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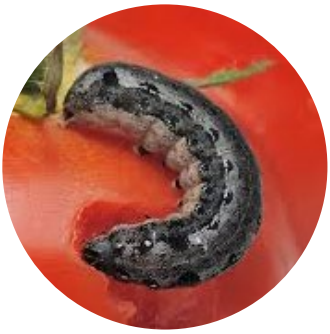
Ghana Veg

Pest Management Guide for Tomato

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Authors:

Ken Okwae Fening (PhD), Agricultural Entomologist, Soil and Irrigation Research Centre, University of Ghana
Emmanuel Moses (PhD), Plant Pathologist, formerly of CSIR- Crops Research Institute

All photos in this manual were taken by the authors (Dr Ken Okwae Fening and Dr Emmanuel Moses) and the others have been duly acknowledged. Cover photos are also from https://pixabay.com/.

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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

PPE . . . . . .Personal Protective Equipment

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

PHI . . . . . .Pre-harvest interval

REI . . . . . .Re-entry interval

1. Introduction

This manual describes using the relevant pictures and illustrations, the pest and disease problems encountered by farmers during tomato production, from planning stage, nursery establishment to harvesting.

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 the last resort, when other control measures fails to offer effective protection against pests and diseases, a concept known as Integrated Pest Management (IPM).

The IPM approach will allow the farmer to put in place measures that will *prevent*, *monitor* for pests and diseases and their timely *control* to ensure significant damage and yield losses do not occur.

This will improve the yield of tomatoes and promote food and environmental safety.

Only pests and diseases that affect the tomato crop in Ghana have been considered.

Tomato cultivation in Ghana is largely open field, however, greenhouse cultivation is gradually becoming popular.

The current manual will address the pest and disease challenges in both open field and greenhouse cultivation of tomatoes.

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.

2. Pests of tomato and their management

2.1 Sweet potato whitefly

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

Main damage symptoms:

- Leaves. Transmission of viral diseases (leaf curl).

IPM measures: prevent, monitor and control

- *B. tabaci* is the vector for the tomato yellow leaf curl virus.
- Since viral diseases have no cure, management intervention should focus on early detection of vector and its control.

Prevent

- Implement good farm sanitation practices – regular weeding of bushes or alternative hosts to destroy breeding places.
- Cover seedlings with a fine mosquito net or mesh to prevent whiteflies attack at nursery stage.

Monitor

- 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 (6–7 a.m.), 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
  - Stimulate or apply predators, parasitoids or beneficial fungi of whiteflies.
  - Conserve local natural enemies' population by minimising the use of synthetic insecticides in the field.
  - If encouraged natural enemies could bring the whitefly menace to a minimum level.

Nymphs and adult of sweet potato whitefly, Bemisia tabaci *and main damage symptoms (leaf curl)*

- 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*
- Biological pesticides (for effective control, weekly application is preferable)
  - 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*
- Synthetic insecticides
  - Spirotetramat
  - Pymetrozine
  - Flubendiamide + Spirotetramat
  - Spinosad
  - Oxymatrine
  - Acetamiprid + Pyriproxyfen
  - Chlorfenapyr
  - Imidacloprid
  - Imidacloprid + Emamectin benzoate
  - Acetamiprid
  - Acetamiprid + Indoxacarb
  - Lambda cyhalothrin
  - Deltamethrin

2.2 South American tomato leaf miner

Scientific name: *Tuta absoluta*
Distribution: *Tuta absoluta* is more common in southern Ghana, and infestation is much severe in greenhouse tomato production.
Stage of crop attacked: Seedling, vegetative and reproductive stages

Main damage symptoms:

- Tunnelling in fruits and leave damage.

Adult and larva on Tuta absoluta *and damage on tomato fruits and leaves (Photo adopted from Mamadou Diatte et al.)*

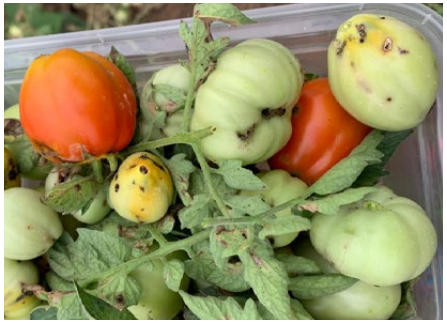
IPM measures: prevent, monitor and control

Prevent

- Intercrop tomato with onions or shallots in order to reduce *T. absoluta* population, while increasing the population of natural enemies.
- Tomato fields should be kept clean and free of any crop residue that may harbour the pest.
- Ploughing, manuring, irrigation, crop rotation, solarisation and the elimination of symptomatic leaves and destruction of infested tomato plants have all been used to control this pest.
- The removal of alternative reservoir hosts such as other solanaceous crops (potatoes, peppers, and eggplants) is strongly recommended before and during the cropping cycle.

Monitor

- Monitor adult male moth's population using a pheromone trap for *T. absoluta* (1 trap per hectare) or yellow sticky traps (5 traps per hectare).
- Inspect plants for characteristic damaged symptoms (e.g. the blotch-shaped mines in the leaves, puncture marks on fruits, exit holes, frass).
- The action threshold is 2 larvae per plant for greenhouse production and 3 larvae per plant for open field production or about 8% defoliation.
- An increase in trap catches of male moths (catches/number of traps/week) is an indication to initiate control measures.



Damage in young tomato seedling, older plants and fruits. (Photo on older plants and fruit damage by H. Nuamah, PPRSD of MoFA, Ghana)

Control

- Mass trapping
  - For mass trapping to suppress pest population more pheromone traps could be placed at different locations in the field.
  - In the greenhouse, place more light traps at different locations. Put the light traps on top of a water bath mixed with detergent to kill and suffocate moths.
- Biological control
  Natural enemies:
  - *Nesidiocoris tenuis*
    - Good predator of *T. absoluta* eggs and neonate larvae.
    - Also, for controlling stem borer and tomato leaf miner.
    - In absence of preys it can also feed on the tomato itself becoming a minor pest.
    - *N. tenuis* is already present in tomato fields in Ghana.
  - *Trichogramma* spp. (effective egg parasitoid)
- 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 insecticide
  - Etofenprox
  - Flubendiamide + Spirotetramat
  - Methoxyfenozide + Spinetoram
  - Spinosad
  - Emamectin benzoate
  - Imidacloprid + Emamectin benzoate
  - Tebufenozide + Emamectin benzoate
  - Acetamiprid + Indoxacarb
  - Chlorfenapyr

2.3 Fruit borer – cotton bollworm

Scientific name: *Helicoverpa armigera*
Distribution: Widespread
Stage of crop attacked: Fruiting stage

Main damage symptoms:

- Tunnelling in fruits.

IPM measures: prevent, monitor and control

Prevent

- Tomato fields should be kept clean from weeds, alternative host plants (e.g. cotton, cowpea, maize, pepper, etc.).
- Tomato field should be free of any crop residue that may harbour the pest.
- Plough field after harvest to expose developing stages in crop residue and pupae in soil to predators and the sunlight.
- Grow trap crops such as pigeon pea (*Cajanus cajan*) and *Crotalaria* spp. in and around tomato fields.

Tomato fruit borer, Helicoverpa armigera *eggs, damage in fruit and larva with their exit holes. (Eggs – Photo by Wasihun Yaregal Wubneh).*

Monitor

- Use pheromone traps for *H. armigera* or sample fruits and look for exit holes of caterpillar, frass, damage symptoms, etc.
- Action threshold: 1-minute scouting threshold of one larva per plant is recommended for implementation of control measures.

Control

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

- Biological control
  - A variety of predatory and parasitic insects, spiders, birds, bats, rodents and diseases attack *Helicoverpa* at different stages of its life cycle.
  - 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.
- 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
  - Novarulon
  - Etofenprox
  - Flubendiamide + Spirotetramat
  - Spinosad
  - Methoxyfenozide + Spinetoram
  - Emamectin benzoate
  - Imidacloprid + Emamectin benzoate
  - Tebufenozide + Emamectin benzoate
  - Chlorfenapyr
  - Indoxacarb
  - Flubendiamide + Thiacloprid

2.4 Spiralling whitefly

Scientific name: *Aleurodicus dispersus*
Distribution: Widespread
Stage of crop attacked: Vegetative and fruiting stage

Main damage symptoms:

- Leaves. Transmission of viral diseases.

IPM measures: prevent, monitor and control

Appy the measures described above for the sweet potato whitefly.

Adults of the spiralling whitefly

2.5 Serpentine leaf miner

Scientific name: *Liriomyza* spp.
Distribution: Widespread
Stage of crop attacked: Vegetative to reproductive stages

Main damage symptoms: Leaves

IPM measures: prevent, monitor and control

Appy the measures described for the *T. absoluta* above.

Serpentine mines of Liriomyza *spp. damage on tomato leaves (seedlings)*

2.6 Spider mites

(Two spotted spider mites and red spider mites)

Scientific name: *Tetranychus urticae, Tetranychus telarius*
Distribution: Widespread
Stage of crop attacked: Vegetative to reproductive stages

Main damage symptoms: Leaves

IPM measures: prevent, monitor and control

Prevent

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.
- Natural rainfall or overhead or sprinkler irrigation helps reduce spider mite's infestation in open field crops.

Two spotted spider mite egg, larva/nymphs and adult mites on the lower leaf surface of their host plant. (Photo by David Cappaert, Bugwood.org)

Monitor

- Mites are very tiny and difficult to see with the naked eye. Observe 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 8–12 mites/leaf in the dry season and 8–14 mites/leaf during the wet season to implement control measures.

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 in order 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 based insecticides
  - Horticultural/mineral oils
  - Paraffinic oils
  - Other natural oil blends
- Synthetic insecticides
  Control mites using miticides or acaricides.
  - Sulphur + Copper
  - Spirotetramat (or combinations with this active)
  - Oxymatrine
  - Chlorfenapyr
  - Fipronil
  - Profenofos

Mites infestation on tomato (Photo on the left by Ayanava Majumdar, Alabama IPM Communicator, USA and the right by A.M. Varela, icipe*). (White arrow points to a cluster of red spider mites.)*

2.7 Aphids

(Cotton aphids and Green peach aphids
Local name: nkokodwee)

Scientific name: *Aphis gossypii* and *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.

IPM measures: prevent, monitor and control

Prevent

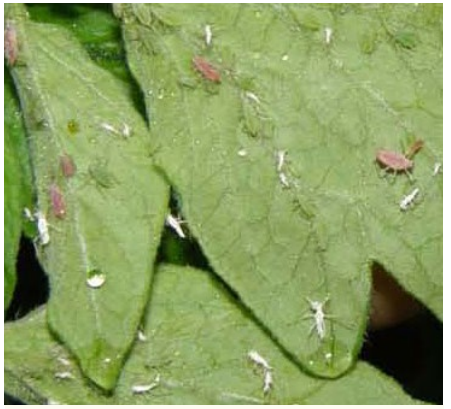
- Before planting, check surrounding areas for sources of aphids and remove these sources.
- Some aphids build-up on weeds such as mustards (*Brassica* spp.), moving onto related crop seedlings after they emerge.
- On the other hand, the aphid-infested weeds can sometimes provide an early source of aphid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

Monitor

- 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 are 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.



Aphids and cast skins underneath the leaves of a tomato plant

- Biopesticides
  - Azadirachtin (neem-based insecticides or neem oil)
  - 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

2.8 Cutworms

Scientific name: *Agrotis* spp.
Distribution: Found in all tomato growing regions in Ghana
Stage of crop attacked: Seedling and young plants

Main damage symptoms:

- Loss of complete young plant.

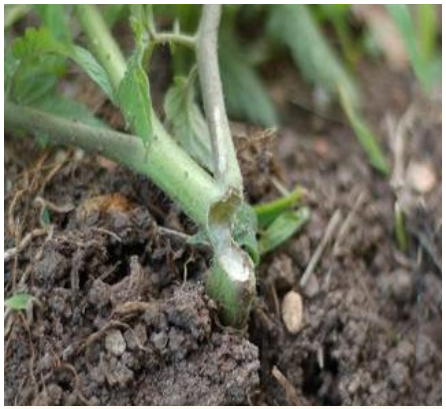
IPM measures: prevent, monitor and control

Prevent

- Remove weeds in and around the fields to reduce the number of sites where the moths can lay eggs. Do this at least 2–3 weeks before planting. The moths prefer to lay eggs in high grass and weeds.
- At the end of the season, plough and harrow surrounding areas to expose cutworms and destroy their habitat.
- Ploughing and harrowing fields properly before planting destroys eggs and expose caterpillars to birds, ants and other predators.
- Apply neem cake or de-oiled castor cake before sowing.
- Encourage the presence of birds with trees and hedges.
- Also promote natural enemies like spiders, ground beetles and lacewings.
- Interplant tomato with onion, garlic or peppermint, this will act as a repellent to cutworms. Sunflowers can be planted as a trap crop.

Monitor

- Cutworms are 2 to 4 cm long larvae, and dark grey-brownish (like the soil colour). They are about 0.5 to 1 cm thick and soft.
- The older or bigger larvae can cut and chew young tomato stems quickly.
- Under a freshly cut seedling, you can often find a cutworm larva in the soil.
- Action threshold: One larva per 100 plants and the presence of cut plants indicate that control is necessary.



Cutworm larvae (2 to 4 cm long) and damage of tomato seedling (young plant) in the field (Top photo by S. Toepfer. Bottom photo by Tomato Casual).

- Known species of cutworms can also be monitored with pheromone traps.
- Seven or more adults per trap per week indicate treatment is necessary.

Control

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

- Biological pesticides
  - *Bacillus thuringiensis*
- Synthetic insecticides
  - Etofenprox
  - Flubendiamide + Spirotetramat
  - Fipronil

2.9 Sting or shield bug

Scientific name: *Nezara viridula*
Distribution: Widespread
Stage of crop attacked: Vegetative to reproductive stages

Main damage symptoms:

- They suck the plant sap. Feeding on young tomatoes induces early maturity and reduces fruit size and weight.

IPM measures: prevent, monitor and control

Prevent

- Ensure good farm sanitation by clearing of weeds and alternative hosts.

Monitor

- Observe the plant parts (underside of leaves, stem, fruits) for the presence of developing stages of pests – eggs, nymphs and adults and their damage symptom - round spots, deformed fruit that appears to have dimples (cat-facing), off-colour hard mass in the fruit.
- These bugs feed on the smaller fruit while they are still green and can be difficult to spot as they move to the opposite side of the fruit when monitoring or to the spaces between a fruit cluster.
- Shake the bushes with a tray underneath and these bugs will drop off and can be collected before they fly or spray the plants with a knockdown insecticide (one of the synthetic pyrethroids, e.g. lambda cyhalothrin, to reveal the culprit.
- Action threshold: For fresh market tomatoes, consider a control measure when stink bugs are present in the crop. The threshold is 0.5–1% of fruits with feeding damage from a total of 10 fruits sampled.

Eggs, larvae and adult of the green sting bug, Nezara viridula. *(Eggs – Photo by Magyar 2011; nymphs' photo by Alamy stock photo; and adult photo by Photo Drees, Texas A&M AgriLife Extension Service).*

Control

- Biological control
  - Limited natural control through Assassin bugs (Reduviids). Apply horticultural oils.
  - No need for chemical control. Avoid spraying with insecticides because the adults also predate on lepidopterous larvae. This will promote the efficiency of natural agents.

2.10 Mealybugs
(Pineapple mealybugs, Cotton mealybugs)

Scientific name: *Dysmicoccus brevipes, Pseudococcus* 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 as a result of honeydew excretion, sooty mould formation and sometimes virus transmission.

IPM measures: prevent, monitor and control

Prevent

- 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 farm or before planting them. If you can not remove all the mealybugs present, discard and destroy the plant.

Monitor

- 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.
  - In outdoor plants, cultural practices and biological control should be adequate for suppressing mealybugs in most situations.

Mealybug attack on tomato (Photo: India Climate Dialogue)

- 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
  - Spirotetramat
  - Profenofos + Cypermethrin
  - The mealybugs' waxy coating repels most contact insecticides, and their habit of aggregating in hidden locations makes them hard to reach.

2.11 Stem fly

Scientific name: *Atherigona orientalis*
Distribution: Widespread
Stage of crop attacked: Vegetative stages

Main damage symptoms:

- Females lay eggs in the cracks of the fruit and the developing larvae will decay the fruit.

IPM measures: prevent, monitor and control

Prevent

- Generally, a minor pest not requiring control.
- Employ good farm sanitation measures by collecting and burying infested and fallen fruits.

Monitor

- Look for maggots in the infested fruits.
- When damage is observed on 2 tomatoes per 10 plants on average, initiate control measures.

Control

- Use neem-based insecticides or systemic organophosphates or other recommended insecticide if destruction is substantial following the establishment of action thresholds.

Adult stem fly, Atherigona orientalis. (Photograph by Gary Steck, Florida Department of Agriculture and Consumer Services, Division of Plant Industry)

2.12 Variegated grasshopper
(Local name: Abɛbɛɛ)

Scientific name: *Zonocerus variegatus*
Distribution: Widespread
Stage of crop attacked: Seedling and vegetative stage

Main damage symptoms:

- Defoliate leaves of crop.

IPM measures: prevent, monitor and control

Prevent

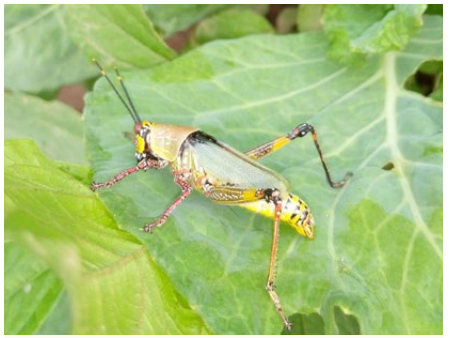
- Scout for breeding sites, *Chromolaena odorata* (Siam or Acheampong weed) to collect and destroy egg masses or egg pods and hopper bands.

Monitor

- Scout for breeding sites to detect outbreaks.

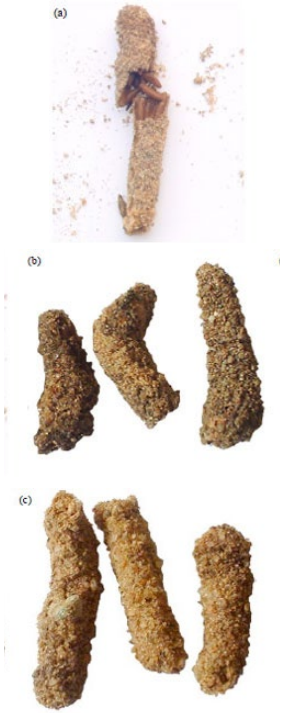
Control

- Physical/mechanical control
  - Handpick and destroy egg masses and other developing stages if not too many.
- Biological control
  - The larvae of the blister beetles (*Epicauta blineata*) are predators on the egg pods of grasshoppers.



Adult of the variegated grasshopper, Zonocerus variegatus

- Biological pesticides
  - *Metarhizium anisopliae* var. *acridum*
  - *Beauveria bassiana*
  - Pyrethrum
- Synthetic insecticides
  - Fipronil
  - Acetamiprid + Emamectin benzoate
  - Acetamiprid + Indoxacarb
  - Imidacloprid
  - Deltamethrin
  - Cypermethrin
  - Pyrethrum + Deltamethrin



Eggs pods of Zonocerus variegatus *(Adopted from Timbilla J. A. et al., 2015).*

2.13 Cotton leafworm

Scientific name: *Spodoptera littoralis*
Distribution: Widely distributed
Stage of crop attacked: Vegetative and fruiting stages

Main damage symptoms:

- Defoliate leaves and bores into fruits.

IPM measures: prevent, monitor and control

Prevent

- Rotate with non-host crops like cassava, yam and others.
- Employ good farm sanitation and improved cultural practices.

Egg mass, larval damage in tomato leaf and fruit by Spodoptera littoralis. *(Egg mass photo by Maarten van Merriënboer/Wageningen Plant Research, Netherlands, larva damage in leaf photo by Anna Erickson, Sweden and in fruit by Markus Züger, Andermatt Biocontrol AG, Switzerland).*

Monitor

- Look for feeding scratches of larvae on leaves.
- Scout leaves and fruits for the presence of larvae or egg mass.
- Check flowers and fruits (holes in fruits) for presence of larvae.
- Look for matured larvae (small yellow to white dots at the base of black patches on 2nd and 3rd abdominal segment).
- Alternatively, sex pheromone baited delta traps can be used to monitor the incidence of *S. littoralis*.
- Action threshold: 10–20% infestation of crops calls for implementation of control measures.

Control

- Physical control
  - Handpick and destroy caterpillars and egg masses.
- Biological control
  - Use of parasitoids (braconids, encyrtids, tachinids and ichneumonids) and predators such as ladybird beetles, predatory beetles and spiders.
  - Ladybird beetles have been noted to prey on young larvae and eggs.
- Biopesticides
  - *Bacillus thuringiensis* (Bt), *Bacillus thuringiensis aizawai* (Bta)
  - *Beauveria bassiana*
  - 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
  - Spinosad
  - Pyrethrum/pyrethrin
- Synthetic insecticides
  - Etofenprox
  - Novaluron
  - Flubendiamide + Spirotetramat
  - Tebufenozide + Emamectin benzoate
  - Emamectin benzoate
  - Imidacloprid + Emamectin benzoate
  - Organophosphates
  - Pyrethroids

2.14 Fruit flies

Scientific name: *Dacus punctatifrons, Bactrocera dorsalis, Zeugodacus cucurbitae, Rhagoletis ochraspis*
Distribution: Widely distributed
Stage of crop attacked: Fruiting stage

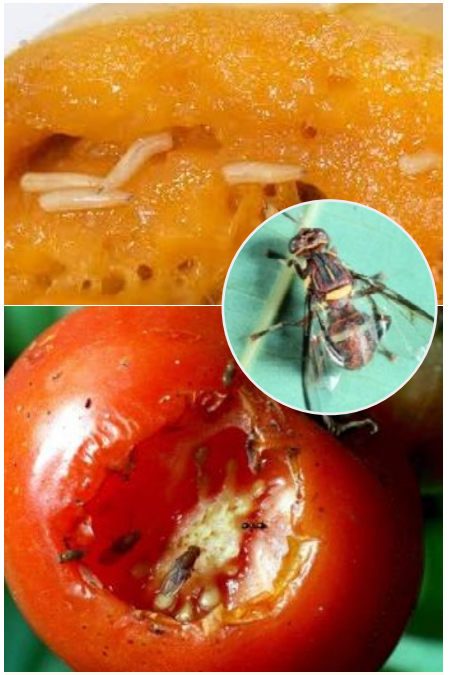
Main damage symptoms:

- Fruits show small holes, to complete loss of tissue and start to rot.

IPM measures: prevent, monitor and control

Prevent

- Plough to bury or harrow and rake to expose matured larvae/pupae to natural enemies and harsh weather conditions.



Larva or maggots of the medfly and adult of fruit fly, Dacus punctatifrons. *(Photo of larva taken from https://agric.wa.gov.au/n/7084. Photo of adult by Kambura, C. 2016, Kenya, Stock Journal, Fairfax Media).*

- Weed farm and prune plants regularly to destroy fruit flies hiding places.
- Put fallen fruits in thick black polythene sheet, tie them tightly and expose the sheet to the sun (10–14 days) or bury them to a depth of 50 cm.

Monitor

- Use fruit fly traps baited with Cuelure to attract *Zeugodacus* and *Dacus* spp. and Methyl Eugenol to attract *Bactrocera* spp.
- Look for fruit fly larvae in rotten fruits or fruits with oviposition punctures.
- Action thresholds: when damage symptoms or larvae is observed on 1 to 2 tomatoes per 10 plants on average, initiate control measures.
- An FTD (flies per trap per day) value of 0.01 or above triggers population suppression measures.

Control

- For sustainable management of fruit flies integrate protein food baits, lures (Cuelure) and farm sanitation.
- Mass trap and kill fruit flies with attractants.
- Spray with protein baits or hydrolysed protein at the recommended rates to attract and kill flies within the tomato field and vicinity.
- Spray with neem seed extract (750 g/15 l of water), neem oil or maltodextrin.

2.15 Crickets

(Tobacco or giant burrowing cricket, mole crickets and field cricket. Local name: Aketɛkyire)

Scientific name: *Brachytrupes membranaceus, Gryllotalpa spp., Gryllus campestris*
Distribution: Widely distributed
Stage of crop attacked: Seedlings and early vegetative stages

Main damage symptoms:

- Root and shoot.

IPM measures: prevent, monitor and control

Prevent

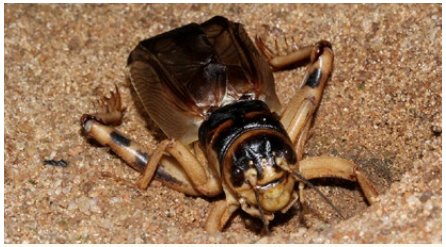
- Pick adults from their burrows and destroy or use as feed to animals.
- Sprinkle wood ash in nursery to dehydrate the larvae.
- Plough to destroy burrows and expose insects to predators (e.g. birds).

Monitor

- Cricket population in the field could be monitored with a pitfall or light trap.

Control

- Biological control
  - Natural enemies include lizards and birds.
- Use bait with recommended insecticides
  - Fipronil
  - Imidacroprid + Emamectin benzoate



Adult tobacco or giant burrowing cricket, Brachytrupes membranaceus *(Photo credit to Bart Wursten, Mozambique).*

2.16 Thrips

Scientific name: *Thrips tabaci*
Distribution: Widespread
Stage of crop attacked: Vegetative and reproductive stages

Main damage symptoms:

- Leaves are damaged, fruits misshaped, growing tip deformed. Transmit viral diseases.

IPM measures: prevent, monitor and control

Prevent

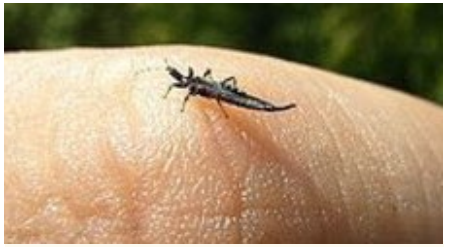
- Ensure good farm sanitation by regular weeding of tomato farm to destroy harbouring places for thrips.

Monitor

- Sample about 30 flowers from different plants in the tomato farm and put into 70% alcohol in a vial.
- Examine flowers inside a Petri dish in the lab for the presence of thrips.
- Can also monitor thrips population by using blue sticky traps.
- Action threshold: treatments may be warranted if an average of more than one (1) adult per flower or more than two (2) larvae per small fruit are detected.

Control

- Botanical insecticides/ biopesticides
  - Pyrethrum/ Pyrethrin
  - Neem seed extract: 750 g/l
  - Neem oil (0.3% Azadirachtin): 60 ml/15 l
  - Neem oil (1% Azadirachtin): 30 ml/15 l
  - Metarhizium anisoplae (ICIPE 69)



Adult thrip and its damage (brown patches) on tomato leaf. (Photo from http://www.pestnet.org/fact_sheets/thrips_086.htm)

- Synthetic insecticides
  - Etofenprox
  - Spinetoram
  - Flubendiamide + Spirotetramat
  - Chlorfynapyr
  - Acetamiprid + Indoxacarb
  - Pyrethrum + Deltamethrin
  - Acetamiprid + Pyriproxyfen
  - Fipronil

2.17 Fruit piercing moths

Scientific name: e.g. *Achaea* sp.
Distribution: Widespread
Stage of crop attacked: Fruits

Main damage symptoms:

- Adult moths pierce into tomato fruits with their proboscis, soften the pulp and suck the fluids leaving a scar and uneven ripening.

IPM measures: prevent, monitor and control

Prevent

- Pick matured fruits before they ripe.
- Clear weeds in the farm and its surrounding to reduce alternate host for the fruit piercing moths.

Monitor

- Monitor moth's population using light traps.

Control

- Biological insecticides
  - *Bacillus thuringiensis*
  - *Metarhizium anisopliae*
- Synthetic insecticides
  - Etofenprox
  - Flubendiamide + Spirotetramat
  - Tebufenozide + Emamectin benzoate

Fruit piercing moth pierces proboscis into tomato fruit and characteristic damage symptoms on tomato fruit (Photos from Patel et al., 2016, India and http://www.pestnet.org).

Table 1. *Summary of biological pesticides for the management of tomato pests*

	Brand name	Group(s)	WHO hazard class*	White-flies	Aphids	Caterpil-lars	Spider mites	Mealy-bugs	Grass-hoppers/ Crickets	Sting bugs	Thrips	Fruit flies	REI (hrs)	PHI (days)
Azadirachtin	Neem	Botanical	II	++	++	++	++	++	++	++	++	++	4	0
Pyrethrum	Pyrethrum 5EW, Agroblaster	Botanical	II	++	++	++			++	++	++		12	0
Maltodextrin	Eradicoat T GH	Botanical	III	++	++	++	++	++			++	++	0	1
Insecticidal soap 'alata samina'	'Alata samina'	Botanical		++	++	++	++	++					12	0
Bacillus thuringiensis (Btk)	NOVA BTK, Agoo, Biopest	Microbial	III			++							4	0
PrGV + Bt	Bypel 1	Microbial	II			++							4	0
Metarhizium anisopliae	Campaign	Microbial	U			++			++		++		0	0
Oxymatrine	Levo 2.45L	Botanical	III	++	++		++					6	1	0

* WHO hazard Class II = moderately hazardous, Class III = slightly hazardous, Class U = unlikely to pose an acute hazard in normal use.

Table 2. *Summary of synthetic pesticides for tomato pests*

	Brand name	Group(s)	WHO hazard class	White-flies	Aphids	Cater-pillars	Mites	Mealy-bugs	Grass-hoppers/ Crickets	Sting bugs	Thrips	REI (hrs)	PHI (days)
Novarulon	Rimon 10 EC	IGR	U	++		++					++	12	1
Chlorfenapyr	Klopar 24 SC	Pyrroles	II	++		++	++				++		
Acetamiprid + Indoxacarb	Viper 46EC, Viper Super 80EC, Zukadoc 46 EC	Neonicotinoid + oxadiazine	II	++	++	++			++	++	++	12	7
Imidacloprid + Emamectin benzoate	Dean 62 EC	Neonicotinoid + Avermectin	II	++	++	++					++	24	7
Deltamethrin	Cisthrin, Decis Forte 100EC	Pyrethroid	II	++							++	12	3
Fipronil	Fipro 50 EC, Fixe 50 SC	Phenylpyrazole	II			++					++	24	14
Pyrethrum + Deltamethrin	Miricon EC	Botanical + Pyrethroid	II	++					++		++	12	3
Acetamiprid + Pyriproxyfen	Trivor 310 DC	Neonicotinoids + IGR	II	++		++	++	++	++	++	++	24	14
Spirotetramat	Movento 100 SC	Keto-enol	III	++	++			++		++	++	12	7
Flubendiamide + Spirotetramat	Tihan 175-ODTEQ	Ryanoid + Keto-enol	III	++	++	++		++		++	++	24	7
Emamectin benzoate	Chemomectin 50SG, Strike 1.9EC, Attack 1.9 EC, Ataka Super EC	Avermectin	II			++	++				++	12	7
Pymetrozine	Afford 50 WG	Pyridine azomethines	III	++	++							12	0
Etofenprox	Inspire 30 EC, Akate Kaptain	Pyrethroid derivative	U	++	++	++		++	++	++	++	12	3
Tebufenozide + Emamectin benzoate	Evite 340 WP	IGR + Avermectin	II			++						12	7
Methoxyfenozide + Spinetoram	Uphold 360SC	Diacylhydrazine + Spinosyn	III	++		++					++	4	1
Profenofos	Hitcel, Select Plus 315EC, Ronfos 550 EC	Organophosphate	II	++	++	++	++			++	++	12	14
Thiamethoxam + Lambda cyhalothrin	Colam 247 ZC	Neonicotinoid + pyrethroid	II	++	++	++		++			++	12	7
Alpha-cypermethrin + Teflubenzuron	Nomax 150SC	Pyrethriod + IGR	II	++	++	++			++	++	++	12	3

3. Diseases of tomato and their management

3.1 Damping-off

Scientific names of causal organisms: *Rhizoctonia solani* (Fungus), *Phytophthora* sp. (Oomycete) and *Pythium* sp. (Oomycete)
Distribution: Worldwide
Stage of crop attacked: Attack seedlings

Main damage symptoms:

- Death or decaying of seeds resulting in failure of germination.
- Decaying of seedlings before germination is completed.
- Appearance of water-soaked lesions around the base of stems of seedlings leading to wilting and collapse of the stem followed by death of the plant.

Damping-off of tomato (Missouribotanicalgarden.org)

IPM measures: prevent, monitor and control

Prevent

- It is important to change positions of nurseries season to season.
- Nursery beds should be raised sufficiently high and should be formed with soil that has good drainage properties.
- Spread seeds thinly in planting tracks to ensure good spacing among seedlings.
- Do not leave un-transplanted seedlings to grow as volunteer crops.
- Dig out the soil in the area where nursery beds are to be constructed to expose soil particles to sunlight and good aeration before forming the beds.
- Burn dry grass over the soil where a nursery bed is to be constructed to destroy pathogens.
- Solarization of nursery soil using black polythene (250-gauge type) for a period of two weeks or more in the sunny months before seed sowing is a good practice.
- Use disease-free certified seeds to raise seedlings of desired varieties.
- Treat seeds with Mancozeb (800 g/kg) (2 g/kg seeds).
- Treat seeds with Copper hydroxide (77%) (2 g/kg).
- Dip seedlings (roots) in 0.1% solution/suspension of Carbendazim (50%) before transplanting.

Monitor

- Monitor nursery regularly (daily if possible) looking for the main damage symptoms indicated above.

Control – options without restriction

- Rogue few infected seedlings and destroy them by burning.

Control – options with restrictions

- Drench nursery beds with cuprous oxide (60%) + metalaxyl M (6%). Restrictions: WHO Class III (slightly hazardous). Apply at 7 days interval. PHI: 7 days.

3.2 Early blight disease

Scientific name of causal organism: *Alternaria linariae* (= *A. tomatophila*) formerly *A. solani* (fungus)
Distribution: Worldwide
Stage of crop attacked: Leaves, stem and fruits of matured plants

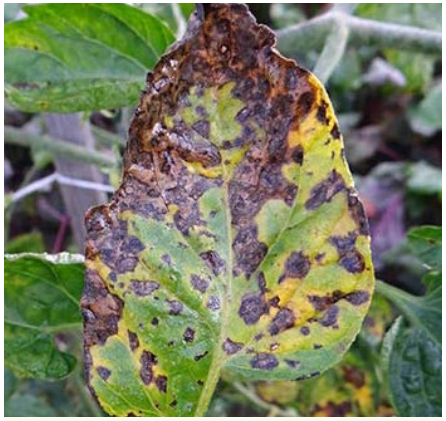
Main damage symptoms:

- Spots with dark borders and grey to tan centres are the first symptoms to be observed on infected leaves.
- These spots (lesions) have concentric rings in the centre.
- Yellow halos develop around the edges of the lesions.
- Several spots join together or coalesce to form large blighted areas on leaves reducing the leaf area available for photosynthesis.
- The disease first attack lower older leaves before spreading to the upper younger leaves.
- Defoliation starts from the lower parts of infected plants. Complete defoliation can occur.
- Defoliation may render fruits susceptible to sunscald.
- Symptoms of the disease may occur as dark sunken lesions on the stem above the soil given the appearance of collar rot.
- Infection can spread to fruits in the green ore ripened stage through the calyx that attaches fruits to the stem.
- Lesions on fruits are sunken, leathery and brown to black in colour.

IPM measures: prevent, monitor and control

Prevent

- Effective weed control including removable and destruction by burning of volunteer tomato plants and that of other solanaceous crops. Also destroy old plant debris.
- Maintain healthy plant growth through adequate fertilization and irrigation.
- Practice 2–3 years rotation with non-solanaceous plants such as maize, cowpea etc. Crop rotations with non-solanaceous crops breaks the life cycle of the pathogen and reduce inoculum levels on the field.



Early blight

- Plant varieties such as Bahubali resistant to *Alternaria* spp. if available.

Monitor

- Monitor plants regularly (at least at weekly intervals) for the symptoms above and take recommended actions when more than one plant show symptoms.

Control – options without restrictions

- Remove and destroy infected plant parts (leaves and branches) by burning or very deep burying.
- This can be done early in the season to reduce spread of the disease.

Control – options with restrictions

- Apply Mancozeb (800 g/kg). Restrictions: WHO Class III (slightly hazardous). Apply at 7–10 days intervals. REI: 24 hours; PHI: 5 days.
- Spray Maneb (800 g/kg). Restrictions: WHO Class III (slightly hazardous). Apply at intervals of 7–14 days. REI: 24 hours; PHI: 7 days.

3.3 Late blight disease

Scientific name of causal organism: *Phytophthora infestans* (Oomycete, water mould)
Distribution: Worldwide
Stage of crop attacked: Leaves, stem and fruits of matured plants

Main damage symptoms:

- The first symptoms are water-soaked lesions with a lighter halo or ring around them starting on younger leaves.
- White cottony growth may be found on the underside of infected leaves when relative humidity is high.
- Infected leaves turn brown, shrivel and die.
- Infected fruits rot. Rotted fruits are firm with greasy leathery texture.

IPM measures: prevent, monitor and control

Prevent

- Avoid planting late in the season to escape infections coming from high disease pressure areas that may exist in neighbouring farms established early in the season.
- Collect infected fruits and plant debris from the field and destroy them by burning.
- Effective weed control and removal and destruction of volunteer tomato plants (including that of other solanaceous) can reduce the level of inoculum on the field.
- Wash farm equipment after use before using them on new fields with 5% bleach solution.
- Wider spacing distances (80 cm × 50 cm) reduce spread of disease on the field.
- Practice crop rotations of two seasons duration with cereals including maize.
- Stake the plants to improve aeration.
- Plant resistant varieties when available. In Ghana, the cherry varieties are more resistant to late blight disease.

Late blight

Monitor

- Monitor field regularly (once every week) looking for the symptoms above and take recommended actions.

Control – options without restrictions

- Rogue infected plants and destroy them by burning.

Control – options with restrictions

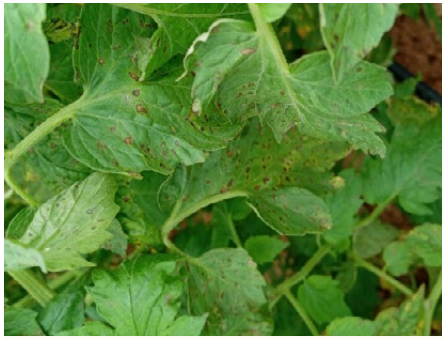
- Apply sprays of cuprous oxide (60%) + metalaxyl M (6%). Restrictions: WHO Class III (slightly hazardous). Apply at 7–14 days intervals. REI: 48 hours; PHI: 7.

3.4 Septoria leaf spot

Scientific name of causal organism: *Septoria lycopersici*
Distribution: Worldwide
Stage of crop attacked: Appear first after fruit set

Main damage symptoms:

- Septoria leaf spot symptoms often appear first after fruit set.
- Characteristic symptoms are circular dark brown spots (lesions) with tan to grey centres on lower leaves that spread to the upper canopy.
- As the disease progresses, the leaf lesions become numerous. The infected leaves turn yellow, then brown and wither. There is severe loss of photosynthetic area at late stages of the infection.



Septoria leaf spot

IPM measures: prevent, monitor and control

Monitor

- Monitor field regularly for symptoms of the disease indicated above and apply recommended actions when more than one plant shows the symptoms.

Control options with restrictions

- Spray copper hydroxide (77%) at 7–10 days intervals. Restrictions: WHO Class III (slightly hazardous). REI: 24 hours; PHI: 3 days or
- Apply copper oxychloride (35%). Restrictions: WHO Class II (moderately hazardous). Apply at 7–10 days interval. REI: 24 hours; PHI: 4 days.

3.5 Fusarium wilt

Scientific name of causal organism: *Fusarium oxysporum* (fungus)
Distribution: Worldwide
Stage of crop attacked: Entire growth phase

Main damage symptoms:

- The first symptom often seen is yellowing (chlorosis) of the leaves on the lower side of an infected plant. The yellowing is often on one side of the plant or on only one branch.
- Vein clearing of young leaves (veins become pronounced).
- Leaves of infected plants droop.
- Wilting of leaves and stem occurs as disease progresses.
- Stunted growth is common.
- There is browning of the vascular system (this can be verified by cutting longitudinally through the stem of an infected plant to observe the internal brown coloration).
- There is defoliation and death of infected plants finally.
- In Fusarium wilt, the foliar symptoms mentioned are more pronounced or limited to one half of the plant and this distinguishes Fusarium wilt from other wilt diseases.
- Foliar symptoms mentioned are more pronounced or limited to one side of plant.

Fusarium wilt

IPM measures: prevent, monitor and control

Prevent

- Use certified seeds (that are disease-free) to raise seedlings. The pathogen is seed borne.
- Farmer-saved seeds must be treated with fungicides before they are sown.
  i. Treat seeds with Mancozeb (800 g/kg) (2 g/kg seeds).
  ii. Treat seeds with Copper hydroxide (77%) (2 g/kg).
- Dip seedlings (roots) in 0.1% solution of Carbendazim (50%) before transplanting.
- Farm equipment and tools must be washed and disinfected using 5% bleach solution before they are used.
- Destroy old plant debris through burning during land preparation.
- Resistant varieties that offer complete protection are hard to come by.

Monitor

- Monitor field regularly (at least at 3 days interval) looking for symptoms of the disease indicated above and implement recommended actions.

Control – options without restrictions

- Rogue (remove) infected plants that develop the disease early and destroy them by burning.
- There is no effective chemical control against Fusarium wilt disease.

3.6 Sclerotium stem wilt

Scientific name of causal organism: *Sclerotium rolfsii*
Distribution: Worldwide
Stage of crop attacked: Post seedling growth phase

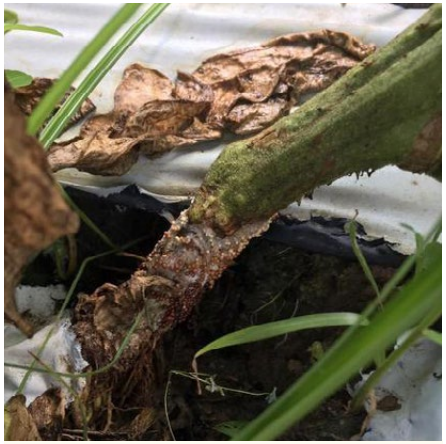
Main damage symptoms:

- The major symptom is a necrotic lesion that first occurs around the neck of infected plants at the soil line.
- This necrotic lesion develops and finally girdles the stem completely destroying the stem tissue.
- The above ground foliar parts suddenly wilts. The wilting is permanent.
- The girdling and destruction of stem tissues may cause the infected plant to fall over at the soil line.
- Under moist conditions, large masses of white mycelium typical of *Sclerotium rolfsii* infection develop in the region of the stem lesion.
- Tan to reddish-brown sclerotia (the resting stage of the pathogen) may develop on the mat of whitish mycelium.
- Infected fruits rot and are often filled with whitish mycelium and sclerotia of the pathogen. No offensive odour is produced.

IPM measures: prevent, monitor and control

Prevent

- Avoid planting in fields with a history of Sclerotium wilt.
- Rotate tomato with maize, sorghum, and rice (practice rotation cycles of 2–3 years).
- Bury infected plant debris from previous harvest deep in the soil through ploughing.
- Effective weed control including destruction of volunteer host crops through deep burying can reduce inoculum levels.
- Avoid planting in acidic soils in areas with a history of Sclerotium wilt disease.



Sclerotium stem wilt (content.ces.ncsu.edu)

Monitor

- Monitor field regularly (at least once a week) for symptoms described above and implement recommended actions when symptoms are observed.

Control – options without restrictions

- Rogue or remove plants that develop symptoms early in the season and destroy them by burning. Do not spread sclerotia on tomato fields.

Control – options with restrictions

- Apply Difenaconazole 25% EC at a concentration of 4 ml in 20 l of water. Restrictions: WHO Class III (slightly hazardous). Apply at 7–10 days intervals. REI: 12 hours; PHI: 7 days.

3.7 Anthracnose

Scientific name of causal organism: *Colletotrichum coccodes*
Distribution: Worldwide
Stage of crop attacked: Fruit bearing plants

Main damage symptoms:

- Major symptoms on ripened fruits are sunken water-soaked circular spots or lesions. Green fruits are infected, but the symptoms are visible in ripened fruits.
- Dark fruiting bodies of the fungus called acervuli develop in the centre of the lesions. Masses of spores are produced from the fruiting bodies that are discharged to cause new infections.
- Infected fruits rot completely.
- Symptoms on leaves are small circular spots with yellow halos.

IPM measures: prevent, monitor and control

Prevent

- Use certified disease-free seeds to raise seedlings.
- Treat farmer-saved seeds with seed dressing fungicides before sowing.
  i. Treat seeds with Mancozeb (800 g/kg) (2 g/kg seeds).
  ii. Treat seeds with Copper hydroxide (77%) (2 g/kg seeds).
- Practice crop rotations with non-host plants in rotations not less than two years.
- Avoid rotations or intercropping with pepper, eggplant and cucurbits.
- Control weeds and volunteer host plants effectively.
- Plant tomato on well drained soils.
- Maintain effective planting distances that can improve aeration around.
- Stake plants to improve aeration and reduce infections at the lower parts of plants through rain splashes.
- Collect old plant debris and rotten fruits left after harvest and burn all these debris during land preparation.

Anthracnose of tomato

- Avoid overhead irrigations as this practice facilitates the spreading of spores.
- Harvest fruits early to avoid over-ripening in the field.

Monitor

Monitor field regularly (at least at weekly intervals) looking for symptoms described above and implement appropriate actions.

- Major symptoms on ripened fruits are sunken water-soaked circular spots or lesions. Lesions are filled with dark fruiting bodies of the fungus that produce masses of spores.
- Infected fruits rot completely.
- Symptoms on leaves are small circular spots with yellow halos.

Control – options with restrictions

- Apply Mancozeb (800 g/kg) at intervals of 7–14 days. Restrictions: WHO Class III (slightly hazardous). REI: 24 hours; PHI: 5 days; or
- Spray Maneb (800 g/kg) at intervals of 7–14 days. Restrictions WHO Class III (slightly hazardous). REI: 24 hours; PHI: 7 days.

3.8 Bacterial wilt disease

Scientific name of causal organism: *Ralstonia solancearum* (formerly *Pseudomonas solanacearum*)
Distribution: Worldwide
Stage of crop attacked: Post seedling phase of growth

Main damage symptoms:

- There is wilting of young leaves.
- Plants affected by bacterial wilt show the wilting symptoms while their foliage remains green.
- Brown cankers may develop at the base of the plant as the disease progresses.
- The roots of infected plants may rot.
- Infected plants may show the wilting symptom in the afternoon and 'recover' at night appearing 'refreshed' in the morning just to wilt again in the afternoon.
- A longitudinal cut through an infected stem may show a brown discoloration of the conducting vessels or vascular bundles.
- A stem piece cut transversely (close to the base) and dipped into a glass of cold water will in some few minutes release a stream of a white slimy substance into the water indicating a strong presence of the bacterium in the vascular tissues.

IPM measures: prevent, monitor and control

Prevent

- Practice crop rotation of 2–3 years with maize, beans and cabbage. Avoid rotation or inter-cropping with solanaceous plants such as pepper and egg plant. This practice can reduce inoculum levels of the soilborne pathogen.
- Use large planting distances (80 cm × 80 cm).
- Disinfect hands and tools after handling plants.
- Farmers should seek information on resistant varieties from their seed suppliers and extension agents.

Monitor

- Monitor field regularly (at least at weekly intervals) looking for symptoms described above and implement recommended actions.

Bacterial wilt. (Plant Pathology, Univ. of Florida)

Control – options without restrictions

- Rogue (remove) infected plants immediately symptoms are observed and destroy rogued plants through burning to reduce the spread of the disease.
- Avoid spreading soil from the base of an infected plant. Farmers should use sound judgment to determine the level of rogueing that is acceptable under their field conditions.
- There is no chemical that can control bacterial wilt disease effectively.

3.9 Tomato yellow leaf curl

Scientific name of causal organism: Tomato Yellow Leaf Curl Virus
Distribution: Worldwide
Stage of crop attacked: Post seedling phase of growth

Main damage symptoms:

- Leaves of infected plants curl upwards and inwards.
- Growth is stunted when plants are infected in early season.
- Plants infected in early season may produce so many branches with smaller leaflets given a bushy appearance.
- Infected plants produce reduced number of flowers due to flower drop. Infected plants therefore produce few fruits.
- When infections occur late in the growth stage, fruits already present develop normally.

IPM measures: prevent, monitor and control

Prevent

- Avoid planting tomato continuously on the same piece of land to reduce population levels of whiteflies that transmit the virus.
- Practice crop rotation with maize to reduce whitefly population.
- Protect seedbeds with a white nylon net with mesh size 40. This prevents early infection of seedlings.
- Plant a barrier crop of maize (few rows of maize plants) around your tomato fields to prevent whiteflies from reaching young tomato plants.
- Practice good farm sanitation through effective weed control.
- Avoid planting cotton or other crops susceptible to white flies close to tomato fields.
- Plant resistant varieties such as Sultan and Bahubali if available.

Monitor

- Monitor field regularly (at least at weekly intervals) looking for symptoms described above and implement recommended actions.

Tomato yellow leaf curl

Control – options without restrictions

- Rogue or pull-out plants with early infections and bury or burn them. This reduces availability of viral inoculum to whiteflies.

Control – options with restrictions

- Spray Imidacloprid (3%) (insecticide) at intervals of 7 days to control whiteflies Restrictions: WHO Class III (slightly hazardous). REI: 12 hours; PHI: 14 days.

3.10 Tomato mosaic

Scientific name of causal organism: Tomato mosaic virus (TMV)
Distribution: Worldwide
Stage of crop attacked: Post seedling phase of growth

Main damage symptoms:

- Leaves of affected plants show mottling with alternating yellowish and dark green patches. The darker green areas appear thicker with blister-like appearance.
- Leaves appear fern-like with pointed tips.
- Younger leaves of affected plants may be twisted and curl.
- Fruits may be distorted in shape.
- Yellow blotches and necrotic spots may form on both green and ripe fruits.
- The internal part under the fruit wall may show brown coloration (both green and ripened fruits may show this brown coloration.
- Stunted growth is common.
- Flowers may be discoloured.

IPM measures: prevent, monitor and control

Prevent

- Use certified disease-free seeds and transplant only healthy seedlings.
- Farmer-saved seeds may be treated by soaking seeds in 10% solution of trisodium phosphate (Na3PO4) for at least 15 minutes to disinfect seeds before sowing.
- Wash hands with soap and disinfect tools to be used in transplanting in bleach (10%) solution before seedlings are transplanted or handling tomato plants.
- Old plant debris of leaves and roots must be destroyed during land preparation by burning before transplanting seedlings.
- Tobacco products should not be brought close to tomato plants. Also, wash hands with soap and water after using tobacco products before and after work on farm.

Tomato mosaic virus (ucanr.edu)

- Stakes should be disinfected appropriately before they are re-used season after season because they potentially could carry viruses to start new infections.

Monitor

Monitor plants for symptoms of the disease including those described above and implement recommended direct control actions when symptoms are found on more than one plant.

- Leaves of affected plants show mottling with alternating yellowish and dark green patches. The darker green areas appear thicker with blister-like appearance.
- Leaves appear fern-like with pointed tips.
- Younger leaves of affected plants may be twisted and curl.
- Fruits may be distorted in shape.
- Yellow blotches and necrotic spots may form on both green and ripe fruits.
- The internal part under the fruit wall may show brown coloration (both green and ripened fruits may show this brown coloration.
- Stunted growth is common.

Control – options without restriction

- Rogue (remove) early infected plants showing symptoms and destroy them by burning.

3.11 Root-knot nematode

Scientific name of causal organism: *Meloidogyne* spp.
Distribution: Worldwide
Stage of crop attacked: All growth stages

Main damage symptoms:

- Stunted growth of plants occurs.
- Chlorosis or yellowing of leaves are observed.
- Wilting of leaves of infested plants occur.
- Infested plants develop galls (swellings) on their roots.
- Infected plants are more susceptible to drought.
- Yield of fruits decline.

IPM measures: prevent, monitor and control

Prevent

- Practice crop rotation with non-host plants. It must be emphasized that the large host range of the *Meloidogyne* spp. makes the selection of plants for rotation difficult.
- Plant resistant varieties if available (ask extension agents and seed suppliers for sources of resistant varieties).
- Destroy old plant debris by burning during land preparation to reduce nematode population.
- Avoid planting tomato on a field with a long history of tomato cultivation.
- Nematodes are limited in their movement. Farmers should work carefully to avoid moving contaminated soil from one part of a field to another.
- Farm equipment, tools, shoes or boots need disinfection in 10% bleach after use.
- In communities where farmers must stay on the same piece of land for a long time, planting Marigold (e.g. *Tagetes patula*) on harvested fields for two months before a tomato crop is planted can reduce nematode population. The Marigold plants can be ploughed into the soil before transplanting. Marigold plants could trap nematodes from the soil leading to reduction in soil nematode population.
- Plant resistant variety such as Kilele if available.

Root knot of tomato (Entoweb.okstate.edu)

Monitor

Monitor field regularly looking for plants showing the symptoms above and implement recommended direct control measures.

- Stunted growth of plants occurs.
- Chlorosis or yellowing of leaves are observed.
- Wilting of leaves of infested plants occur.
- Infested plants develop galls (swellings) on their roots.
- Infected plants are more susceptible to drought.
- Yield of fruits decline.

Control – options without restriction

- Rogue and burn plants showing typical nematode symptoms. Chemical control options including the use of nematicides and fumigants are not recommended.

Table 3. *Recommended fungicides, active ingredients, examples of trade names in Ghana and their restrictions*

Active ingredient	Trade name (examples)	FRAC Code	WHO Toxicity class*	REI (hrs)	PHI (days)
Copper hydroxide	Champion WP Delco 75 WP	M 01	III	24	3
Copper oxychloride (35%)	Cuprozin 35 WP Curenox	M 01	II	24	4
Difenoconazole 25% EC	Dizole 250 EC	3	III	12	7
Mancozeb (800 g/kg)	Agrithane 80 WP Benco 80 WP Conti-Zeb Ivory 80 WP	M 03	III	24	5
Maneb (80%)	Maneb 80 WP Trimangol 80 WP	M 03	III	24	7
Copper oxide	Nordox 750 WG	M 01	III	24	
Carbendazim (50%)	Callet 50 WP Goldazim 500 SC	1	III	24	5
Cuprous oxide + metalaxyl	Agro Comet 72 WP Ridomil Gold Plus 66 WP	M 01	III	24	7

* WHO Toxicity Class: Class Ia = extremely hazardous; Class Ib = highly hazardous; Class II = moderately hazardous; Class III = slightly hazardous.

4. Other considerations

4.1 How to handle pesticides safely

- Pesticides for the control of pests or diseases are mostly chemicals that are harmful or toxic and must therefore be handled with care.
- Some of them can cause damage to the skin when spilled.
- Some of these chemicals can cause cancer and damage to internal organs and tissues when inhaled or ingested.
- There is the need therefore, for pesticide users to be careful when handling and applying pesticides of all kind. Personal Protective Equipment (PPE) have been designed to ensure that farmers handle and apply these chemicals safely.
- Some of the common PPEs that must be worn at all time when handling or applying pesticides are the following to protect the body:
  - Gloves
  - Goggles
  - Overall dress that will not trap heat to the body
  - Nose Mask
  - Cap or hat
  - Safety boot.

Caution to farmers

- Farmer when handling or applying pesticides should avoid:
  1. Drinking fluids including water
  2. Eating any food
  3. Smoking.

Protective cap: *Prevents head from injury and drift from insecticide*

Safety goggles: *Protects the eyes from water, chemical and particles*

Respiratory mask: *Filters out unwanted particles and limits absorption of insecticide vapour*

Protective gloves: *Protects the hands against insecticide contact and injuries*

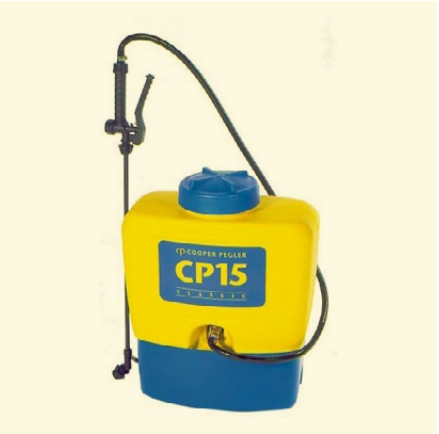
Long-sleeved protective clothing *protects the skin from pest, insecticide and injuries*

Safety boots: *Protects the feet from insecticide spills, falling and puncturing objects*

Personal protective equipment for farmers

Advise to farmers

- Farmers must always take time to read and understand the instructions given on the pesticide label.
- For farmers safety and effectiveness of the product, manufacturer's information on recommended dosages or application rates need to be adhered and the necessary PPEs must be worn.
- Knapsack or motorized sprayers must be washed properly before use and after use.
- Observe the re-entry period and pre-harvest intervals for pesticides.
- The re-entry interval (REI) is the minimum amount of time that must pass between the time a pesticide was applied to an area or crop and the time that people can go into that area without protective clothing.
- The pre-harvest interval (PHI) is the minimum amount of time between the last application of a pesticide and when the crop is safe to be harvested.
- The PHI is normally found on the pesticide label. Farmers must check on the label and observe it and must also inform your choice of pesticide.
- Judicious use of insecticides is encouraged based on economic or action thresholds (the no. of pests that necessitates a control action) and regular scouting to ascertain pest population levels as part of an IPM strategy.
- Apply synthetic insecticide during the seedling, early growth stages to the onset of flowering.
- From flowering to fruiting, use the biological pesticides, usually sprayed during late afternoon (4–6 p.m.), for enhanced action and to ensure food and environmental safety.
- This will prevent pesticide residues in food and preserve beneficial insects – pollinators-, bees and natural enemies (predators and parasites) of the pest.
- Use the right applicator for your pesticide.



Knapsack sprayers (15 l) for the application of pesticides

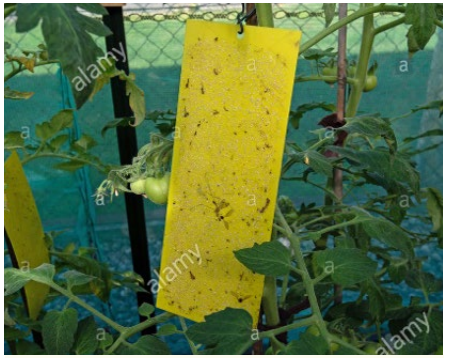
- For tomato, a knapsack is recommended.
- Cone nozzle is suitable for insecticides and fungicides application, and flat fan or deflector nozzle is most suitable for herbicides.
- Herbicides are normally dispensed with a low pressure and insecticides with a high-pressure gauge as indicated by H or L in the CP-15 Knapsack sprayer (H – Insecticides and L – Herbicides).
- Calibrate your knapsack before use.
- Calibrate to determine the flow rate, enhance the applicator's efficiency, and ensure that the correct amounts of insecticides were delivered consistently over the target plots with the correct amount of active ingredient.
- Variables to consider during calibration include sprayer or tank capacity, operator walking speed, the pressure, the type of nozzle being used and the nozzle height from the target which can affect what area a full tank of spray will cover.
- If a sprayer is incorrectly calibrated this can result in under dosing or overdosing areas with chemical.

How to prevent insecticide resistance by pests

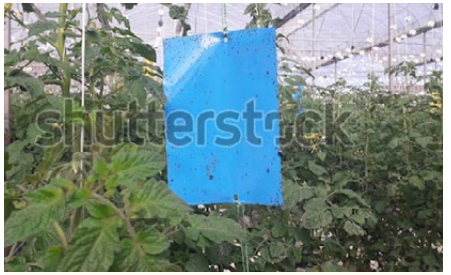
- It is important to use the correct or recommended dose of a pesticide to ensure effective pest and disease control.
- Alternate different classes of pesticides to avoid or delay the development of resistance.
- IPM approach involving the use of a combination of different pest and disease management tactics (cultural, biological, host plant resistance and chemical control) will minimise the risk of the pest developing resistance to a pesticide.

4.2 Guidelines on monitoring pests in the field using traps

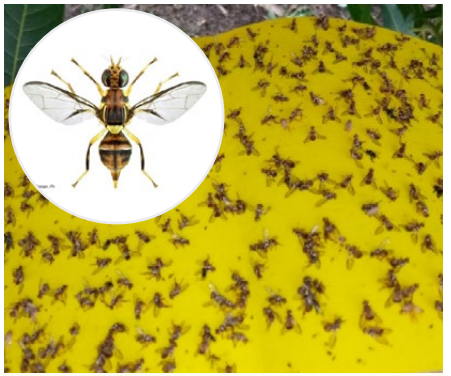
- Farmers can always scout or monitor pest numbers by inspecting plant parts (root, stem, leaves, flowers) for the presence of the pest.
- In addition to direct scouting for pests on the crop, various traps can be used to monitor the arrival, presence and build-up of pests' population on a crop.
- Mass trapping, involving the placement of more traps than needed for monitoring purposes, can also be undertaken to attract and kill more of the target pests over time to serve as a population suppression tool.
- Some common traps for trapping various pests in the tomato cropping system include pheromone traps, sticky traps, light traps, yellow pan traps and pitfall traps.
- In addition to direct pests counts on the crop, trap catches can also be used to decide the action threshold for some of the pests to ensure timely implementation of control measures.
- Action thresholds based a combination of trap catches and sampling on the crop will offer a more accurate information on when to initiate control measures.



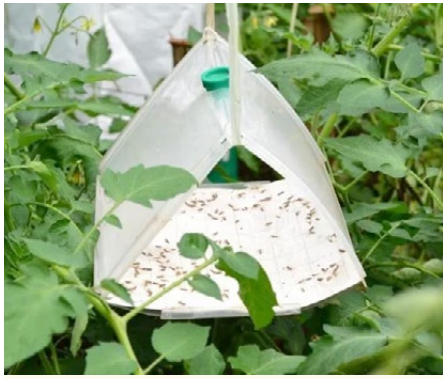
Yellow sticky trap for monitoring whiteflies on tomato (Photo from Barrie Sheerman / Alamy Stock Photo).



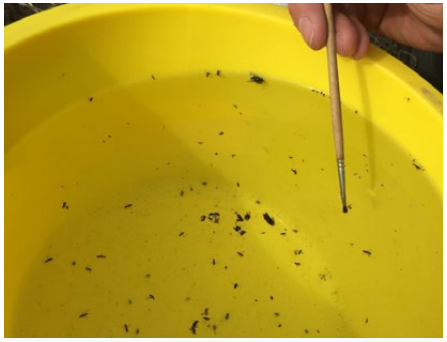
Blue sticky trap for monitoring thrips population on tomato (Photo: www.shutterstock.com).



Yellow sticky card, coated with methyl eugenol lure, with catches of the oriental fruit fly, Bactrocera dorsalis. *(Photo of single adult of B. dorsalis by MK Billah, Univ. of Ghana).*



Delta trap with pheromone for monitoring male adult moths of Tuta absoluta *in a tomato cropping system. (Image by Chris; www.hortzone.com).*



Yellow pan trap with catches, some of which are winged aphids (image from https://aphidtrek.org)

Establishing action thresholds for pests

- The aim of using traps for insect monitoring is to predict insect densities that cause crop damage or yield reduction or commodity losses so that timely control actions can be taken.
- Pest densities are monitored indirectly from the crop, using trap catches as an indication of pest density on the plant.
- Therefore, determining the relationship between trap catches of the pest with its numbers in the crop and related yield losses are critical to make correct control decisions.
- Begin monitoring pest population before applying or changing pest control practices.
- First learn what the trap catches reflect in comparison with pest injury and crop quality when using your conventional management practices.
- Then begin modifying pest control actions based on monitoring information.
- Farmers who regularly monitor their crops can develop their own thresholds, such as number of adults caught each week in well-maintained traps.
- Other types of numerical thresholds can be developed for pest monitoring, including visual inspection on plants for pests' presence or damage – e.g. percent number of plants with infestation or number of pests per shaken sample of plants.
- Due to the many variables and the lack of adequate research, growers and farmers can experiment over time to develop thresholds that are appropriate to their situations.
- Establish thresholds by judging the acceptability of the harvested crop in comparison with your records of pest density monitored throughout that production cycle.
- Keep good records and be flexible in adjusting thresholds or adapting monitoring and management methods appropriately.
- E.g. sticky traps alone are generally not a good tool for directly determining the need or timing of treatment application.
- Traps must often be used in combination with visual inspection of plants and other scouting methods to be effective or for informed decision making.
- However, traps are often very efficient and important tool alerting growers of the presence of pests before damage is observed on the crop.

Table 4. *Some suggested thresholds for some common pests from trap catches in tomato cropping system*

Name of pest	Type of trap	No of traps per hectare (monitoring)	No of traps per hectare (mass trapping)	Action threshold	Comments
Tuta absoluta	Pheromone trap with a sticky surface	2–4	40	45–100 males per pheromone trap per day	This may be modified to suit your local situation
Fruit flies – e.g. *Bactrocera* spp. *Dacus* spp.	Sticky trap	1	5	FTD (flies per trap per day) value of 0.01 or greater	This can be modified to suit local situation
Whiteflies	Yellow sticky traps	5	> 5	5 *B. tabaci* per trap per week (one trap per 200 plants)	This threshold was linked to a crop infestation level of 5% infested plants
Thrips	Blue sticky traps	5	> 5	15 or more per week per 100 m²	Normally used for monitoring
Aphids	Yellow pan traps	5	–	–	Only traps the winged forms and is good for monitoring

Things to do to make traps effective for pest monitoring and mass trapping

- Traps must be serviced regularly by replacing them when the sticky surface is full of catches or change lure when it expires.
- Traps should be suspended at the same height of crop to make them efficient.
- The correct trap density (number of traps per unit area) is required to achieve the desired purpose, either for monitoring or mass trapping of pests.
- Choose the preferred colour for trap based on the target pests.
- Most insects are attracted to yellow colour, whiles others are also attracted to blue and white colours.

4.3 Overview of commercial or beneficial biocontrol agents for pest management in vegetable (tomato) cropping system

Ghana now has the Phytosanitary and regulatory framework in place by the Plant Protection and Regulatory Services Directorate (PPRSD) of the Ministry of Food and Agriculture (MoFA), that allows the importation of beneficial or biocontrol agents into the country to control pests or the augmentation of locally available biocontrol agents.

Table 5. *Some commercial/beneficial biocontrol agents for pest management*

Pest	Potential biocontrol agents
Whiteflies – *B. tabaci*	• the parasitoid *Encarsia Formosa* • *Amblyseius swirskii* • the predatory fly, *Coenosia attenuate* • Mirid bug, *Nesidiocoris tenuis* • lacewings • predatory bugs • ladybird beetles • predatory mites
Leaf miners – *Tuta absoluta*	• *Nesidiocoris tenuis* • *Trichogramma* spp. (effective egg parasitoid) • Beneficial bacteria *Bacillus thuringiensis* • beneficial fungi – *Metarhizium anisopliae* var. *anisopliae, Beauveria bassiana* • Entomopathogenic nematodes (EPNs), *Steinernema carpocapsae, Steinernema feltiae* and *Heterorhabditis bacteriophora* attack *T. absoluta* larvae, pupae, and adults • eulophid wasp *Necremnus artynes* • *Dicyphus errans* has potential for controlling *T. absoluta* eggs and 1st instar larvae
Fruit borer (bollworm)	• *Bacillus thuriengiensis (Bt)* • *Metarhizium anisopliae* • *Beauveria bassiana*
Aphids	• Parasitic wasp *Aphidius* spp. and several predators; spiders, midges, hoverflies, ladybird, lacewings and predatory bugs
Thrips – *Thrips tabaci*	• Entomopathogenic fungi, *B. bassiana, M. anisopliae, Lecanicillium lecanii* and *Metarhizium flavoviride* var. *minus*
Variegated grasshopper	• The larvae of the blister beetle, *Epicauta blineata* are predators on the egg pods of grasshoppers • Entomopathogenic fungi, *M. anisopliae* var. *acridum* and *B. bassiana*
Mites	• Predatory mites, *Phytoseiulus persimilis* and *P. longipes* • *Amblyseius andersoni* (a native predatory species) • *Amblyseius californicus* (predatory mite) – an indigenous natural enemy for the control of spider mites *(Tetranychus urticae)* • *Orius insidiosus* (Pirate bug) • *Stethorus* (lady beetles that attack spider mites) • *Chrysopa* (green lacewings) • Entomopathogenic fungi, *M. anisopliae, Hirsutella* spp., *Verticillium lecanii* and *B. bassiana*
Root knot nematodes	• free living soil fungi, *Trichoderma* spp. • three antagonistic microbes' bacterium *Pseudomonas fluorescens*, fungus *Paecilomyces lilacinus* and yeast *Pichia guilliermondii*
Green Sting bug – *Nezara viridula*	• the parasitoid *Trissolcus basalis* feed on egg masses of *N.viridula* • The predatory bug *Podisus maculiventris*
Cotton leafworms – *Spodoptera littoralis*	• Use of parasitoids (braconids, encyrtids, tachinids and ichneumonids) and predators such as ladybird beetles, predatory beetles and spiders • Ladybird beetles have been noted to prey on young larvae and eggs • *Bacillus thuringiensis aizawai* (Bta) • *Beauveria bassiana*
Mealybugs	• Ladybird beetles, green and brown lacewings, spiders, minute pirate bugs, and larvae of predaceous midge

5. Conclusion

- In order to effectively manage pests and diseases, a combination of management strategies (cultural, biological, physical, host plant resistance, chemical, etc.) must be used to achieve sustainable control.
- Preventive measures must be put in place to prevent the occurrence and spread of pests and diseases.
- Monitor or scout for pests and diseases regularly before they spread to implement control measures on time.
- Once the action threshold of pests is reached, control measures must be implemented to avoid pests causing serious damage to your crop.
- Pesticides will continue to be an integral part of our pests and diseases management efforts, but careful selection of the right pesticides is required to achieve effective pest control 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.
- It is recommended that the synthetic pesticides are used mostly from the nursery to the onset of flowering and fruiting.
- Use the biological or biorational pesticides during flowering and fruiting stages of the tomato crop to ensure food safety and to promote the activities of beneficial insects (pollinators and natural enemies of the pests) in the field.

HortiFresh West Africa

Sheila Assibey-Yeboah
Program Manager
(+233) 263794715
www.hortifresh@snv.org