inoculum in growing media before planting.

Synthetic fungicides

- In most cases, fungicides may not cure existing infections. Hence apply fungicide treatments to protect the plants.
- Follow chemical labels direction for use.

Active ingredient	PHI	Remarks
Copper hydroxide (770 g/kg)	2 weeks	Apply as a protectant on aerial plant parts at 2 weeks interval
Azoxystrobin (200 g/l) + Difenoconazole (125 g/l)	3 weeks	No more than two applications per season. Use for soil drenching and spraying aerial plant parts.
1, 3-Dichloropropene (60.8%) + Chloropicrin (33.3%)		Use as a pre-plant soil disinfectant (fumigant). Apply to soil 2–4 weeks before planting.

3.3 Nematodes of sweet pepper

3.3.1 Root-knot of pepper

Scientific name of causal organism: *Meloidogyne* spp.
Distribution: Worldwide
Stage of crop attacked: Seedling and vegetative stages

Description of main symptoms:

- Symptoms of nematode infestations reflect those of a malfunctioning root system.
- Feeding by root-knot nematodes results in characteristic galls on roots.
- Galled roots appear malformed, shortened, and thickened.
- Roots of plants infested with stubby root nematode are likely to have numerous, short and stubby lateral roots.
- Aboveground symptoms of nematode infestations include patches of chlorotic, stunted, necrotic, or wilted plants.
- Nematode-infested plants are more susceptible to moisture or temperature stress and exhibit stress symptoms earlier than other plants.
- Nematode-damaged root systems are often more susceptible to infection by soilborne fungi such as *Fusarium* and *Verticillium*.

Prevention

- Use nematode-resistant varieties for planting if available.
- Plough the field deep enough or turn the soil to expose nematodes to solar radiation for two weeks or more before planting.
- Mulch field with a black plastic sheet. This produces steam to kill the nematodes.
- Avoid the use of manure and plant mulches suspected to come from infected locations.

Monitoring

- Initial soil samples should be examined to determine the total nematode population for immediate action before and during plant establishment.

Galling of pepper roots due to Meloidogyne *spp. (Source: https://infonet-biovision.org)*

Cultural control

- Intercrop pepper with trap crops as the main crop for nematode control.
- Ensure adequate drainage system on the field.
- Crop rotation may not be feasible in fields infested with nematodes because of their extensive host range; care is needed to select rotation crops because some may be good alternate hosts.

Physical control

- Practice heat sterilisation of soil (or steam at 81°C for 30 mins) in the sunny months using a black polythene cover (250-gauge type) for two or more weeks before planting.
- Solar sterilisation of field beds (clear instead of black polythene sheet) for three weeks can be used to kill and control nematodes. These treatments lower the nematodes population in the topsoil to help plants escape an early infestation.

Biological control

- Plant repellent plants such as marigold in between rows to control nematode population.
- Apply 2 kg of MULTIPLEX Niyantran (Paecilomyces) in 100 kg FYM and broadcast uniformly on an acre of land.
- Application of 250-400 kg of neem cake/ha is useful in controlling nematode population build-up in the soil.

Synthetic nematicides

- Follow chemical labels direction for use.

Active ingredient	PHI	Remarks
1, 3-Dichloropropene (60.8%) + Chloropicrin (33.3%)		Use as a pre-plant soil disinfectant (fumigant). Apply to soil 2–4 weeks before.
Fosthiazate (5%)	14 days	Soil application. Apply into the soil after planting.
Oxamyl	14 days	Foliar applications are not effective for controlling moderate and high populations of nematodes

3.4 Viruses of sweet pepper

3.4.1 Alfalfa mosaic virus of pepper

Scientific name of causal organism: *Alfalfa mosaic virus (AMV)*
Distribution: Worldwide
Stage of crop attacked: Any of the growth stages

Description of main symptoms:

- The foliage displays distinct bright yellow to white mosaic symptoms, occasionally causing large areas of the interveinal leaf tissue to appear bleached.
- Chlorotic line patterns and veinal necrosis also may occur.
- Generally, the leaves are not distorted in shape.
- If infection occurs in young plants, the plants become stunted with misshaped fruits.

Prevention

- Pepper varieties resistant to AMV are not available.
- Use virus-free pepper seeds for planting.
- Establish nursery under Nylon net cover (50 mesh) to protect young plants from aphids.
- Always transplant healthy virus-free seedlings in the field.
- Do not plant pepper in proximity to other susceptible hosts of AMV (alfalfa, pepper, tomato, tobacco, potato, clover, many cucurbits and beans, and several weeds) that act as virus reservoirs.

Monitoring

- Frequent monitoring of symptoms on the field will enhance early control.

Yellow mosaic symptoms on pepper leaves. (Source: https://invasive.org)

Cultural control

- Various control measures are required because AMV can be transmitted in many ways: seeds, aphids, and mechanically.
- Check transplants for symptom development and discard those with symptoms.
- Eradicate infected plants and weed hosts in the nursery and field early enough to prevent disease spread.
- Maintain weed control in and around the pepper plantings.
- Disinfect tools, stakes, and equipment before moving from diseased to healthy areas in the greenhouse.
- Work in unaffected parts of a field first before working in diseased areas.
- Plant barrier crops that are not susceptible to AMV, such as corn, millet, etc.
- Spray the pepper crop with mineral oil to delay virus spread in the field by interfering with aphid transmission of the virus.

Control of insect vector with synthetic insecticides

- Viruses cannot be controlled directly, so the vector needs to be managed.
- Grow trap crops nearby to attract aphids and then spray these plants with a contact insecticide to destroy the aphid populations.
- Aphid control may be difficult because these insects transmit the virus very rapidly. Use fast-acting insecticide sprays since aphids may move to nearby unsprayed plants when disturbed.
- See the section on aphids for a list of recommended insecticides.

3.4.2 Beet curly top virus of pepper

Scientific name of causal organism: *Beet curly top virus (BCTV)*
Transmission: The beet leafhopper *(Circulifertenellus)*
Distribution: Worldwide
Stage of crop attacked: Seedling, vegetative or reproductive stage

Description of main symptoms:

- BCTV disease symptoms of tomatoes, peppers, and beans are common and mimic symptoms of moisture stress. However, with BCTV, the stress symptoms may not be reversed after watering.
- Symptoms include stunting, yellowing, and curling of leaves upwards. Leaves also thicken to become stiff and crisp.
- Petioles curl downward while fruits appear dull, wrinkled, and ripen prematurely.
- Fruit set reduces significantly in infected plants.
- Mature plants tend to be less susceptible to the virus; however, early infection in young plants may lead to wilting and death.
- This virus is not mechanically transmitted.

Prevention

- Use disease-resistant varieties if available.
- Transplant only virus-free seedlings in the field or greenhouse.
- Establish nursery under Nylon net cover (50 mesh) to protect young plants from aphids and leafhoppers.

Monitoring

- Timely monitoring of the plants for the above symptoms is key to control.

Cultural control

- Transplant early or late to escape leafhopper infestations increase plant density to compensate for losses due to BCTV.
- Rogue infected plants in the greenhouse and field to reduce disease spread.
- Control weeds near pepper fields to reduce virus reservoirs.
- Use intercropping to protect pepper plants from leafhoppers.
- Plant barrier crops that are not susceptible to BCTV, such as corn, millet, etc.
- Plant trap crops near the pepper plants to attract insect vectors and then spray these plants with a contact insecticide to kill the insects.

Control of insect vector with synthetic insecticides

- Viruses cannot be controlled directly, so the vector needs to be managed.
- Use insecticides to control insect vectors, such as aphids and leafhoppers.
- See section on aphids for recommended insecticides.

Beet curly top virus symptoms on pepper. (Source: https:// agnetwest.com)

3.4.3 Chili leaf curl virus

Scientific name of causal organism: *Tobacco leaf curl virus (TLCV)*
Transmission: Whitefly *(Bemisia tabaci)*
Distribution: Worldwide
Stage of crop attacked: All stages of the crop

Description of main symptoms:

- Symptoms consist of upward and downward curling of leaves.
- Leaf margins develop pale green to yellow colour, which extends into the interveinal areas.
- The nodes and internodes reduce in size significantly.
- The infected plants assume a bushy appearance with severely stunted growth.
- The plant generally looks pale and produces several lateral branches giving a bushy appearance.
- The fruits from infected plants are small and deformed.
- TLCV is a single-stranded DNA virus.

Prevention

- Use resistant/tolerant pepper varieties to reduce the rate of disease development.
- Raise seedling under Nylon net cover (50 mesh) to shield the young plants from whiteflies.

Leaf curl symptoms on pepper caused by TLCV . (Source: https://www. saillog.co)

Monitoring

- Monitor and scout for whiteflies for immediate control of their population.

Cultural control

- Control/minimise whitefly populations by using plastic mulch and yellow sticky traps.
- Use intercropping or trap crops to protect pepper plants from whiteflies.
- Eradicate infected plants early and control the population of weed hosts in the field.
- Two rows of border cropping using a cereal crop can help reduce the rate of disease spread.

Control of insect vector with synthetic insecticides

- Viruses cannot be controlled directly, so the vector needs to be managed.
- Spray imidacloprid (Confidor) to control sucking insects.
- Chemical spray followed by neem seed kernel extract (2%) is effective in the rotation of insecticides.
- See the section on Whitefly for more information on recommended insecticides.

3.4.4 Cucumber mosaic virus of pepper

Scientific name of causal organism: *Cucumber mosaic virus (CMV)*
Transmission: Aphids
Distribution: Worldwide
Stage of crop attacked: All stages of the crop

Description of main symptoms:

- Symptoms vary widely. One of the most common expressions is a severely stunted, non-productive plant with a dull light green foliage that looks leathery.
- In some cases, the leaves become narrow and stop growing, while in others, small necrotic specks or ring spots with oak leaf patterns develop.
- Sometimes a necrotic line develops across the leaf.
- Affected leaves may drop prematurely.
- Older plants may show foliar mottling or no symptoms on foliage or fruit.
- Fruits become wrinkled, bumpy, pale yellow-green, sometimes with sunken lesions.
- On some varieties, lines or ring spots may develop.

Mosiac symptoms on pepper caused by CMV. (Source: ijcmas.com)

Prevention

- Current control measures for CMV are mainly preventive due to the virus's wide host range and numerous aphid vectors.
- Grow seedlings in a structure or seedbed protected with a mesh (size 32) to protect young plants from aphids.
- Use resistant/tolerant seeds for raising seedlings.
- Transplant only virus-free seedlings to the field.

Monitoring

- Monitor and scout for aphids for immediate control of their population.

Cultural control

- Disinfect tools, stakes, and equipment before moving from diseased to healthy areas. Hands and devices may be washed with soap or milk.
- Plant barrier crops that are not susceptible to CMV, such as corn, to shield the main plants from insects.
- Use sticky traps or ground covers that deter aphids.
- Grow trap crops nearby to attract aphids and then spray these plants with a contact insecticide to kill the aphids.
- Control/minimise aphid population by using plastic mulch and yellow sticky traps.
- Rogue infected plants in the greenhouse and field to reduce disease spread.
- Eliminate weeds in and around the pepper fields to reduce virus reservoirs.

Control of vector with synthetic insecticides

- Insecticide sprays that are not fast-acting may be less effective because aphids move to nearby unsprayed plants when disturbed. Consequently, use fasting acting insecticide to control aphids.
- Spray imidacloprid (Confidor) to control sucking insects.
- Spray seedlings before transplanting and every two weeks after transplanting until the flowering stage.
- Chemical spray followed by neem seed kernel extract (2%) is also effective in the rotation of insecticides.
- See section on Aphids for recommended insecticides.

3.4.5 Potato virus Y of pepper

Scientific name of causal organism: *Potato virus Y (PVY)*
Transmission: Aphids
Distribution: Worldwide
Stage of crop attacked: Any of the growth stages

Description of main symptoms:

- Plants can be infected at any growth stage by virus-transmitting aphids.
- Symptoms of PVY include stunting, systemic vein clearing, leaf mosaic or mottling, and dark green vein-banding of the leaves.
- Necrosis in the veins and petioles often develops. This may be followed by stem necrosis and defoliation, death of the top buds, and plant death.
- Fruits become smaller and deformed with a mosaic pattern on the skin tissues.
- Symptoms of other viruses may mask PVY symptoms.

Potato virus Y symptoms on pepper. (Source: invasive.org)

Prevention

- The most effective control measure is the use of resistant cultivars.
- Protect the young seedlings from aphids using screen nets.

Monitoring

- Monitor and scout for aphids for immediate control of their population.

Cultural control

- Plant early to avoid high aphid populations that occur later in the season.
- Reflective mulches may be used to repel aphids, thereby reducing the spread of aphid-borne viruses.
- Avoid planting peppers close to established tomato, tobacco, and pepper fields since these fields may harbour aphids.
- Spray weeds bordering the field with an insecticide before weeding. This will prevent the aphids from moving to hide in other plants during weed control.
- Destroy all annual weeds in the field, including those in ditches, hedges or fencerows, and other locations. Weed control can effectively lower virus reservoirs.
- Where feasible, infected plants should be pulled up and destroyed, but only after spraying them thoroughly with an insecticide to kill the insects, they may harbour.
- Encourage natural enemies of aphids by practicing mixed cropping.
- Sprays mineral oil to reduce the virus's transmission frequency by the vector and delay the development of the disease in the pepper crop.

Control of vector with synthetic insecticides

- Viruses cannot be controlled directly, so the vector needs to be managed
- See the section Aphids to find information on recommended insecticides.

3.4.6 Tobacco etch virus of pepper

Scientific name of causal organism: *Tobacco etch virus (TEV)*
Transmission: Aphids
Distribution: Worldwide
Stage of crop attacked: Any of the growth stages

Description of main symptoms:

- The severity of symptoms depends on the time of infection, the variety grown, and the virus strains present.
- Infected pepper plants show foliar mottling or mosaic patterns, leaf distortion, and stunting. Vein-clearing and vein-banding symptoms also occur.
- Plants infected early have small, misshapen fruit and can be severely stunted.
- Fruits from such plants have severe mosaic symptoms.
- Tabasco pepper infected with *TEV* shows root necrosis, wilting, and death. Symptoms may be confused with other viruses such as potato virus Y *(PVY)* or pepper mottle virus *(PMV)*.

TEV symptoms of pepper leaves and fruits (Source: pinterest.com)

Prevention

- The most effective control measure is the use of resistant cultivars.
- Use a net house or screen house with 32-mesh or finer to keep out aphids during the seedling stage of the plants.
- Use virus-free and aphid-free transplants and minimise plant handling during the growing season to reduce the mechanical spread of the virus.

Monitoring

- Monitor and scout for aphids for immediate control of their population. Monitor aphid populations early in the season and apply fast-acting insecticide treatments.

Cultural control

- Plant earlier to avoid high aphid populations that occur later in the season.
- Remove nearby volunteer plants and solanaceous weeds from production fields, nearby ditch banks, hedges, fence-rows, or other locations.
- Use reflective mulches to reduce aphid visits to plants and delay virus spread.
- Intercrop pepper with trap crops to serve as the main crop for aphid control.
- Encourage natural enemies of aphids by practicing mixed cropping.
- Spray mineral oil to reduce the virus transmission frequency by the vector and delay the development of the disease in the pepper crop.

Control of vector with synthetic insecticides

- Chemical control of the insect vectors in the field is generally difficult because of insecticide resistance development. Consequently, rotating the insecticide classes is the best approach to insect control.
- Several insecticides (e.g., imidacloprid) applications should be made at 5-day intervals to significantly reduce aphid infestation in seedlings.
- See section Aphids for recommended insecticides.

3.4.7 Tobacco mosiac virus of pepper

Scientific name of causal organism: *Tobacco mosaic virus* (TMV)
Transmission: Mechanically
Distribution: Worldwide
Stage of crop attacked: Any of the growth stages

Description of main symptoms:

- Foliar symptoms of *TMV* in pepper are variable but are generally mild. They include chlorotic mosaic, distortion, and at times, systemic necrosis and defoliation.
- Infected seedlings become stunted and are generally chlorotic.
- Leaves develop a subtle mosaic, can be crinkled, and remain small.
- Infected plants produce small, disfigured fruits, usually with distinct chlorotic and/or necrotic areas.
- Fruit may be mottled, rough, or wrinkled.

Symptoms of TMV *on pepper leaves and fruits. (Source: pinterest.com)*

Prevention

- *TMVs* are not a significant problem in open field pepper production when an indexed seed is planted and preventive sanitation practices are established. However, indexed pepper seed is not guaranteed to be free of *TMV*.
- Use seeds that have been tested and certified to be free of *TMV* for planting.
- Treating seeds with 10% trisodium phosphate (Na3PO4) solution for 2 hr can be used to manage these viruses but is not completely effective. The treatment does not inactivate virus particles under the seed coat and endosperm.
- Use *TMV*-resistant pepper varieties in a greenhouse or field where *TMVs* are a problem. Some strains of *TMV* may overcome plant resistance. However, plants containing the L1 allele are resistant to almost all strains of *TMV*.
- To a limited extent, the prevention of *TMV* spread by coating hands, plants, and equipment with a solution of powdered non-fat milk has been shown in a few reports.

Monitoring

- Monitor fields for symptoms of the disease and take immediate actions.

Control

- Restrict access to the crop, wash hands and equipment with a soap solution between plants or plant rows, and before entering a greenhouse.
- Maintain a clean farm by controlling alternate host weeds that may represent inoculum sources.
- Rogue symptomatic and adjacent plants early to reduce the rate of disease spread.
- Practicing crop rotation with non-solanaceous crops also helps minimise disease incidence and spread.
- Enforce strict sanitation practices during production and harvest to minimise *TMV* infection and spread.

3.4.8 Tomato spotted wilt on peppers

Scientific name of causal organism: *Tomato spotted wilt virus (TSWV)*
Transmission: Thrips
Distribution: Worldwide
Stage of crop attacked: Vegetative and fruiting stages

Description of main symptoms:

- Young plants infected by *TSWV* display severe stunting, yellowing, chlorotic flecking, and necrosis.
- As the disease progresses, necrotic spots become more pronounced on the leaves, petioles, and stems.
- Fruits on infected shoots may become bumpy, deformed with necrotic spots, streaks, mosaic, and ring patterns.
- On ripe fruit, yellow spots with concentric rings or necrotic streaks may be present.

Prevention

- Use disease-resistant varieties if available. There are few commercial pepper cultivars with *TSWV* resistance, although there are promising pathogen-derived (transgenic resistance in tomato and tobacco) developments.
- Use virus and thrips-free transplants.
- Maintain seedbeds away from cropped areas and other susceptible plants.
- Thrips-proof screens can prevent or delay infection in greenhouse production.
- During seedling production, use a net house structure or seedbed covered with a netting of 40-mesh or higher to exclude thrips from seedlings before transplanting.
- Keep infected field areas fallow for 3–4 weeks to allow thrips to emerge from crop debris and disperse from the field.
- Plant early to escape high thrip populations that occur later in the season.

Monitoring

- The presence of thrips in pepper fields can be monitored using yellow sticky cards. If thrips are present, take appropriate actions to control the thrip population and virus-infected plants.

TSWV symptoms on pepper fruit and leaf. (Source: https://aces.nmsu.edu/)

Cultural control

- The extremely wide and overlapping host range of *TSWV* and its vectors makes control difficult. Hence practice good weed management in and around fields planted with pepper and maintain a 10-m plant-free border.
- Multicomponent management approaches are the most effective.
- Avoid sequential planting because thrips can continue to emerge from the soil 2–3 weeks after crop residues are ploughed and roto-tilled.
- Rogue infected and adjacent plants early to reduce the rate of disease spread.

Control of vector with synthetic insecticides

- Chemical control of the insect vectors in the field is generally difficult because of insecticide resistance development. Consequently, rotating the insecticide classes is the best approach to insect control.
- Several insecticides (e.g., imidacloprid) applications should be made at 5-day intervals to significantly reduce aphid infestation in seedlings.
- See section Aphids for recommended insecticides.

3.5 Physiological disorders of sweet pepper

3.5.1 Blossom end rot of pepper

Cause: Calcium deficiency
Distribution: Worldwide
Stage of crop attacked: Fruits

Description of main symptoms:

- Blossom-end rot begins as a light-coloured area on the blossom end of the fruit.
- The affected area enlarges and darkens, sometimes involving up to half the fruit surface.
- On peppers, the rot is tan and may be mistaken for sunscald. Sunscald, however, results in a bleached, white area on the fruit.
- On sweet pepper, the rot usually occurs on the tip of the lobes.
- On pimento pepper, the pod's side near the tip is affected.
- Secondary fungi may cause the tan area to turn dark.

Prevention

- Applying lime or gypsum can provide calcium. Lime corrects low pH and low calcium levels, while gypsum only affects calcium levels in the soil.
- Avoid using high nitrogen fertilisers, especially ammonium-containing ones, which accelerate vegetative growth and reduce the uptake of calcium by plants.
- Drip irrigate to supply an even amount of water and apply lime to soils low in calcium.
- Fertilise with calcium nitrate in areas where blossom end rot is known to occur.
- Damage to the roots by deep cultivation should also be avoided, especially after fruit set and in dry weather.
- Although the results are often disappointing, in some cases, calcium chloride sprays applied to the foliage may help prevent blossom-end rot on developing fruit. Apply the Calcium chloride at four pounds per 100 gallons/acre four times on a weekly schedule, beginning when symptoms first appear.

Blossom end rot symptom on pepper fruit. (Source: pinterest.com)

Monitoring

- Monitoring will give you information on how to prevent the problems in the next season. Once present, the problem cannot be cured.

3.5.2 Sunscald of pepper

Cause: Sunburn
Distribution: Worldwide
Stage of crop attacked: Fruits

Description of main symptoms:

- Affected areas are straw-coloured or white, soft, sunken, and wrinkled.
- These dead areas form only on the side exposed to the sun, in contrast to blossom end rot, where the symptoms will also appear on unexposed areas.
- The dead areas eventually become papery in texture and may become dark-coloured if infected by secondary fungi.
- Fruits affected by sunscald are unmarketable.

Prevention

- No resistant cultivars are available.
- Provide sufficient nitrogen for healthy plant growth.
- Keep foliage healthy by controlling diseases and insect pests.
- Also, avoid drought stress.
- If feasible, provide support for pepper plants by using stakes or string running along the rows or wire running horizontally along the beds.
- Grow the plant under a shade net if sunlight is too much to be tolerated by the plant.

Monitoring

- Monitor the fruit for the symptoms described above and take appropriate action.

Cultural control

- Properly space or prune the plants to reduce too much sunlight exposure to fruits.
- Care should be taken during harvest to minimise plant breakage, leading to exposure of fruits in the canopy to direct sunlight.
- Carry out all agronomic practices well to prevent diseases that defoliate the plant.

Sunscalded pepper fruit. (Source: pinterest.com)

Fruit crack in sweet pepper. Photo from https://unece.org/fileadmin/DAM/trade/agr/promotion/Brochures/SweetPeppers_LowResolution.pdf

3.5.3 Growth cracks

Fruit cracking is usually associated with fluctuations in humidity condition. If the vegetables grow in drought and then high humidity start to be (e.g. heavy rain, intensive watering) – plant body fails to cope with immediate excess water and therefore its fruits crack. These cracks in the fruit is a gateway to various infections. Various microorganisms can attack such plant body very quickly.

3.5.4 Physiological leaf roll

Curled or rolled leaves is a physiological disorder that is often associated with hot dry weather or wind, however it can also occur in response to other stresses like high moisture and nitrogen, fast growth, heavy production, pruning and root damage.

Physiological leaf roll in sweet pepper. Photo from https://www.houzz.com/discussions/4608853/curling-yellowing-bell-pepper-leaves

4. Insecticide resistance management

- Insecticide resistance is the ability of an insect to survive even repeated application of the recommended dose of an insecticide.
- Pesticides will continue to be an integral part of our pests and diseases management efforts, but careful selection of the right pesticides and their combinations is required to achieve effective pest control, minimise the development of insecticide resistance by pests, and with minimal negative impact on humans and the environment.
- Pesticides must always be used in a lawful manner, consistent with the product's label and observe all safety protocols.
- Always carefully select and rotate different Mode of Action (MoA) classes of pesticides to help manage insecticide resistance.
- Similarly, biopesticide such as neem (azadirachtin) which exhibits different modes of action (e.g., anti-feedant, causes abnormal and delayed moults, growth regulator, mortality, sterility effect, etc.) could be used alongside other insecticides to manage insecticide resistance.
- It is recommended that the synthetic pesticides are used mostly from the nursery to the onset of flowering and alternated with the biological or biorational pesticides during flowering and fruiting stages of the crop to ensure food safety and to promote the activities of beneficial insects (pollinators and natural enemies of the pests) in the field.

5. Options for biocontrol importation in Ghana

The Plant Protection and Regulatory Services Directorate (PPRSD) of the Ministry of Food and Agriculture (MoFA), Ghana has now developed the procedures for importation of Biological Control Agents (BCAs) (MoFA/PPRSD 2000a). BCAs such as *Amblyseius swirskii*, and *Orius laevigatus* have been imported into the country as biocontrol agents for greenhouse vegetable production. Hitherto, this wasn't the case. You can visit the head office of Ghana's NPPO, which is PPRSD at Pokuase in Accra or any of their regional offices for a copy of the guidelines to offer more information about the procedures involved and the requirements for their importation.

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Appendix 1 – Summary of biological pesticides for the management of pests of sweet pepper

	Group(s)	Mode of action class	WHO hazard class*	White-flies	Aphids	Caterpil-lars	Spider mites	Mealy-bugs	Thrips	REI (hrs)	PHI (days)
Azadirachtin	Botanical	Unknown or uncertain MoA	II	++	++	++	++	++	++	4	0
Pyrethrum/Pyrethrins	Botanical	Nerve & muscle targets	II	++	++	++			++	12	0
Maltodextrin	Botanical	Mechanical disruptor	III	++	++	++	++	++	++	0	1
Spinosad	Microbial	Nerve & muscle targets	U			++				0	0
Insecticidal soap 'alata samina'	Botanical			++	++	++	++	++		12	0
Bacillus thuringiensis (Btk)	Microbial	Midgut targets	III			++				4	0
PrGV + Bt	Microbial	Midgut targets	II			++				4	0
Metarhizium anisopliae	Microbial	Unknown or uncertain MoA	U			++			++	0	0
Oxymatrine	Botanical	Unknown or uncertain MoA	III	++	++		++			1	0

* WHO hazard Class II = moderately hazardous, Class III = slightly hazardous, Class U = unlikely to pose an acute hazard in normal use.
REI = Re-entry interval, PHI = Pre-harvest interval. The reader is advised to check the latest EPA list of registered pesticides.

Appendix 2 – Summary of synthetic pesticides for the management of pests of sweet pepper

	Group(s)	Mode of action class	WHO hazard class*	White-flies	Aphids	Cater-pillars	Mites	Mealy-bugs	Thrips	REI (hrs)	PHI (days)
Novarulon	IGR	Growth & development targets	U	++		++			++	12	1
Chlorfenapyr	Pyrroles	Respiration targets	II	++		++	++		++		
Acetamiprid + Indoxacarb	Neonicotinoid + oxadiazine	Nerve & muscle targets	II	++	++	++			++	12	7
Imidacloprid + Emamectin benzoate	Neonicotinoid + Avermectin	Nerve & muscle targets	II	++	++	++			++	24	7
Deltamethrin	Pyrethroid	Nerve & muscle targets	II	++					++	12	3
Fipronil	Phenylpyrazole	Nerve & muscle targets	II			++			++	24	14
Pyrethrum + Deltamethrin	Botanical + Pyrethroid	Nerve & muscle targets	II	++					++	12	3
Acetamiprid + Pyriproxyfen	Neonicotinoids + IGR	Growth & development targets	II	++		++	++	++	++	24	14
Spirotetramat	Keto-enol	Growth & development targets	III	++	++			++	++	12	7
Flubendiamide + Spirotetramat	Ryanoid + Keto-enol	Growth & development targets	III	++	++	++		++	++	24	7
Emamectin benzoate	Avermectin	Nerve & muscle targets	II			++	++		++	12	7
Pymetrozine	Pyridine azomethines	Nerve & muscle targets	III	++	++					12	0
Etofenprox	Pyrethroid derivative	Nerve & muscle targets	U	++	++	++		++	++	12	3
Tebufenozide +Emamectin benzoate	IGR + Avermectin	Nerve & muscle targets	II			++				12	7
Methoxyfenozide +Spinetoram	Diacylhydrazine + Spinosyn	Nerve & muscle targets	III	++		++			++	4	1
Profenofos	Organophosphate	Nerve & muscle targets	II	++	++	++	++		++	12	14
Thiamethoxam + Lambda cyhalothrin	Neonicotinoid + pyrethroid	Nerve & muscle targets	II	++	++	++		++	++	12	7
Alpha-cypermethrin + Teflubenzuron	Pyrethriod + IGR	Nerve & muscle targets	II	++	++	++			++	12	3
Abamectin	Avermectins & milbemycins	Nerve & muscle targets			++		++			12	

* WHO hazard Class II = moderately hazardous, Class III = slightly hazardous, Class U = unlikely to pose an acute hazard in normal use.
REI = Re-entry interval, PHI = Pre-harvest interval. The reader is advised to check the latest EPA list of registered pesticides.

Appendix 3 and 4 – Tracking and scouting sheets I and II

See attached sheet I (Appendix 3) and sheet II (Appendix 4). Growers in the greenhouse could use either sheet I or II to undertake the scouting, preferably twice a week for timely decision making.

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