W 916

Hemp Disease and Pest Management

Zachariah Hansen, Assistant Professor and Extension Specialist;
Ernest Bernard, Professor;
Jerome Grant, Professor;
Kimberly Gwinn, Associate Professor;
Frank Hale, Professor and Extension Specialist;
Heather Kelly, Associate Professor and Extension Specialist;
and Scott Stewart, Professor and Extension Specialist

Department of Entomology and Plant Pathology

Overview

Hemp acreage has increased dramatically in Tennessee in recent years. In 2019, approximately 3,400 licenses were granted for hemp production in Tennessee, composed of more than 46,000 acres, with an estimated half of those acres planted. Nearly all hemp produced in Tennessee in 2019 was for cannabidiol (CBD), although hemp can also be grown for grain and fiber. An overview of hemp production in Tennessee can be found in the University of Tennessee Extension publication "W 777 Status of Industrial Hemp in Tennessee."

Hemp is defined by the USDA as "the plant species *Cannabis sativa* L. and any part of that plant, including the seeds thereof and all derivatives, extracts, cannabinoids, isomers, acids, salts, and salts of isomers, whether growing or not, with a delta-9 tetrahydrocannabinol [also commonly written as Δ9-THC] concentration of not more than 0.3 percent on a dry weight basis." More information on the distinction between hemp and marijuana can be found in the USDA Interim Final Rule on U.S. Domestic Hemp Production.

Hemp is susceptible to several diseases and insect pests that can cause economic loss. In Tennessee, where humid conditions tend to favor disease development, several of these issues have resulted in significant yield losses for Tennessee hemp growers. Leaf spots, southern blight and corn earworm have been the most destructive pest and disease problems over the past several seasons, but other issues have also occurred. The purpose of this publication is to describe the most common hemp diseases and insect pests observed in Tennessee in recent years and to outline strategies to manage these problems. With very few pesticides registered for use on hemp in Tennessee, growers must take an integrated pest management (IPM) approach focusing on cultural practices to reduce losses.

Common Diseases of Hemp in Tennessee

Leaf spot diseases

Leaf spot diseases were common and widespread in Tennessee in 2018 and 2019. Several fungal pathogens may be associated with hemp leaf spot diseases in Tennessee including *Bipolaris* spp. and *Cercospora* spp. (Figures 1 and 2). Leaf spot symptoms range from small circular lesions with tan centers and brown margins to larger lesions with dark centers and brown/purple margins. Lesions may coalesce (grow together) and cause blighting to large portions of the leaf area. Leaves may turn yellow and premature defoliation may occur under severe infections. The fungus *Periconia* spp. is often observed on dead hemp tissue, but it is most likely a saprophyte and not the cause of disease (Figure 3). *Curvularia* spp., a recently confirmed leaf spot pathogen of hemp, have also been associated with hemp leaf spots in Tennessee. Leaf spot most likely spreads through wind and rain splash, but

research is needed to better understand how hemp leaf spot epidemics start and progress. Significant differences in cultivar susceptibility to leaf spot were observed in field trials across three locations in Tennessee in 2019 (Table 1). Growers who experienced significant leaf spot disease pressure in 2019 should consider avoiding highly susceptible cultivars, while still considering yield components. Examples of high-CBD-yielding cultivars with low leaf spot susceptibility include 'OG', 'Sweetened' and 'Carolina'. See UT Extension publication "W 900 Hemp Variety Trials in Tennessee 2019" for a summary of yield data from 2019 hemp-for-essential oil field trials.

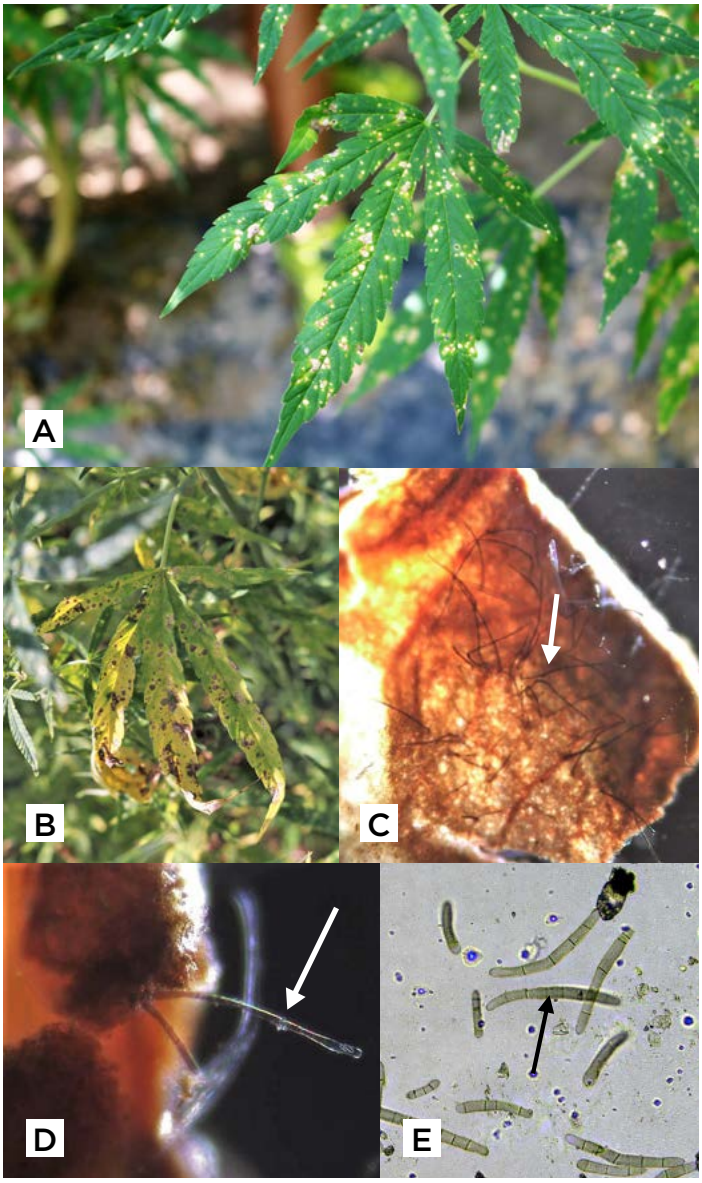

Figure 1. Hemp leaf spot symptoms and signs. A) Hemp leaf spot caused by *Bipolaris* spp. on field-grown hemp showing light brown/tan lesions with tan borders. B) As leaf spot progresses, lesions coalesce and cause leaf yellowing and premature defoliation. C, D) *Bipolaris* spp. spore structures (conidiophores and conidia), indicated by arrows, viewed under a dissecting microscope. E) *Bipolaris* spp. spores (conidia), indicated by the arrow, viewed under a compound microscope.

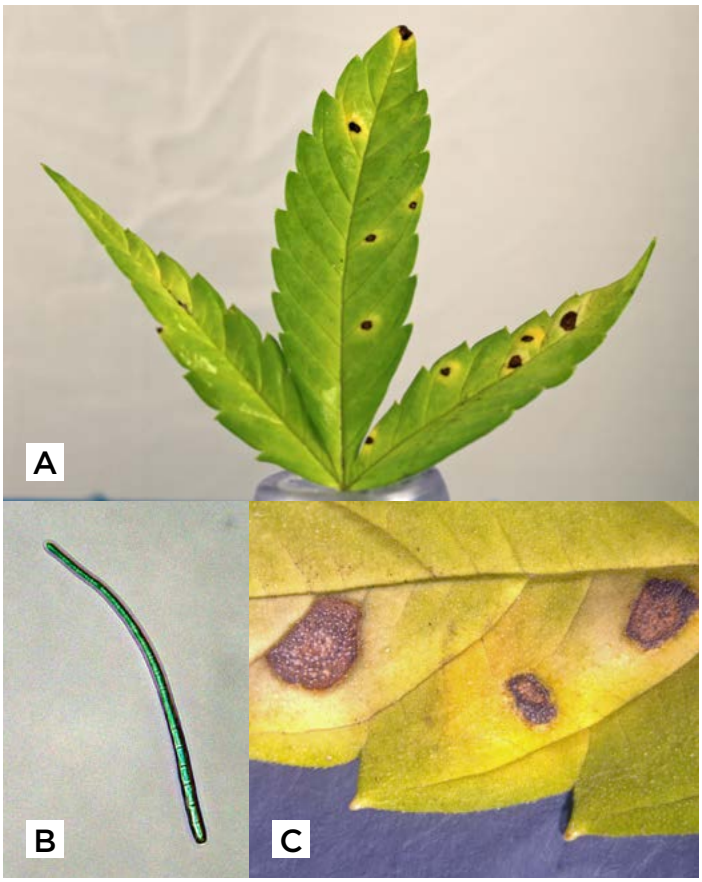

Figure 2. A) Cercospora leaf spot on hemp appears as dark lesions, which may be surrounded by a yellow halo. B) *Cercospora* spp. spore (conidium) viewed under a compound microscope. C) Cercospora leaf spot lesions viewed under a dissecting microscope. Photos courtesy of Alan Windham, Extension specialist and professor, UT Department of Entomology and Plant Pathology.

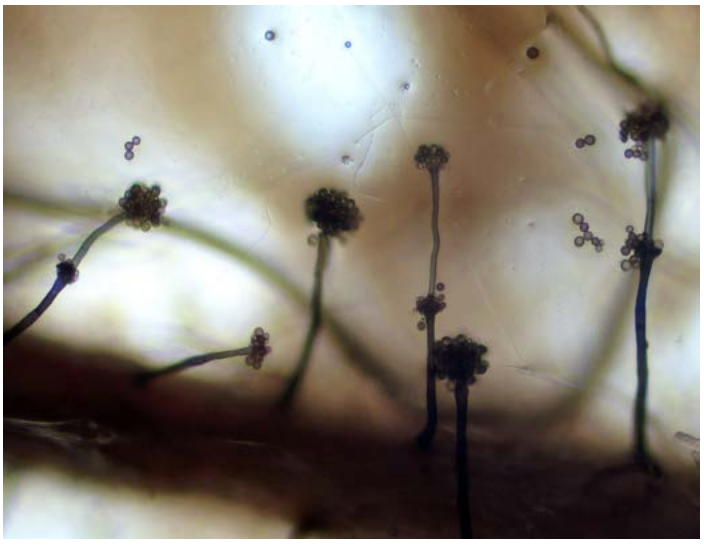

Figure 3. The fungus *Periconia* spp. is often associated with dead hemp tissue, although it is likely a saprophyte and not the cause of disease. The image shows long, darkly pigmented spore structures (conidiophores and conidia) of *Periconia* spp. Photo courtesy of Alan Windham, Extension specialist and professor, UT Department of Entomology and Plant Pathology.

Table 1. Leaf spot susceptibility ratings based on hemp-for-essential oil cultivar trials at three locations in Tennessee in 2019.

		Leaf spot susceptibility[1]		
Cultivar	Source[2]	GREC	HRREC	Jackson
Late Sue	Indoor Growers World	low	-	-
T-Rex	PWP	low	low	low
Franklin	MMH	low	low	low
CBD Therapy	MMH	low	low	moderate
Super CBD	MMH	low	low	low
OG	PWP	low	-	-
Cherry Wine	MMH	low	low	moderate
Sweetened	MMH	low	low	moderate
Frosted Lime[3]	Oregon CBD	low	low	-
ACDC	PWP	low	-	-
Cherry	MMH	low	moderate	-
HA3EZ	MMH	low-mod	moderate	low
CB Dawg	Oregon CBD	moderate	low-mod	-
Siskiyou Gold	Oregon CBD	low	low-mod	-
VG	PWP	moderate	-	-
Wife	MMH	moderate	low-mod	moderate
Carolina	Blühen	moderate	low	moderate
Hawaiin Haze	Corbin Sciences	moderate	moderate	moderate
Wife	PWP	moderate	-	-
Suver Haze	Blühen	moderate	moderate	moderate
Cherry[4]	South Central Growers	moderate	-	moderate
Cherry	South Central Growers	mod-high	moderate	moderate
T1	PWP	mod-high	-	-
T1	South Central Growers	high	mod-high	high
T1[4]	South Central Growers	high	-	high
Cherry Tart	PWP	high	-	-
Cherry	PWP	high	-	-

Cultivar	Source[2]	GREC	HRREC	Jackson
Baox	MMH	high	mod-high	-
Tangerine	Corbin Sciences	high	high	high

[1]Leaf spot susceptibility ratings based on 2019 disease incidence and severity ratings averaged across four replicates at each experimental location. Trial locations were the University of Tennessee AgResearch and Education Center at Greenville, TN; UT Highland Rim AgResearch and Education in Springfield, TN; and an on-farm location in Jackson, TN.
[2]Indoor Growers World, Goodlettsville, TN; PWP Greenhouses Inc., Pall Mall, TN; MMH, Athens, TN; Oregon CBD, Independence, OR; Blühen, Knoxville, TN; Corbin Sciences, Springfield, TN; South Central Growers, Springfield, TN.
[3]'Frosted Lime' showed high phenotypic variability among individuals. Only the predominant phenotype was rated.
[4]Cultivars were topped prior to transplanting.

Southern blight

Southern blight has been the most damaging disease in Tennessee hemp production in recent years. The disease is caused by the soilborne fungus *Athelia rolfsii* (also called *Sclerotium rolfsii*). The most obvious symptom of southern blight is dramatic wilting that does not improve following irrigation (Figure 4A). Wilt may be associated with leaf yellowing. Infections are often sporadic within a field, and affected plants may be surrounded by healthy plants. Affected plants show white fungal growth, easily observed with the naked eye, at the base of the plant near the soil line (Figure 4B). Small, round, tan/brown balls, called sclerotia, resembling mustard seeds will be embedded in the white fungal growth (Figures 4B and C). The white fungal growth and sclerotia may extend beyond the plant stem to surrounding plant residue on the soil surface. Sclerotia are the pathogen's hardy overwintering structures and are responsible for initiating disease each season. These sclerotia can overwinter for several years without a host. The pathogen does not produce spores, and so a plant must be in close physical proximity to one of these sclerotia to become infected.

Southern blight has a wide host range and can cause disease on numerous other crops including several vegetable crops. Grasses are considered the best crop rotation partners to reduce southern blight. Some fields that have been fallow or in pasture for several years preceding a hemp crop have had high incidence of southern blight, illustrating the wide host range and challenge of relying on crop rotation for southern blight management. Deep plowing can reduce disease pressure by physically burying sclerotia, but the act of working the soil may also spread inoculum through the field. Diseased plants, and the soil immediately around them if practical, should be carefully removed to reduce overwintering inoculum. Bud material can be harvested from plants that become infected near or at maturity. This disease is favored by low soil pH. Hemp plants are susceptible at any age from seedling to full maturity. The question of whether plasticulture increases incidence of southern blight has been raised by growers, but research is needed to determine if this is an important factor.
Once a plant becomes infected with southern blight there is no cure. More research is needed to determine if hemp cultivars differ in susceptibility to southern blight.

Figure 4. Southern blight on hemp. A) A well-established plant in the field displaying wilt and leaf yellowing resulting from southern blight infection (note: surrounding plants remain healthy). B) White fungal growth and tan/brown sclerotia are observed near the soil line on a hemp plant infected with southern blight. C) A close-up view of the hardy overwintering sclerotia, which resemble mustard seeds.

Hemp rust

Hemp rust is a fungal disease caused by *Uredo kriegeriana* (Figure 5). Little is known about this pathogen's life cycle and mechanisms for overwintering. Hemp rust was first confirmed on samples collected in East Tennessee on August 26, 2019, at the UT Soil, Plant and Pest Center. Following the initial observation, the disease became widespread and was observed in West, Middle and East Tennessee as well as surrounding states. Symptoms of hemp rust begin as yellow/orange spots on the leaf surface, and eventually clusters (pustules) of orange spores (uredospores) become visible to the naked eye on the leaf underside. Lesions eventually become dark orange/brown and may coalesce. More research is needed to determine if hemp cultivars differ in susceptibility to rust.

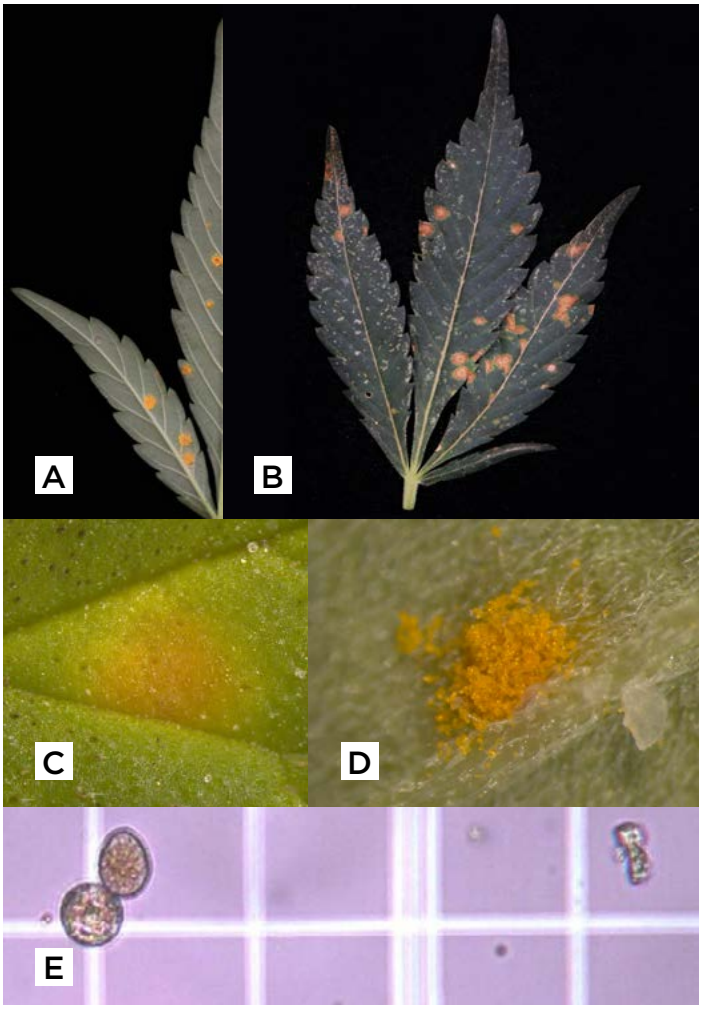

Figure 5. Hemp rust caused by the fungal pathogen *Uredo kriegeriana*. A) The underside of a hemp leaf showing orange rust spore pustules. B) Hemp rust lesions on the upper leaf surface. As disease progresses, lesions become darker orange/brown and may coalesce. C) Lesions start as yellow/orange spots with poorly defined margins on the upper leaf surface. D) Orange spore clusters (pustules) containing spores (uredospores) can be seen with the naked eye on the leaf underside directly beneath leaf lesions (image shown viewed under a dissecting microscope). E) Hemp rust spores (uredospores) under a compound microscope.

Powdery mildew

Powdery mildew is a foliar disease of hemp caused by the fungal pathogen *Golovinomyces cichoracearum*. This pathogen also causes powdery mildew on cucurbits such as squash, cucumbers and melons. As the name implies, the most obvious symptom of powdery mildew is white, powdery fungal growth on the upper leaf surface (Figure 6). Symptoms may also include leaf distortion, necrosis and premature defoliation. Powdery mildew is often a problem on hemp grown in protected culture, such as high tunnels or greenhouses, where leaf wetness is limited. Powdery mildew thrives under humid conditions but is suppressed by leaf wetness. However, leaf wetness encourages several other diseases, including leaf spots, and therefore should be reduced as part of a hemp IPM program. Powdery mildew has also been observed on field-grown hemp in Tennessee. The pathogen is spread through airborne spores that may be dispersed long distances. More research is needed to determine if hemp cultivars differ in susceptibility to powdery mildew.

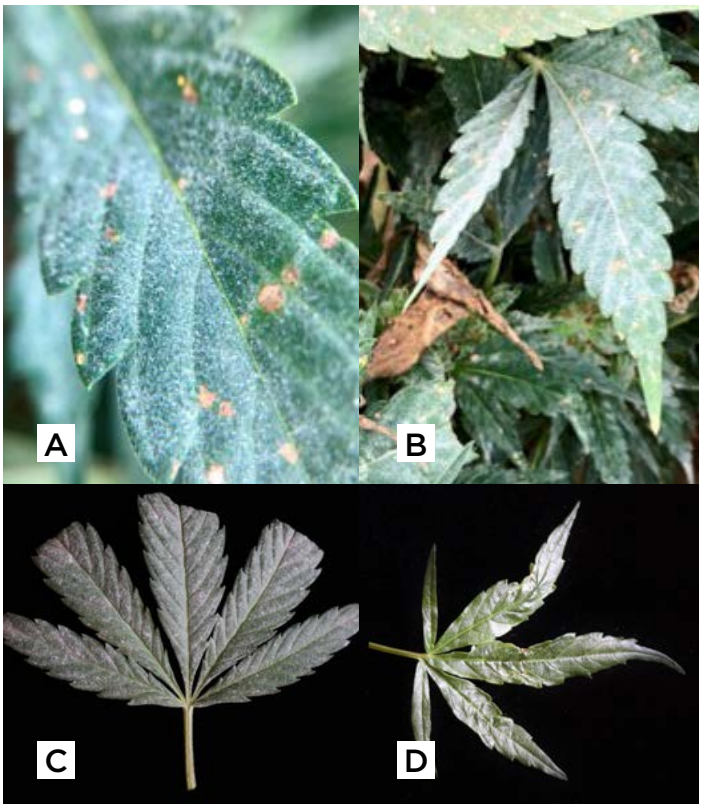

Figure 6. Powdery mildew on hemp caused by the fungal pathogen *Golovinomyces cichoracearum*. A) Powdery mildew appears as a white powdery fungal growth on the leaf surface and is easily seen with the naked eye (note: the brown circular lesions in panels A and B are due to leaf spot, not powdery mildew). B) Powdery mildew on field-grown hemp. C) Powdery mildew on a greenhouse-grown hemp leaf. D) Leaf distortion caused by powdery mildew on a greenhouse-grown hemp leaf.

Fusarium wilt and Fusarium crown rot

Fusarium wilt and crown rot of hemp may be caused by several fungal pathogens in the genus *Fusarium*. In the field, fusarium diseases may be confused with southern blight, but disease caused by *Fusarium* will not produce the brown sclerotia resembling mustard seeds that are characteristic of southern blight. The exact specie(s) responsible for these diseases in Tennessee are not yet known. Fusarium crown rot is characterized by wilting that does not recover following irrigation. The stem tissue near the soil line shows brown discoloration if cut lengthwise, rather than the white color of healthy stem tissue (Figure 7). *Fusarium* species are soilborne pathogens and can likely survive in the soil for several years. The host ranges of *Fusarium* species affecting hemp are not known, but crop rotation should reduce disease pressure. More research is needed to determine if hemp cultivars differ in susceptibility to diseases caused by species of *Fusarium*.

Figure 7. Fusarium crown rot is characterized by plant wilting and brown discoloration of the vascular tissue (stem tissue) near the soil line. Brown discoloration can be seen by cutting the stem lengthwise near the soil line and is easily distinguished from the surrounding healthy white tissue with the naked eye.

Damping-off

Damping-off has been observed on greenhouse-grown hemp seedlings and clones (*Figure 8*). This disease kills seedlings and is caused by several fungi and oomycetes (fungi-like organisms called water molds), including *Rhizoctonia* and *Pythium*. Prior to seedling death, plant may show wilt, a brown lesion near the soil line, and roots may show brown discoloration. Damping-off is worsened by over watering and poor drainage. Greenhouse sanitation and the use of pathogen-free irrigation water are important practices for managing damping-off.

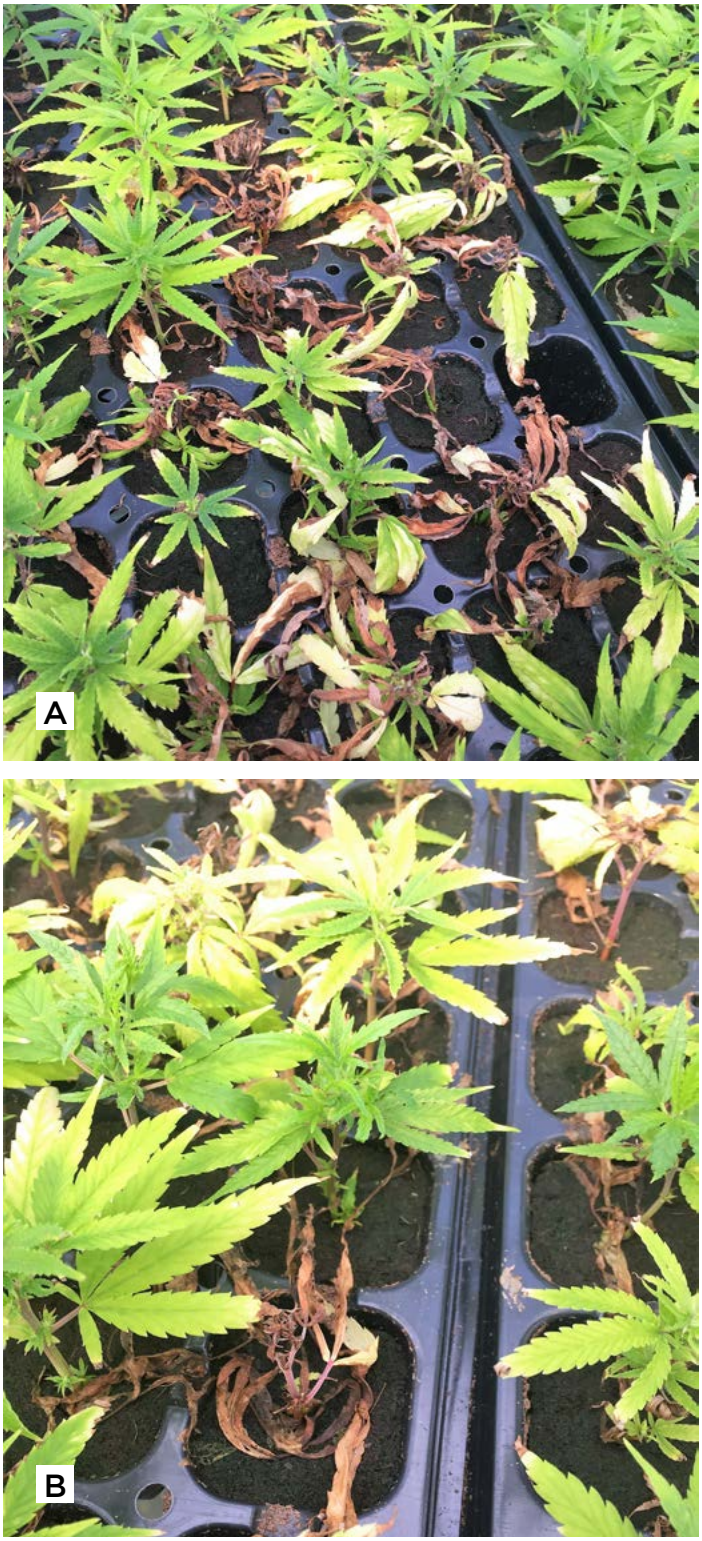

Figure 8. Damping-off of greenhouse-grown hemp clones. Damping-off is often caused by inadequate greenhouse sanitation and is worsened by excessive irrigation.

Nematodes on hemp

A wide range of plant-parasitic nematodes have been associated with hemp, but little is known about their ability to develop and reproduce on the crop, or to cause yield loss. The only nematodes so far studied experimentally are the root-knot nematodes (*Meloidogyne* spp.) (Figure 9). These nematodes are common pathogens on many crops and in home gardens and are considered the most important plant-pathogenic nematodes in the world. The female nematode resides within a root gall it induces, feeding on nutrients from altered plant cells and producing hundreds of eggs that hatch into juveniles, which will invade growing root tips. In susceptible crops, root-knot nematodes can cause wilting, slow growth and reduced yield due to interruption of nutrient flow between roots and leaves. Two species of economic importance occur in Tennessee, both of which can attack hemp. *Meloidogyne incognita* (southern root-knot nematode) is ubiquitous and can be expected nearly anywhere a susceptible plant species is grown. *Meloidogyne hapla* (northern root-knot nematode) has a spottier distribution. Both species can attack hemp. The main symptom is development of small, hard, white galls on the roots, each of which normally contains a single female. Susceptibility varies, but most hemp cultivars and selections tested so far in greenhouse conditions are moderate-to-good hosts of *M. incognita* and *M. hapla*. However, the cultivars 'Wife' and 'Siskiyou Gold' appear to be resistant to *M. incognita* on the basis of very limited testing. There appears to be no correlation of resistance to type of hemp (fiber, seed, CBD). Hemp has not been experimentally challenged with root-knot nematodes in the field, and significant field infestations have not yet been reported in the state.

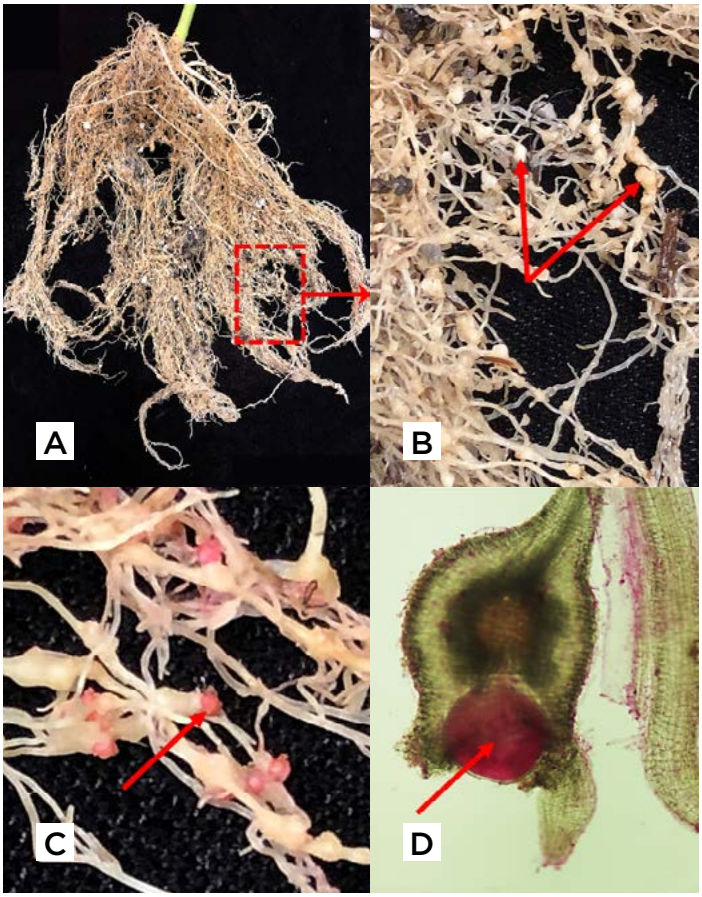

Figure 9. *Meloidogyne incognita* (southern root-knot nematode) on roots of 'Delores' hemp. A) Galled root system. B) Enlargement of box in A, close-up of typical galls produced on hemp, indicated by arrows. C) Egg masses stained pink to show extensive nematode reproduction (nematode inside gall), indicated by arrows. Each egg mass contains about 500 eggs. D) Gall on hemp shows swollen nematode inside, stained pink (indicated by arrow). Feeding cells are in the center of gall; phloem and xylem surround feeding cells. Egg mass has fallen away.

Keys to Integrated Disease Management

The disease triangle is a concept related to plant disease management that helps illustrate the ways in which growers can manage plant diseases. The disease triangle includes a susceptible host, a virulent, or infectious, pathogen, and an environment favorable for disease development (Figure 10). If all three factors are present at the same time, a plant disease will occur. Diseases are managed by eliminating one or more of these factors. This concept underlies how we can approach plant disease management.

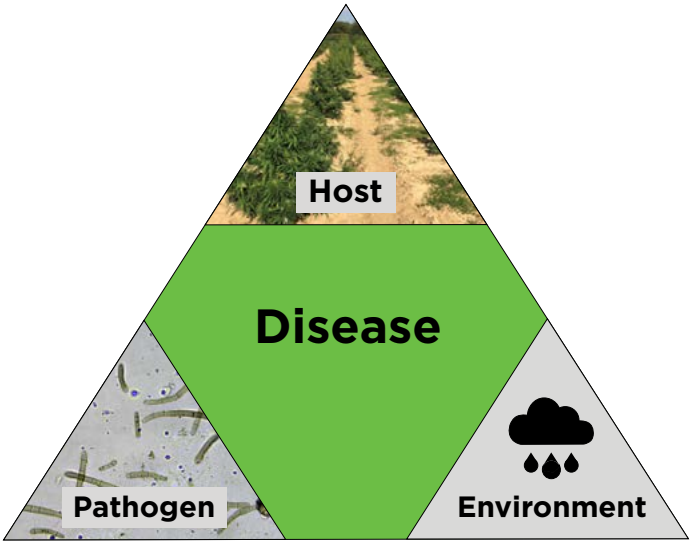

Figure 10. The plant disease triangle includes a susceptible host, a virulent, or infectious, pathogen, and an environment favorable for disease development, and helps illustrate the ways in which we can manage plant diseases. If all three factors are present at the same time, a plant disease will occur. Diseases are managed by eliminating one or more of the three factors included in the triangle.

Host

Choosing disease-resistant cultivars is one of the best ways to manage plant diseases. Research is needed to evaluate hemp cultivars for differences in susceptibility to diseases commonly observed in the Southeast. As indicated in Table 1, several cultivars show strong resistance to leaf spot diseases. However, it is not clear how leaf spot affects overall CBD yield; therefore, growers should select cultivars with good CBD yield and low-to-moderate leaf spot susceptibility. Cultivar evaluations for susceptibility to the remaining diseases described here have not been done, although there may be significant differences. Growers should record observations of diseases and pests along with cultivar information to help inform future cultivar selections until detailed cultivar disease susceptibility information becomes available.

Pathogen

Understanding the spread of pathogens is an integral part of disease management. Limiting pathogen spread can slow the rate of disease development. The following steps can limit the introduction and movement of pathogens.

- Start with disease-free transplants or seed from a trusted source.
- Sanitation is especially important in greenhouse production. Below are resources that discuss this topic in more detail.
  - Sanitation Guidelines for Management of Pests and Diseases of Greenhouse Vegetables
  - PB 1825 An Overview of Systems-based Pest Management for Nursery Production
- Avoid working with plants while they are wet.
- Avoid moving soil between fields to limit the introduction of pathogens.
- Crop rotation can reduce disease pressure by limiting the amount of overwintering inoculum in the soil.
- Weed management can reduce disease pressure because weeds can serve as disease reservoirs.
- For southern blight or fusarium diseases, remove infected plants to reduce overwintering inoculum.
- Untreated surface irrigation water should be avoided if possible because it can harbor pathogens like *Pythium*. This is especially true for greenhouse production. Municipal or well water are preferred, or surface water may be treated to eliminate pathogens.

Environment

Managing the crop environment can reduce disease pressure by making conditions less favorable for disease infection and spread. The following cultural practices will help make the crop environment less favorable for disease.

- Plant into well-drained soil.
- Use drip irrigation rather than overhead.
- Space plants and orient fields to maximize air flow and rapid drying of foliage.
- Manage weeds to avoid humid microclimates.
- Maintain optimal soil pH (between 6 and 7) for overall plant health and to avoid conditions that favor southern blight (low pH).

Table 2 lists each pathogen described in this publication and its most likely source and method of spread.

Table 2. Hemp diseases, inoculum sources and methods of spread.

Disease	Pathogen Name	Most Likely Inoculum Source*	Most Likely Method of Spread*
Leaf Spots	*Bipolaris* spp., *Cercospora* spp., possibly others	Soil and crop residue, weeds	Airborne spores spread by rain, wind, soil splash and workers/tools/ equipment
Southern blight	*Athelia rolfsii* (also called *Sclerotium rolfsii*)	Soil and crop residue	Movement of soil
Rust	*Uredo kriegeriana*	Nearby, or possibly distant, hemp fields via long-distance spore dispersal	Airborne spores spread by rain, wind, soil splash and workers/tools/ equipment
Powdery mildew	*Golovinomyces cichoracearum*	Nearby, or possibly distant, hemp or cucurbit fields via long-distance spore dispersal	Airborne spores spread by rain, wind, soil splash and workers/tools/ equipment
Fusarium wilt and Fusarium crown rot	*Fusarium* spp.	Soil and crop residue	Movement of soil, airborne spores
Damping-off	*Pythium* spp. and *Rhizoctonia solani*	Soil, contaminated seedling trays, tools, water	Movement of soil, surface water

*Several of these diseases are newly described and not well understood, so this information may change as new research results become available.

Fungicides

When cultural practices fail to provide adequate disease management, fungicides are often used to protect crops from disease. This is often the case in Tennessee where conditions tend to favor disease development. This is especially true with hemp because of the lack of known disease-resistant cultivars. There are now four products registered for use on hemp in Tennessee to help growers manage plant diseases. These products have not been evaluated in university research trials, so the efficacy of each product is not known. Growers are urged to continue to follow recommendations for cultural practices aimed at reducing disease pressure. The products listed in Table 3 may aid in disease management. As with all pesticides, each product must be used in accordance with its labeling.

Insects and Mites Found on Hemp in Tennessee

Hemp, like any other plant, is fed upon by a number arthropods. Other arthropods, including predators and parasitoids, will also be found where hemp is grown. Although many insects may be present within a field of hemp, only a few are likely to cause significant economic damage. The type of production also affects how much damage a pest might cause. For example, insects that feed on seed may not affect hemp being grown for fiber. It should also be remembered that definitive data is not available for many arthropod pests that documents if and how likely they are to cause economic losses. Further, sampling protocols and treatment thresholds have not been well developed. However, there are several arthropods that almost certainly

Table 3. Fungicides registered for use on hemp in Tennessee.*

Trade Name	EPA Registration Number	Active Ingredient	Manufacturer	Target Activity	OMRI Listed**
Regalia	84059-3	Extract of *Reynoutria sachalinensis*	Marrone Bio Innovations	Fungicide and Fungistat	yes
Amplitude/ Stargus	84059-28	*Bacillus amyloliquefaciens* strain F727	Marrone Bio Innovations	Fungicide	yes
Exile	91865-2	Potassium Salts of Fatty Acids	Hawthorne Hydroponics LLC	Insecticide, Fungicide and Miticide	yes
Defguard	91865-3	*Bacillus amyloliquefaciens* strain D747	Hawthorne Hydroponics LLC	Fungicide and Bactericide	yes

*These products have not been evaluated in University of Tennessee research trials and their efficacy for managing hemp diseases is not known. Inclusion in this publication does not indicate endorsement.
**OMRI (Organic Materials Review Institute). All four registered fungicides are approved for use on organic crops.

cause significant damage on some occasions. The most common examples are described below. Additional, more comprehensive resources about potential arthropod problems and management considerations can be found at the sites below.

- Whitney Cranshaw, Melissa Schreiner, Kadie Britt, Thomas P Kuhar, John McPartland, Jerome Grant. Developing Insect Pest Management Systems for Hemp in the United States: A Work in Progress, Journal of Integrated Pest Management, Volume 10, Issue 1, 2019, 26. doi.org/10.1093/jipm/pmz023
- Colorado State Hemp Insect Website, hempinsects.agsci.colostate.edu
- Cannabis aphid, Koppert Biological Systems, koppert.com/challenges/aphids/cannabis-aphid

Mites

The twospotted spider mite (*Tetranychus urticae*, Figure 11) and the eriophyid hemp russet mite (Aculops cannibicola, Figure 12) can both cause injury and in some cases plant death in both indoor and outdoor production of hemp. They are perhaps the most serious pests of hemp grown in greenhouse conditions. Mites are very small and may not be visible without the aid of magnification. Infestations of mites can reduce the plant's ability to thrive, and with severe infestations may cause premature defoliation, stunting and plant death. They feed on all plant structures but are most commonly observed on the undersides of leaves. Feeding often results in a discoloration of leaves, with a grayish, yellowing or bronzing effect. Silk webbing is often seen where large populations of twospotted spider mites are present.

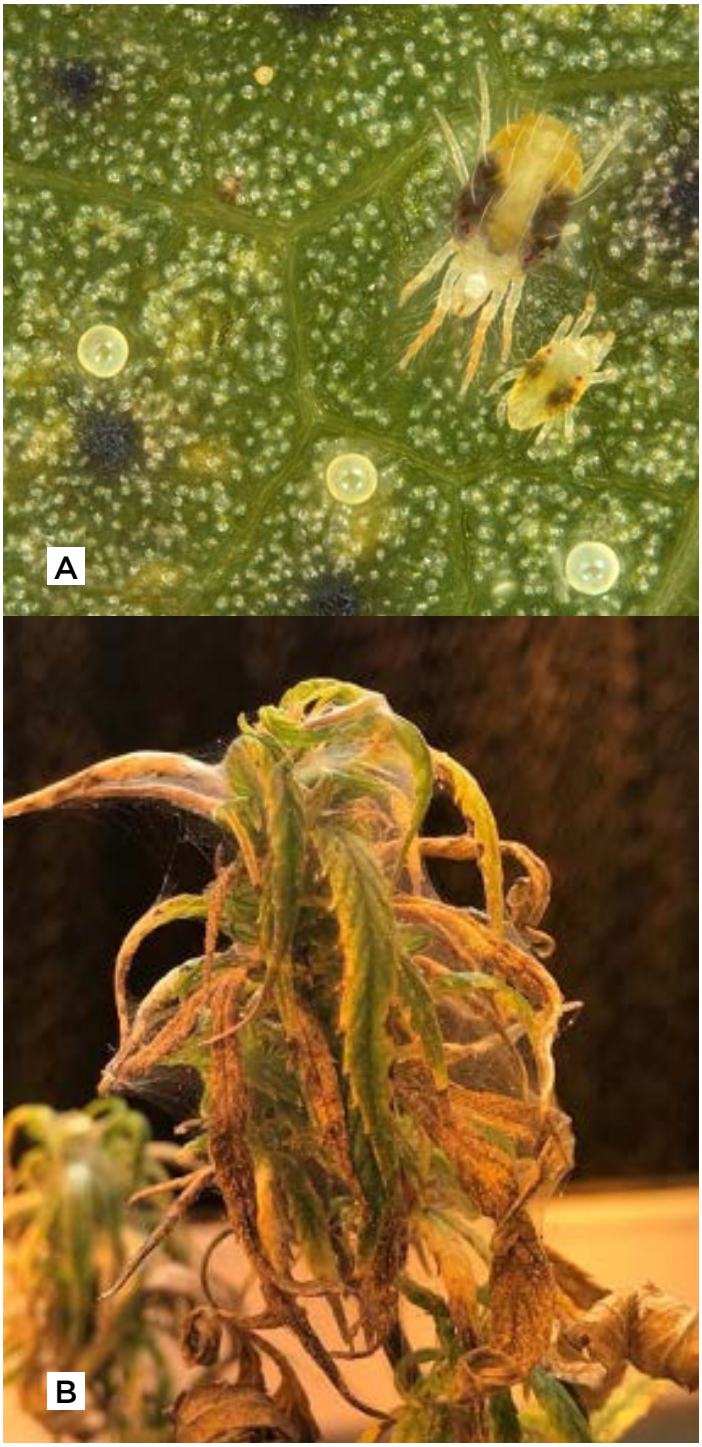

Figure 11. A) Twospotted spider mite eggs, nymph and adult. B) Webbing from high infestation.

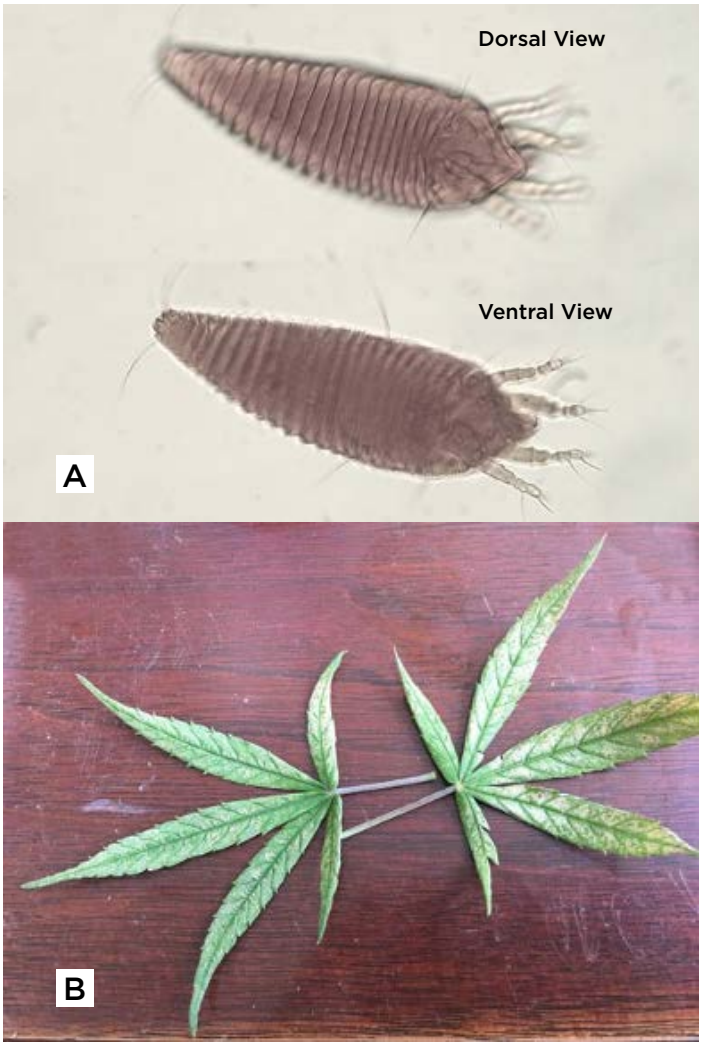

Figure 12. A) Hemp russet mite nymph. B) Speckling on leaves caused by feeding.

Aphids

Like the mites mentioned above, aphids are considered indirect pests of hemp by generally reducing the vigor of plants. They typically are found on the undersides of leaves and stems where they feed on the phloem (sap) of plants (Figure 13). As they feed, they produce a sugary waste known as honeydew. Large infestations will result in shiny and sticky leaves from the accumulation of honeydew, and sooty mold may grow on the honeydew. The most common species found is the cannabis aphid (*Phorodon cannabis*). The bean aphid (*Aphis fabae*) and the cotton or melon aphid (*Aphis gossypii*) have also been reported on hemp. The rice root aphid (*Rhopalosiphum abdominalis*) is somewhat unique in that it feeds underground and has been reported to cause decline of plants grown indoors or in greenhouses. It is unclear how much economic loss is caused by aphids in hemp, and populations are often kept in check by predators, parasitoids and fungal pathogens.

Figure 13. Cannabis aphid (courtesy of Cranshaw, W. et al., Journal of Integrated Pest Management, Volume 10, Issue 1, 2019.)

Corn Earworm

Identification of the various caterpillars found in hemp requires some training. However, the corn earworm (*Helicoverpa zea*) is a caterpillar that is commonly found feeding on floral buds and may be the most important pest of hemp grown under field conditions (Figure 14). The moths are attracted to plants while the buds are developing, and thus, the corn earworm is a late-season pest of hemp being grown for seed or CBD production. The tobacco budworm (*Chloridea virescens*), which is very difficult to distinguish from corn earworm during the larval stage, is less commonly found in hemp but causes identical damage. Larvae "chew" within the buds, causing considerable injury and the accumulation of frass ("worm feces"). Many other caterpillars, including woolybear species and armyworms (*Spodoptera* spp.), are also found in hemp but appear to cause less damage.

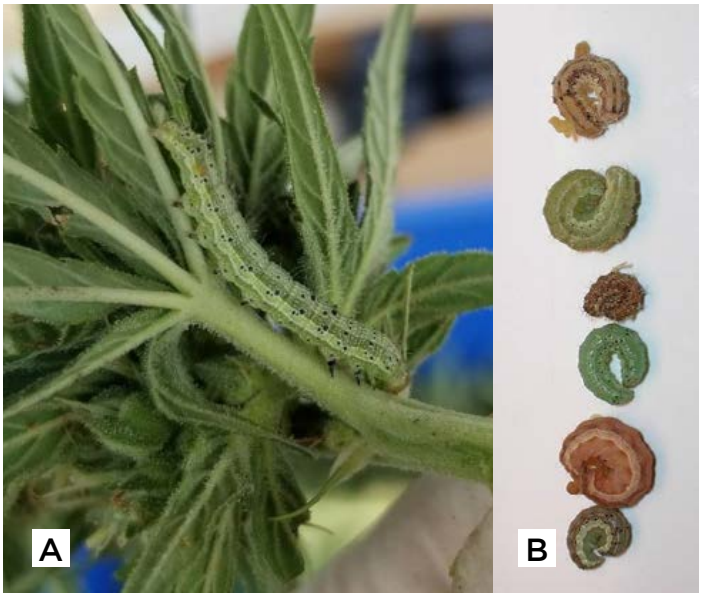

Figure 14. A) Corn earworm larvae on hemp. B) Corn earworm color variation.

Other Common Arthropods Found in Hemp

Figure 15 shows pictures of some other common insects found in hemp. Various species of thrips (Thysanoptera: Thripidae) are observed on hemp throughout the season. These small insects can be serious pests of some other crops, primarily during the seedling stage, but little is known about their potential to cause damage in hemp. Thrips injury has been observed to stunt hemp plants and reduce vigor under greenhouse conditions. Similarly, the potential for underground plant feeders, such as white grubs or wireworms, to damage hemp has not been studied. Larvae of fungus gnats have been reported as a root-feeding pest of hemp grown in greenhouse conditions and may increase the incidence of root diseases.

The tarnished plant bug (*Lygus lineolaris*) is frequently found on hemp as are several species of stink bugs. These insects are thought to cause little damage, except possibly for hemp being grown for seed production. Besides the armyworm species mentioned above, other defoliating insects include saltmarsh caterpillar (*Estigmene acrea*), Japanese beetle (*Popillia japonica*), spotted cucumber beetle (*Diabrotica undecimpunctata howardi*), and several species of grasshoppers, among others, that will feed on the leaves and sometimes within developing buds. It appears these species only rarely cause significant harm. However, there is much to be learned about arthropod pests and their management in hemp.

Beneficial arthropods found in hemp are very important in keeping pest populations in check. Adult and immature lady beetles are commonly found, especially where aphids are abundant. Many species of spiders, lacewings, syrphid flies, ground beetles, soldier beetles, wasp parasitoids and predatory hemipteran bugs, such as *Orius*, *Geocoris*, and *Nabis* spp., are also frequently observed.

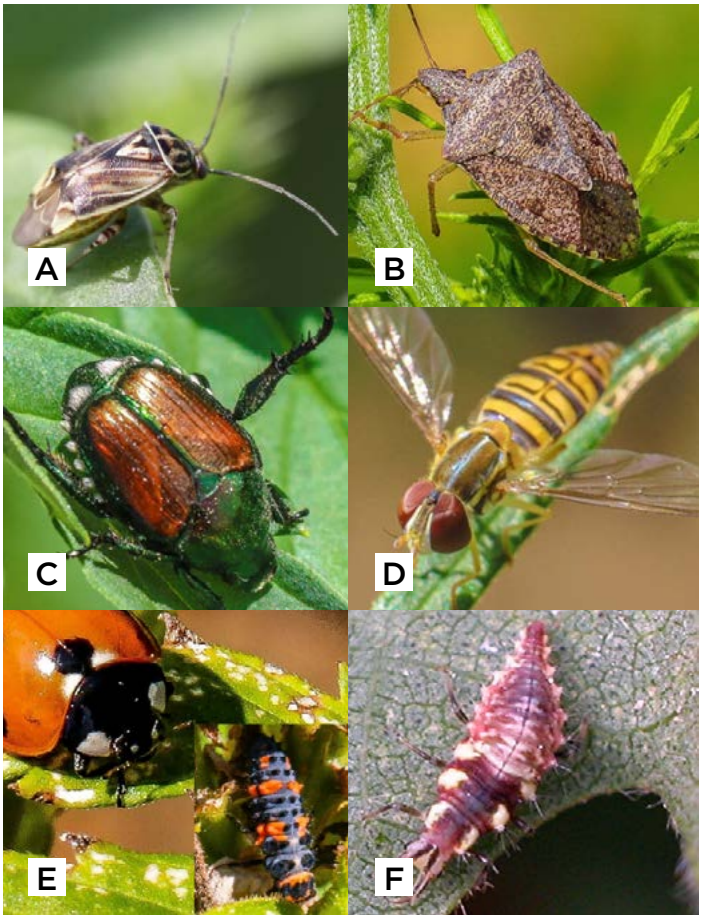

Figure 15. Other common insects found in hemp. A) Tarnished plant bug. B) Brown stink bug. C) Japanese beetle. D) Syrphid fly. E) Lady beetle adult (larva inset). F) Lacewing larva.

Insect Management Options

Few insecticides and miticides are currently labeled for hemp, and these products are often only marginally effective. Thus, the best method of preventing serious crop loss is using cultural controls. In general, healthy plants that are adequately fertilized and watered will be able to tolerate pest infestations better than those that are stressed. Follow recommended fertility and other agronomic practices that help ensure plant vigor. This includes the selection of well-drained sites with good water-holding capacity. Eliminating weedy vegetation that competes for nutrients and water will help maintain vigor. Corn earworm populations often peak from mid-August through mid-September, which often coincides with the flowering of hemp.

Predatory mites for control of plant feeding mites, lacewing larvae and lady beetles can be purchased from several online vendors for release to help control or suppress some pest populations. This approach is likely to be most helpful for indoor and greenhouse settings. Unfortunately, there is little data showing how well releasing natural enemies will work on the common pests found in hemp. We recommend initially trying this approach on a limited basis.

Table 4 shows a list of labeled insecticides that can be used in Tennessee. Little data is available about the efficacy of these products to control arthropod pests, especially under field conditions. Indeed, it is expected that these insecticides will not provide adequate control against serious infestations of mites and corn earworm, the most serious known pests of hemp. Products containing *Bacillus thuringiensis* (Bt) have been suggested for control of corn earworm. Bt insecticides were not labeled for use in Tennessee at the time of this publication, and based on their performance in other crops, they are not expected to provide good control.

Insecticide "soaps," such as those in Table 4, that contain oils, fatty acids and/or potassium salts can provide some suppression of aphids and twospotted spider mites when applied regularly and with ample application volume. These products are probably most suitable for use in indoor or greenhouse production. Insecticides not listed in this publication, like the Bt products, may be available based on special labels granted by the Tennessee Department of Agriculture. Please check with your local county Extension agent about other products that may be labeled for use in Tennessee.

Nutritional Disorders

Hemp is vulnerable to nutritional disorders when fertility is improperly managed or soil pH is not optimal (between 6 and 7). Plants experiencing nutrient disorders can display a variety of symptoms including chlorosis (leaf yellowing), necrosis (plant tissue death), or abnormal development. Such symptoms are sometimes confused with disease and pest damage. Proper diagnosis of plant problems is crucial for developing an effective management strategy. Growers should utilize county Extension agents, Extension specialists or the UT Soil, Plant and Pest Center to assist with plant problem diagnostics.

Detailed nutrient management recommendations have not been developed for hemp in Tennessee, but fertility recommendations for corn, tomato and tobacco have been proposed as temporary guidelines until hemp-specific guidelines are developed. A foliar nutrient analysis can offer insight into the nutrient status of a crop and may be warranted if a nutrient disorder is suspected. Foliar nutrient analysis is available through the UT Soil, Plant and Pest Center or through private labs.

Table 4. Insecticides registered for use on hemp in Tennessee.*

Trade Name	EPA Registration Number	Active Ingredient	Manufacturer	Target Activity	OMRI Listed**
AzaMax	91865-4	Azadirachtin	Hawthorne Hydroponics LLC	Insect Growth Regulator and Repellent	yes
Prevasyn	91865-1	Soybean Oil, Garlic Oil, and Capsicum Oleoresin Extract	Hawthorne Hydroponics LLC	Insecticide and Repellent	no
Exile	91865-2	Potassium Salts of Fatty Acids	Hawthorne Hydroponics LLC	Insecticide, Fungicide and Miticide	yes

*These products have not been evaluated in University of Tennessee research trials, and their efficacy for managing arthropods in hemp is not known. Inclusion in this publication does not equal endorsement.

Additional Resources

- Hemp Variety Trials in Tennessee 2019. University of Tennessee Extension publication W 900 Hemp Variety Trials in Tennessee.
- An Overview of Systems-based Pest Management for Nursery Production. University of Tennessee Extension publication PB 1825 An Overview of Systems-based Pest Management for Nursery Production.
- Cannabis aphid, Koppert Biological Systems. koppert.com/challenges/aphids/cannabis-aphid
- Colorado State Hemp Insect Website. hempinsects.agsci.colostate.edu
- Integrated Pest Management of Hemp in Virginia. Virginia Cooperative Extension. ENTO-349NP.

  *This guide offers an extensive list of Extension fact sheets from other land-grant university Cooperative Extension Services in the resources section.
- Sanitation Guidelines for Management of Pests and Diseases of Greenhouse Vegetables. Ontario Ministry of Agriculture, Food, and Rural Affairs. omafra.gov.on.ca/english/crops/facts/14-033.htm
- Status of Industrial Hemp in Tennessee. University of Tennessee Extension publication W 777 Status of Industrial Hemp in Tennessee.
- Systems-based Approach to Pest Management: A Quick Reference Guide. University of Tennessee Extension publication.
  - English version available here.
  - Spanish version available here.
- University of Tennessee Soil, Plant and Pest Center. ag.tennessee.edu/spp/Pages/default.aspx
- USDA Interim Final Rule on U.S. Domestic Hemp Production. federalregister.gov/documents/2019/10/31/2019-23749/establishment-of-a-domestic-hemp-production-program
- Whitney Cranshaw, Melissa Schreiner, Kadie Britt, Thomas P Kuhar, John McPartland, Jerome Grant, Developing Insect Pest Management Systems for Hemp in the United States: A Work in Progress, Journal of Integrated Pest Management, Volume 10, Issue 1, 2019, 26. doi.org/10.1093/jipm/pmz023

Disclaimer

This publication contains pesticide recommendations that are subject to change at any time. The recommendations in this publication are provided only as a guide. It is always the pesticide applicator's responsibility, by law, to read and follow all current label directions for the specific pesticide being used. The label always takes precedence over the recommendations found in this publication.

Use of trade or brand names in this publication is for clarity and information; it does not imply approval of the product to the exclusion of others that may be of similar, suitable composition, nor does it guarantee or warrant the standard of the product. The author(s), the University of Tennessee Institute of Agriculture and University of Tennessee Extension assume no liability resulting from the use of these recommendations.

Precautionary statement

To protect people and the environment, pesticides should be used safely. This is everyone's responsibility, especially the user. Read and follow label directions carefully before you buy, mix, apply, store or dispose of a pesticide. According to laws regulating pesticides, they must be used only as directed by the label.

UTIA.TENNESSEE.EDU

W 916 06/20 20-0236 Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development. University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and county governments cooperating. UT Extension provides equal opportunities in programs and employment.