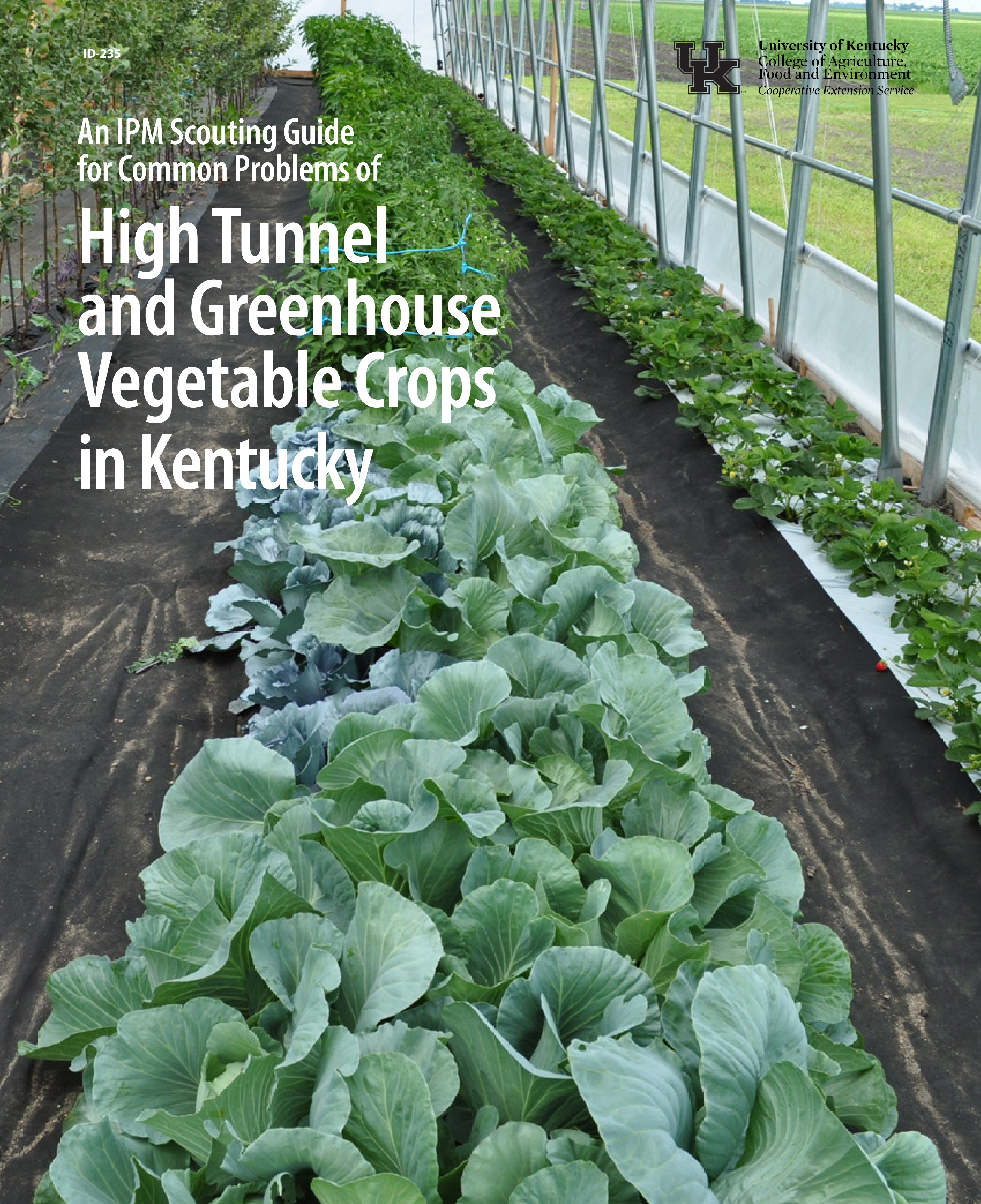
ID-235

University of Kentucky
College of Agriculture,
Food and Environment
Cooperative Extension Service



An IPM Scouting Guide for Common Problems of

High Tunnel and Greenhouse Vegetable Crops in Kentucky

Cooperative Extension Service | Agriculture and Natural Resources | Family and Consumer Sciences | 4-H Youth Development | Community and Economic Development

Photo Credits

The Amalgamated Sugar Company
Oliver T. Neher, Bugwood.org—25a

Auburn University
Ed Sikora, Bugwood.org—22a

Bugwood.org
William M. Brown, Bugwood.org—21a

California Polytechnic State University at San Luis Obispo
Gerald Holmes, Bugwood.org—12a, 21d, 24

Clemson-USDA
Clemson-USDA Cooperative Extension slide series, Bugwood.org—22b

Kentucky State University
Mike Bomford—37c

Lincoln University
Jaime C Pinero, Bugwood.org—8

Purdue University
Dan Egel, Bugwood.org—23a, 23b, 23c, 37a

University of Georgia
Alfredo Martinez, Bugwood.org—21b
David Langston—21e

University of Kentucky
Paul R Bachi—21c
Ric Bessin—27a, 27b, 27c, 28a, 28b, 28c, 29a, 29b, 29c, 30a, 30b, 30c, 30d, 31, 32a, 32b, 33a, 33b, 33c, 33d, 34a, 34b, 34c, 35a, 35b, 35c, 35d, 35e, 35f
Timothy Coolong—36b
John Hartman—14c
Cheryl Kaiser—25c
Brenda Kennedy—27d
Emily Pfeufer—13c, 14b, 15a, 15b, 15c, 17a, 17c, 20a, 20b, 20c, 20d
Shubin Saha—1a, 1b, 2, 3, 4, 5a, 5b, 6, 7, 9a, 9b, 10, 36a, 37b, 38, 39
Kenneth Seebold—11a, 11b, 11c, 11d, 12b, 13a, 13b, 13d, 14a, 15d, 16a, 16b, 17b, 18a, 18b, 19a, 19b, 20e, 26, 29d
Unknown UK photographer—25b

University of Minnesota
Randy Nelson—front cover

Virginia Polytechnical Institute
Mary Ann Hansen, Bugwood.org—11e

An IPM Scouting Guide for Common Problems of High Tunnel and Greenhouse Vegetable Crops in Kentucky

This manual is the result of efforts of the University of Kentucky Vegetable IPM team. Funding for this publication is from the University of Kentucky Pest Management Program.

Contents

Sponsored by Kentucky IPM

UK Vegetable IPM Team

Shubin Saha, Extension Horticulturist
Emily Pfeufer, Extension Plant Pathologist
Ric Bessin, Extension Entomologist
Shawn Wright, Extension Horticulturist
Cheryl Kaiser, Editor

Acknowledgements

The authors would like to thank Dr. Dan Egel, Extension Plant Pathologist, Purdue University, for his review.

Long before the term "sustainable" became a household word, farmers were implementing sustainable practices in the form of Integrated Pest Management (IPM) strategies. IPM uses a combination of biological, cultural, physical, and chemical methods to reduce and/or manage pest populations. These strategies are used to minimize environmental risks, economic costs, and health hazards. Pests are managed (although rarely eliminated) to reduce their negative impact on the crop.

Scouting and monitoring diseases, insects, weeds, and abiotic disorders in order to identify potential problems before they result in serious losses is essential to the IPM approach. The key to effective monitoring is accurate identification. The pictures included in this guide represent the more common abiotic and biotic problems that occur on vegetable crops grown in high tunnel and greenhouse structures in Kentucky.

This manual is not all-inclusive, and growers may encounter problems not included here. Please contact a local Cooperative Extension Service office for assistance.

Additional Resources

Additional vegetable crop information on identification, production, fertility, and pest management that could be related to protected agriculture can be found in the following publications; University of Kentucky publications are available at county Extension offices and online.

General Production Guides

Home Vegetable Gardening in Kentucky (ID-128)
http://www.ca.uky.edu/agc/pubs/id/id128/id128.pdf

Vegetable Production Guide for Commercial Growers (ID-36)
http://www.ca.uky.edu/agc/pubs/id/id36/id36.htm

Other IPM Scouting Guides

IPM Scouting Guide for Common Pests of Solanaceous Crops in Kentucky (ID-172)
http://www.ca.uky.edu/agc/pubs/id/id172/id172.pdf

IPM Scouting Guide for Common Problems of Cole Crops in Kentucky (ID-216)
http://www.ca.uky.edu/agc/pubs/ID/ID216/ID216.pdf

IPM Scouting Guide for Common Problems of Cucurbit Crops in Kentucky (ID-91)
http://www.ca.uky.edu/agc/pubs/id/id91/id91.pdf

IPM Scouting Guide for Common Problems of Legume Vegetables in Kentucky (ID-227)
http://www2.ca.uky.edu/agc/pubs/ID/ID227/ID227.pdf

IPM Scouting Guide of Natural Enemies of Vegetable Pests in Kentucky (ENT-67)
http://www2.ca.uky.edu/agc/pubs/ent/ent67/ent67.pdf

Cover: Diversified crop production in a high tunnel (Randy Nelson, University of Minnesota).

Physiological Disorders

Blotchy fruit external appearance (a) and internal necrosis (b).

Cracked, leaking cucumber fruit.

1. Blotchy ripening results in irregularly ripened tomato fruit with green to gray areas on the skin. When fruit is cut, dark necrotic tissue is present internally. Affected fruit are generally not marketable. This condition is associated with short days, cool temperatures, and excessive nitrogen.
Management—Provide adequate potassium fertility to help reduce incidence. Obtain soil and/or tissue nutrient tests; adjust fertility accordingly. As much as possible, modify structure environments to provide optimum growing conditions for crops.

Chimera on English cucumber.

2. Chimera appears as variations in leaf color and is generally manifested as varying shades of yellow and green. These symptoms result from a naturally occurring genetic mutation, which only appears occasionally and randomly. For example, a chimera may be observed on one in 2,500 cucumber plants in a greenhouse. It is generally not considered a problem in vegetable crops.
Management—No action is necessary.

3. Cracking and **fluid leaking** can occur in high tunnels when cucumbers are exposed to cold temperatures in late fall during fruit development. Cool temperatures reduce the elasticity of fruit skin, making it more prone to cracking.
Management—Optimize conditions environmentally by proper management of ventilation and heating based on the structure type.

Curved cucumber fruit.

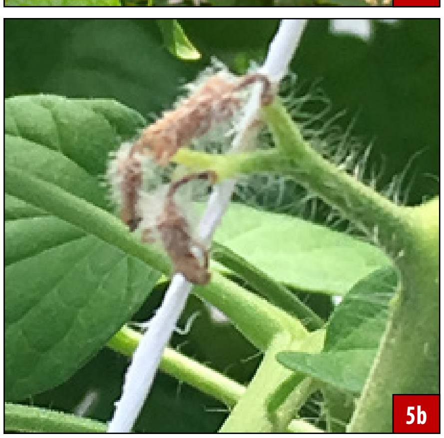
4. Curved fruits often occur in long English cucumbers when a leaf or a stem interferes with elongation of young, developing fruit. It can also be associated with improper irrigation and fertility management. Cucumbers developing close to the ground or top of container can also become curved.
Management—Prune cucumbers developing close to soil surface; do not allow longer English cucumbers to develop closer than 15 to 18 inches. Properly manage irrigation and fertility.

5. Flower drop/fruit abortion can be due to many conditions in protected structures, such as extreme heat, water stress, and fruit load. Flowers can also drop due to low light levels and relatively high nitrogen fertility.
Management—Adjust planting dates to avoid seasonal low light levels during flowering. Insure proper fertility and water management for crops when temperatures are high. As much as possible, modify the structure environment to provide optimum growing conditions for the crop.

6. Green core occurs when tomato fruit centers become hard and vegetative; normal red flesh fails to develop in that portion of the fruit. It is often associated with cool temperatures, low light levels, and excessive nitrogen fertilization.
Management—Manage structure environment to provide ideal temperature levels as much as possible. Maximize light by preventing condensation formation and removing shade cloth when sunlight is limited during cooler seasons of the year.

7. Marginal leaf burning and **marginal yellowing** occur on cucumbers grown in protected structures. It is associated with excess salt in the soil or soilless media.
Management—Properly manage fertility, avoiding over-fertilization. Frequent tissue tests can help manage nutrient applications. Periodically leach soil with fresh water to help remove some excess salt; however, effectiveness will vary based on soil type or soilless media.

Internal green core on tomato.



Aborted cucumber fruit (a) and aborted tomato flowers (b).

Marginal leaf yellowing on English cucumber foliage resulting from excess salt.


8

Pollutants from heater causing damage to tomato plants.

8. Pollutants, such as ethylene, sulfur dioxide, and nitrogen oxides, can cause plant injury that may be confused with herbicide injury. These pollutants can be generated by wood-fired boilers or natural gas/propane heaters. When heaters are used in protected structures, gases can build-up to damaging levels. Pollutants can also enter from exterior boilers as well. Symptoms of ethylene injury include distortion, yellowing, stunting, and flower/bud abortion. Other pollutants can cause flecking (typical of ozone injury) and/or burning of leaves and fruit.
Management—Regularly inspect heaters and maintain them in good working condition. Make sure heaters exhaust properly so pollutants are not trapped in structures.


9a


9b

Puffiness of tomato fruit external symptoms (a) and internal symptoms (b).


10

Zipper scar on green tomato fruit.

9. Puffiness of tomatoes causes fruit to appear flattened on one or more sides and partially hollow inside. It can be attributed to an interaction of various factors during winter and early spring conditions, including low light levels, high fertility, and poor pollen viability.
Management—Choose varieties not prone to this disorder. Proper nutrient management and maximizing light penetration is critical. For structures with two layers of polyethylene, use outdoor air to inflate layers, rather than air from inside the structure; this prevents condensation formation between layers, which can reduce light.

10. Zippering is characterized by the presence of brown tissue (resembling a zipper) running down the sides of tomato fruit, often from the stem to blossom end. Zippering is the result of a flower anther remaining attached to newly forming fruit. It may be associated with incomplete shedding of lower petals when fruit is forming.
Management—Select varieties that do not seem prone to zipper.

Diseases

Aboveground Diseases

Any of the bacterial diseases can become significant greenhouse issues if bacteria are introduced via infested seed, transplants, or trellis materials. Thus, bacterial diseases are of particular concern for transplant producers or growers starting their own plants from seed. These pathogens can spread from initially infected plants through splashing water or by normal trellising activities. Transplants showing symptoms of bacterial diseases should never be set in the field or production greenhouse.

11. Bacterial canker (*Clavibacter michiganensis* subsp. *michiganensis*) causes wilting and marginal browning or necrosis (called 'firing') of foliage; necrotic tissue may have a yellow border; leaves tend to curl upward. Elongated, tan lesions may also appear on tomato stems and petioles; lesions split and stem piths become grainy or pitted. Small (roughly 1/16 inch in diameter) raised lesions with white margins (called 'birdseye' spots) may appear on fruit. Seed infested with this bacterial pathogen, as well as contaminated trellis materials, provide sources of inoculum. **Management**—Sanitation (debris removal and use of thoroughly disinfested trellis materials) is the most effective management tactic. Use pathogen-free seed and transplants. Apply labeled bactericide sprays to suppress secondary infections.

Bacterial canker causing marginal browning (a); "firing" (b); pith necrosis (c); stem canker (d); and fruit spotting (e).

12. Bacterial speck (*Pseudomonas syringae* pv. *tomato*) results in small, circular, brown spots on stems, foliage, and fruit, primarily on tomatoes. Spots on foliage may be surrounded by a yellow border. These lesions coalesce to form large blighted areas in the plant canopy; defoliation may occur in severe cases. Small specks, which may be sunken or very superficial, appear on green fruit. This disease tends to be more severe under cool temperatures. **Management**—Use transplants started from pathogen-free seed. Follow good sanitation practices. Apply a labeled bactericide to reduce secondary spread.

Bacterial speck on tomato foliage (a) and fruit (b).

13. Bacterial spot (*Xanthomonas* spp.) occurs as spots on foliage, stems, and fruit of peppers and other solanaceous crops. Foliar lesions begin as small, circular, brown spots and may take on a wet appearance. These lesions may coalesce to form large blighted areas, which may also follow leaf veins. In severe cases, plants become defoliated and fruit drops. Lesions on green fruit develop as raised blisters about ¼ inch in size with a scabby appearance. This disease is favored by warm/hot temperatures. Contaminated seed and reused, unclean stakes are initial pathogen sources. Overhead irrigation and injured tissue from trellising spreads the bacteria among plants. **Management**—Use disease-free transplants and practice sanitation as the primary management tactics. Apply labeled bactericide sprays to manage secondary spread.

Bacterial spot on tomato foliage (a); tomato fruit (b); banana pepper fruit (c); and bell pepper leaf (d).

Early blight on tomato foliage in planting (a) and close-up of lesions (b, c).

14. Early blight (*Alternaria tomatephila*) may occur in structures where tomatoes and other solanaceous crops are planted in ground beds or near open sidewalls. Leaf, stem, and fruit symptoms may occur. Foliar lesions are tan-to-brown with concentric ring patterns. Older leaves are usually affected first, but the disease will spread to newer growth under favorable conditions. Extensive blighting and loss of foliage can result. Fruit lesions are brown-to-gray.
Management—Rotate to non-solanaceous crops. Apply labeled fungicides at regular intervals.

15. Gray mold (*Botrytis* spp.) occurs in structures with prolonged high humidity. This disease can affect actively growing and injured tissue, including leaves, stems, and fruit. Lesions are tan-to-brown; abundant masses of gray spores form on the surface of diseased tissues. In advanced cases, sclerotia may also develop. The gray mold pathogen has a very wide host range and can infect most vegetable crops and ornamentals.
Management—Reduce humidity by increasing air flow and eliminating standing water. Trellis plants carefully to avoid injuries. Remove fallen and diseased plant material from structures. Spray with a labeled fungicide on a regular schedule.

Botrytis gray mold fungus sporulating on tomato leaf and spent blossom (a), leaf (b), and stem (c); and on lettuce stem (d).

Leaf mold on tomato foliage (a) and pathogen sporulation (b).

16. Leaf mold (*Passalora fulva*) occurs on tomato plants grown in structures with high humidity and cool temperatures. Light green to yellow spots appear on upper leaf surfaces, while a velvety green-brown layer of spores develop on undersides and occasionally on upper leaf surfaces. This disease often occurs with Botrytis gray mold; however, leaf mold sporulation is more common on the underside of leaves, while gray mold sporulation may occur anywhere on plants. **Management**—Resistant varieties are available for some pathogen races. Reduce humidity by increasing air flow and eliminating standing water. Trellis plants carefully to avoid injuries. Remove dead plant material from structures. Spray labeled fungicides on a regular schedule.

17. Powdery mildew (various species) affects nearly all vegetable crops and is benefited by high humidity, but low free water on plant surfaces. This disease is characterized by the presence of a white powdery fungal growth appearing on upper and lower leaf surfaces, as well as stems and petioles. Over time, necrotic areas form, resulting in blighting of affected leaves. While powdery mildew does not affect fruit directly, it can significantly reduce yields due to lowered rates of photosynthesis in leaves. **Management**—Increase air flow within structures and decrease humidity. Apply labeled fungicides on a regular schedule.

Powdery mildew on tomato foliage (a, b) and petiole (c).

18. Septoria leaf spot (*Septoria lycopersici*) may occur in protected structures where tomatoes are cropped in the same soils year after year, or disease may initially begin near open sidewalls. Circular brown lesions with tan centers appear on foliage. Small black specks (pycnidia) are often found in centers of older lesions. Disease begins in lowest leaves and can progress up plants. Complete defoliation may result when disease is severe. Fruit are not affected; however, lesions may develop on stems under high disease pressure.

Management—Practice crop rotation. Apply labeled fungicides on a regular schedule. Remove infected crop debris promptly at season end.

Septoria leaf spot on tomato foliage in planting (a) and close-up (b).

19. Southern blight (*Sclerotium rolfsii*) typically causes lesions at or near the soil line, with white fungal growth (mycelium) often evident on plant stems and expanding into surrounding soil. Numerous spherical fungal resting structures (sclerotia) roughly the size of mustard seeds can be found on the surface of the mycelia. Sclerotia initially appear white, but become tan or reddish brown as they develop. This pathogen overwinters in soil as sclerotia and can infect numerous different crops.

Management—Fungicides may only be suppressive. Rotate to non-host crops. Deep tillage to bury sclerotia may hasten their decay. Consider fumigation or solarization.

Southern stem blight sclerotia and mycelia on tomato stem (a) and on soil around infected pepper plant (b).

Sclerotinia white mold/timber rot on trellised cucumber (a) and carrot (b); fruit drop on tomato (c); black sclerotia in decayed tomato fruit (d) and within a tomato stem (e).

20. Timber rot/white mold/drop (*Sclerotinia* spp.) can affect a number of vegetable crops. Infections girdle stems, eventually killing whole plants. White mycelium covers affected tissue under humid conditions; under drier conditions, elongated lesions appear bleached or tan. Infected fruit become limp and rotten; this phase occurs most commonly on tomatoes. Dark brown to black overwintering structures (sclerotia) are often formed on and within diseased tissues. **Management**—Remove diseased plant parts or entire plants, as well as sclerotia; burn infected debris or dispose of it in uncropped areas far from structures. Maintain a weed-free border around cropping structures. Apply labeled fungicides or biocontrol products preventatively where this disease has previously been a problem.

21. Tomato spotted wilt virus (TSWV) causes a number of different symptoms on a wide variety of vegetable plants; it is particularly localized to young foliage and fruit. Foliar symptoms can include dark circular lesions, ringspots, and bronzing; infected fruit show ring spots, discoloration, malformation, and/or poor fruit set. TSWV can persist in association with ornamental plants, many weeds, and thrips in greenhouses. Thrips serve as a vector, moving TSWV from plant to plant.

Management—Carefully inspect plants prior to bringing them into structures to prevent introduction of disease. Aggressively manage weeds and other non-crop plants in and around agricultural structures. Monitor for thrips and manage their populations (see 34).

Tomato spotted wilt in planting (a); on foliage (b, c, d); and on fruit (e).

Fusarium wilt on tomato plants (a) and vascular discoloration (b).

22. Verticillium wilt (*Verticillium* spp.) and **Fusarium wilt** (*Fusarium* spp.) are caused by common soilborne fungi that do not readily produce airborne spores. Entire plants may wilt, or wilt may be confined to only one side of the plant; leaves become chlorotic (yellow). Cutting through infected stems reveals a brown discoloration of the vascular tissue (xylem). Fusarium wilt is favored by warm temperatures, while cool conditions favor Verticillium wilt. These fungi persist in soils from year to year and some species may infect multiple plant species.
Management—Select resistant cultivars when growing plants in infested soils. Rotate to a non-host crop. Consider fumigation or solarization.

Root Diseases

23. Fusarium crown and root rot (*Fusarium oxysporum* f. sp. *radicis-lycopersici*) of tomato is caused by a different *Fusarium* species than the pathogen causing Fusarium wilt. This soilborne disease advances more slowly than Fusarium wilt, though roots and stems still show extensive discoloration. Plants eventually wilt, but this may not occur until fruit bearing stage. Cracked cankers, sometimes with sporulation, may become evident on plant stems at the soil line.
Management—Plant only resistant varieties in soils known to be infested. Avoid physically damaging plants. Rotate to a non-host. Do not allow high levels of soluble salts to develop. Fumigation or solarization may need to be considered.

Wilting due to Fusarium crown and root rot (a); discoloration in lower stem (b); lesion at stem base (c).

24. Pythium root rot (*Pythium* spp.) causes brown, rotting roots. Stem constrictions may occur at the soil line, sometimes with a lesion extending upward. Like other root rot diseases, plants may be stunted, exhibit nutrient deficiency symptoms, and suffer reduced yields. *Pythium* species are water molds that have a very wide host range.

Management—Increase soil drainage and avoid overwatering. Use approved soil- or media-applied fungicides labeled for *Pythium* spp.

25. Rhizoctonia root rot (*Rhizoctonia solani*) is caused by a fungus that overwinters in soils and in association with crop debris. Similar to other root rots, roots decay and turn brown; however, Rhizoctonia lesions on roots and lower stem are often reddish-brown in color. *Rhizoctonia* also has a foliar phase on select crops in Kentucky, notably beans and tobacco.

Management—Practice crop rotation and minimize overwatering. Apply labeled fungicides to suppress disease. Fumigation or solarization may need to be considered.

Pythium root rot (left) and healthy (right) watermelon transplant roots.

Rhizoctonia root rot on beet (a), cabbage (b), and bean (c).

Root knot nematode symptoms on summer squash roots.

26. Root knot nematode (*Meloidogyne hapla* and *M. incognita*) infects a broad range of host plants. Aboveground symptoms include stunting, chlorosis (yellowing), and reduced yields; roots show characteristic knots or galls. Root knot nematodes are microscopic roundworms that can move through moist soils as juveniles. Mature female nematodes become permanently attached to plant roots and produce thousands of eggs that are released when females die.

Management—Select resistant varieties. Use non-fumigant nematicides for suppression. Immediately remove plant material, especially roots, from structures at season end.

Insects and Other Arthropod Pests

Broad mites (a); eggs (b); deformed, hardened plant tissue (c); and fruit injury to pepper (d).

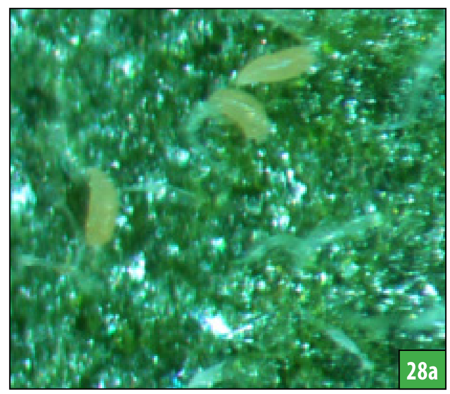
Mites

27. Broad mite (*Polyphagotarsonemus latus*) has a wide host range that includes peppers and tomatoes. When present, they are in and around plant buds; however, due to their small size, confirmation requires a microscope. Broad mite injects a toxin that causes leaves and stems around buds to become deformed (often curling downward) and hardened; fruit may appear scarred. Eggs are clear with characteristic rows of raised white bumps that give them a jeweled appearance. Broad mites are more common at cooler temperatures.

Management—At the first signs of damage, use an approved miticide labelled for broad mites; apply as needed. Miticides that control spider mites are not necessarily effective against broad mites.

28. Tomato russet mite (*Aculops lycopersici*) causes bronzing of tomato stems and yellowing and drying of leaves. Damaged fruit remain small, turn brown, and have a russetted appearance. Symptoms move up plants from lower areas. Presence of this mite can only be confirmed with a hand lens (10X or greater) or microscope. Look for minute, cone-shaped mites on the green tissue. While this mite feeds on various solanaceous vegetables, damage has only been observed on tomato in Kentucky.

Management—Watch for characteristic damage; once tomato russet mite is confirmed, treat with an approved miticide. Miticides that control spider mites are not necessarily effective against russet mites. Evaluate miticide effectiveness by tagging the limits of stem bronzing on a plant and monitoring it for additional damage. Remove alternate hosts, such as nightshades, bindweed, and morningglory, from in and around structures.



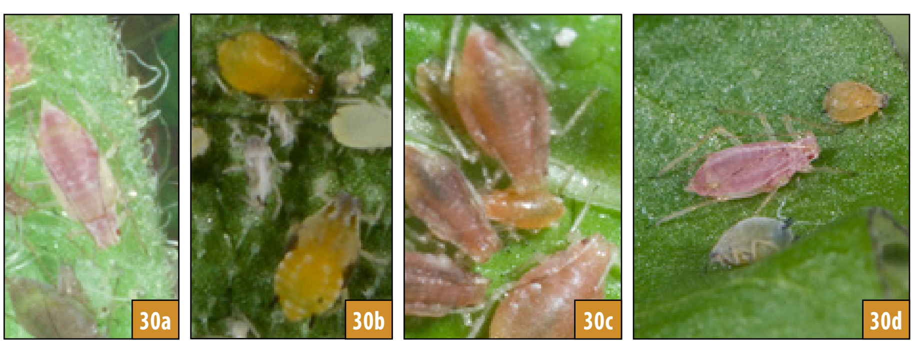
Tomato russet mites (a); bronzed, greasy appearance to stems (b); and undersized, dark, russetted fruit (c).

Two-spotted spider mite (a); stippling damage to leaf (b) and fruit (c); and webbing on severely damaged leaves (d).

29. Two-spotted spider mite (*Tetranychus urticae*) is the most common mite occurring on greenhouse and high tunnel vegetable crops; it will feed on hundreds of plant species, particularly during hot, dry conditions. Adult mites are less than 1 mm in size and can vary from light green to straw-colored; a large dark spot is present on each side of the body. Eggs are clear and spherical. Spider mites cause stippling (tiny light-colored spots) on leaves and fruit as they feed with their piercing-sucking mouthparts. Webbing between plant structures may be noticeable when populations are large.
Management—Release predaceous mites for biological control or apply foliar miticides.

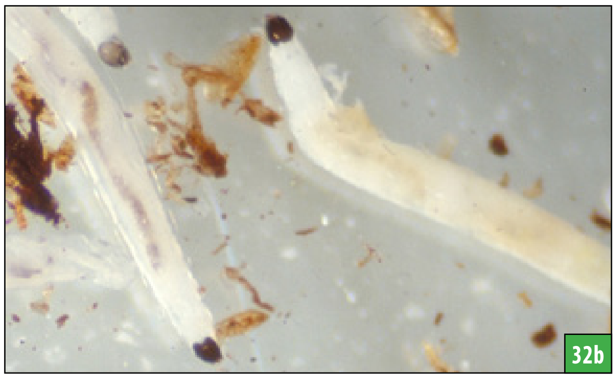
Insects

30. Aphids (Family Aphidae) occuring in high tunnels include green peach, melon (cotton), and potato aphids. Aphids feed with piercing-sucking mouthparts and are vectors of several potyviruses. Aphid bodies are pear-shaped to round with two tailpipe-like projections (cornicles) near the end of their abdomens. Some adults are winged; others are wingless. Sugary honeydew and black sooty mold fungal growth are often found underneath aphid infestations. Large populations will turn leaves yellow, stunt plants, and reduce yields.
Management—Release predators or minute wasp parasitoids, or use foliar insecticides. Eliminate weeds in and around structures. Monitor for winged aphids with yellow sticky cards (see 34c). Avoid over fertilizing plants with nitrogen.



Potato aphids (a); melon aphids (b); green peach aphids (c); comparison of size and shape of potato aphid (center) and melon aphids (d).

Yellow-striped armyworm in tomato fruit.



Fungus gnat adult (a) and larvae (b).

Brown stink bug (a); brown marmorated stink bug (b); green stink bug (c); and stink bug damage to tomato (d).

31. Caterpillars (various species), including yellow-striped armyworm and corn earworm, can damage foliage and/or fruit, depending on the species and type of vegetable grown. Caterpillars feed with chewing mouthparts, thus, holes in leaves and fruit are signs of possible activity. Adults are moths, which do not damage plants.

Management—Use screens over ventilation windows to prevent moth entry. Avoid placing security lights, which can attract moths, near structure entrances or windows. Sprays using *Bacillus thuringiensis* to control caterpillars are compatible with biological control methods.

32. Fungus gnats (Family Sciaridae) are small, delicate, dark-bodied, slender flies. Adult flies are about 1⁄10 inch in size and have long antennae, slender legs, and a tapering spindle-shaped abdomen. Larvae are legless with white bodies and dark head capsules about the size of poppy seeds. Larvae, which primarily feed on fungi, algae, and organic matter, require continuously wet conditions to develop. While adult flies are not damaging, large numbers of larvae can injure roots and stunt plant growth.

Management—Controls are directed toward larvae rather than adults. Avoid continuously wet soil/media. Eliminate standing water and repair irrigation leaks. Place raw potato slices on soil surfaces to attract and monitor for larvae. Use entomopathogenic nematodes and predatory mites. Apply soil drenches containing *Bacillus thuringiensis israelensis*.

33. Stink bugs (*Euschistus* spp., *Chinavia hilare, Halyomorpha halys*) are ½ inch to ¾ inch in size and shield-shaped. Stink bugs feed with piercing-sucking mouthparts and cause off-color corky areas under skins of tomato and pepper fruit; these symptoms are called 'cloud spots.' When disturbed, stink bugs give off an odor similar to that of crushed cilantro,

Management—Use screens over ventilation windows to prevent stink bug entry. Eliminate weeds around the outside of high tunnels. When stink bugs are detected, use foliar insecticide sprays as needed to prevent fruit injury.

34. Thrips (Family Thripidae) are narrow, tiny insects (about 1/20 inch in length) that have four narrow wings fringed with hairs. While they can live in flowers and buds, thrips leave characteristic damage on leaves with their rasping mouthparts. Silvery to brown feeding scars about ¼ inch in size or less, along with black tar spots (their waste material), are diagnostic. Thrips can vector tospoviruses, including tomato spotted wilt virus (see 21).

Management—Early detection is important. To monitor, use yellow sticky cards hung just above crop canopies (a minimum of four per high tunnel) and/or tap plant parts over white paper to inspect for thrips. Eliminate weeds in and around structures. Thrips predators are commercially available, or use approved insecticides as necessary.

Thrips (a); damage to leaves, along with associated insect waste material (tar spots) (b); and yellow sticky card for monitoring thrips and other insect pests (c).

35. Whiteflies (*Bemisia tabaci*, *B. argentifolii, Trialeurodes vaporariorum, T. abutilonea*), such as sweetpotato, greenhouse, and banded wing whiteflies, infest undersides of leaves. Greenhouse whitefly holds its wings flat on its back; sweetpotato whitefly holds its wings vertical and roof-like; and banded wing whitefly has prominent gray bands on its front wings. Whitefly eggs are often laid in arcs or partial circles on undersides of leaves. Immature whiteflies are sedentary, scale-like, light yellow in color, and found on middle and lower leaves. White fly feeding can cause leaf yellowing and generate ripening disorders with tomatoes. *Bemisia* whiteflies can vector begomoviruses. Whiteflies produce honeydew, which can result in sooty mold fungal growth on plant surfaces.

Management—Eliminate weeds in and around structures. Monitor for whiteflies with yellow sticky cards (see 34c). Use commercially available minute wasp parasitoids and predators (match with the species of whiteflies present). Apply systemic and foliar insecticides.

Whitefly eggs (a); greenhouse whitefly (b); banded wing whitefly (c); sweetpotato whitefly nymph (d); sweetpotato whitefly (e); and tiny black specks of sooty mold growth on whitefly honeydew secretions (f).

High Tunnel Weekly Monitoring Form

Name: ______________ Date: ____________ Greenhouse/High Tunnel: ______________ Conditions: ____________________

General Walk-through Observations

Section/Row	Honeydew	Aphids	Thrips	Whiteflies	Fungus gnats	Spider mites	Rust mites	Other:	Other:
Total									

Yellow Sticky Cards

Location	Winged aphids	Thrips	Whiteflies	Fungus gnats	Other:	Other:	Map
Total							

Plant Inspections

Section	Aphids	Thrips	Whitefly adult	Whitefly nymphs	Fungus gnats	Shore flies	Spider mites	Rust mites	Other:
Total									

Herbicide Injury and Weeds

2-4, D (a) and glyphosate (b) injury to tomato plants.

36. Herbicide drift can be an issue for high tunnel and greenhouse growers. Growth regulator herbicides, such as 2-4,D, may easily volatilize and become trapped inside structures. If backpack sprayers are used at a much higher pressure than is recommended for herbicides, the smaller droplets that form are prone to drift. Typical growth regulator herbicide injury includes malformation and irregular growth habit. Glyphosate (Roundup) can also drift and cause damage to sensitive plants. Most herbicide damage will occur on the upwind side of structures.

Management—If possible, avoid using liquid herbicides anywhere on the same property as structures. If they must be used on nearby fields, apply herbicides only on calm days with closed walls. Discuss herbicide usage with neighboring growers to enlist their cooperation.

37. Weeds within tunnels compete for light, nutrients, and water; increase the incidence of insect and disease problems; and can reduce air circulation. Because high tunnels are considered greenhouses in Kentucky, few herbicides can be used within structures, except when plastic coverings have been removed for replacement.

Management—Before constructing tunnels, be sure perennial weeds are under control at

Weeds within tunnels (a); white woven reusable ground cover in row middles (b); and hand tools for use in weed management (c), next page.

37c

the site. Manage weeds within structures using hand tools or rototiller. Use mulch (black plastic, paper, or white-on-black plastic) in production areas. Straw (not hay), which should not contain seeds, can also be used as mulch. Do not allow weeds around structures to go to seed. Only use compost that has been properly produced so weed seeds are killed. If no crops are present during summer, close structures; weeds should die off from high temperatures.

38. Weeds around tunnels increase the chance of weed seeds entering structures, hamper airflow, and provide potential reservoirs for insects and diseases. A vegetation-free strip should be maintained around perimeter of structures.

Management—Remove or mow vegetation in outside perimeter. Apply gravel, plastic mulch, landscape fabric, or natural mulch near exterior walls.

38

Gravel on the ground surrounding structure exterior.

General IPM Best Management Practices

Prevention

- Manage perennial weeds at high tunnel sites before construction
- Plant seed/transplants that have been screened for pathogens and appear disease-free
- Use new commercial transplant media from a reputable source
- Use insect screen to cover openings
- Inspect new plants coming into structures for pests and diseases
- Avoid wearing brightly colored clothes that could attract certain insects
- Apply mulch to inhibit weeds (organic mulches need to be free of weed seeds and other propagules)
- Avoid herbicide applications near tunnels
- Close and remove bumblebee colonies prior to use of pollinator-toxic insecticides; store bees in a shady location for a day before returning them to the structure

Sanitation

- Eliminate all weeds in and around structures (20-foot perimeter)
- Maintain a 2-week plant-free period prior to each new crop cycle
- Thoroughly sanitize all stakes and trellis materials between crops
- Remove and destroy or dispose of fallen plant debris
- Do not allow clippings from mowing to blow into tunnels

Insect screening over greenhouse openings and gravel around exterior.

Environmental management

- Avoid excessive watering or use of nitrogen
- Avoid temperature extremes
- Reduce leaf wetness by using drip irrigation and repairing sagging or leaking ceilings
- Use summer solarization to destroy weed seeds and reduce soilborne disease pressure

Monitoring

- Use yellow sticky cards to monitor for insect pests; check cards regularly
- Frequently inspect plants for signs and symptoms of pests and disease
- Watch for weeds and remove; do not allow weeds to go to seed in or around structures
- Record all scouting observations and maintain for reference in future years

Biological control

- Consider using biological control for reoccurring pests
- Avoid using pesticides damaging to beneficial insects and mites
- Evaluate compatibility of biological control with other pest and disease management

Chemical

- Only apply pesticides as necessary
- Apply only those pesticides labeled both for the crop and for greenhouse use
- Never exceed the application rate or season limit of any applied pesticide
- Rotate pesticide modes of action to manage resistance in populations

Issued 7-2016