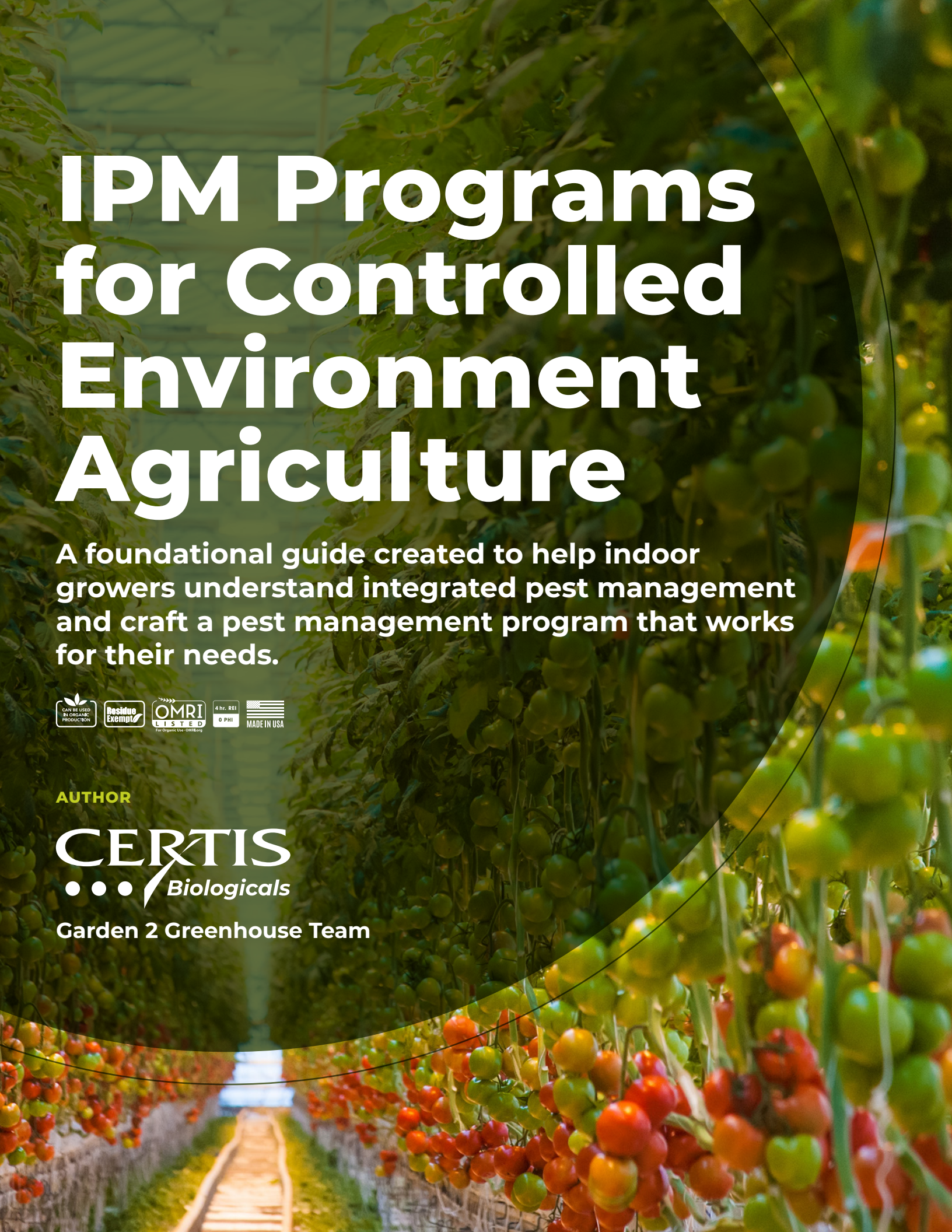

IPM Programs for Controlled Environment Agriculture

A foundational guide created to help indoor growers understand integrated pest management and craft a pest management program that works for their needs.

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Garden 2 Greenhouse Team

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Introduction

Integrated Pest Management (IPM) has been practiced for many years as a sustainable approach to agricultural production. The adage of an ounce of prevention is worth a pound of cure is certainly true when it comes to pest infestations and IPM programs in Controlled Environment Agriculture (CEA) production.

THE TRADITIONAL APPROACH TO IPM FOLLOWS A FOUR-TIERED APPROACH:

1. Setting the threshold for acceptable pest levels
2. Identifying pests and frequently monitoring progress
3. Applying preventative measures to stop infestations before they happen
4. If pests pressure exceeds the acceptable threshold, deploying pest control measures to stop infestations and minimize damage

THERE ARE FOUR MAIN CATEGORIES OF PEST CONTROLS THAT FORM IPM'S FOUNDATION WITHIN A CONTROLLED ENVIRONMENT:

- Cultural
- Biological
- Mechanical/Physical
- Pesticide Controls

In CEA on high-value crops, the first tier of traditional IPM (setting a threshold for acceptable pest levels) is not a recommended practice. However, growers of large operations that cultivate many plants of lower value may tolerate thresholds of 10-15% damage or a certain number of insects per plant or unit area in their plan. High-value crops grown in controlled conditions present the grower with a unique challenge: they must prevent damage and crop loss through the remaining three tiers of an IPM program.

Certis Biologicals understands the challenges of growers, and our portfolio of OMRI Listed® products fits perfectly into both traditional and Controlled Environment Agriculture IPM programs.

System Design & Capacity

The cornerstone to creating a CEA facility requires a well-thought-out design with optimal mechanical systems. As an example, one of the most common CEA facility design mistakes is to under-size the environmental controls. Growers and investors are wise to spend the requisite time and resources to plan the facility to meet the anticipated needs of the business. The upfront process should include contingency plans along with redundancies in power and systems.

FOR EFFECTIVE PLANNING, INCLUDE INPUT FROM:

- Facility Architect
- Mechanical Engineer
- General Contractor
- Structural Engineer
- Environmental Engineer

Best Practices in Plant Growth

Four primary factors affect plant growth: light, water, temperature, and nutrients. In CEA, other factors such as CO2 enrichment, humidity, and air circulation/ ventilation play equally important roles in optimizing the genetic potential of crops.

YOUR SELECTION AND USE OF BEST PRACTICES WILL DEPEND ON MANY FACTORS:

- Crop; cultivar/strain
- System set up
- Stage of growth
- Growing media
- Container size
- Light intensity, temperature, and environment

Plants grow at varying paces, depending on their location in the greenhouse bench. For example, rows of crops on the exterior of CEA plantings have different conditions than those in the center of a planting.

The key to optimizing growing high quality, high yielding crops starts with the fundamental foundation of best practices. Providing the optimal conditions for growth discourages insects, mites, and diseases, thus providing the grower with an increased return on investment. Weak plants open the door for various diseases to spread to healthy plants in certain environmental conditions, which can cause loss of plant vigor and yield.

Best Practices for Environment Factors

Light

Adequate lighting is essential to optimizing plant growth in CEA. There are four main things to consider when it comes to light if you want to create the optimal environment in order to reduce pest activity.

THEY ARE:

1. The distance of the light
2. The intensity of the light
3. The color spectrum of the light
4. The frequency of the light (lighting schedule)

Lighting causes significant variables with heat and humidity in closed environments. Other factors to consider within this category are seedling/clone in vegetative light, flower/fruit in bloom light, and how the wrong light spectrum during different stages is directly correlated to the impact on yield.

Temperature

Temperature directly impacts nutrients and watering needs. Each crop and cultivar/variety or strain will have an ideal temperature range, so knowing and providing the optimal diurnal (day/night) temperature will ensure the best outcome.

For example: a plant may grow best at temperatures between 20-30°C (70-85°F) during the day, whereas at night, plants prefer slightly cooler temperatures of roughly 17-20°C (62-68°F).

Water

How much and when to water plants is not an exact science, and many different factors contribute to how much water is needed for optimal growth.

As plants get bigger, their watering needs will change; but there are other more complex variables that also determine how much or little you should water your plants. The use of tensiometers can help guide the process of monitoring moisture conditions and decision-making on how much and when to apply water.

Air Circulation

Air movement along with humidity are two of the most critical factors in reducing the disease potential in CEA. Every situation varies, but having a blueprint on ventilation, fans, and the air circulation system capability is important.

THERE ARE TWO CRITICAL COMPONENTS TO A VENTILATION SYSTEM:

- Room Ventilation: intake and exhaust
- Air Circulation: fans placed throughout the area

Humidity

Humidity is one of the most critical factors in the integrated management of diseases in CEA. Plant requirements differ greatly depending on growth phase, but generally levels between 40-60% are optimal. System designs should allow the grower to manage humidity levels. Early in the growth cycle, plant mass and thus respiration is low and may require increasing humidity levels. Conversely, mid and later growth cycles have more plant mass and increased respiration, thus requiring the need to reduce humidity levels.

RECOMMENDED HUMIDITY LEVELS ACCORDING TO GROWTH STATE:

- Seeds and clones: 80-90% relative humidity
- Vegetative Stage: 60-70% relative humidity
- Flower Stage: 40-60% relative humidity

Nutrients

Plant nutrition and the management, timing, rate, and product selection are some of the most important cultural factors in CEA production. The foundation of a successful nutrition program in CEA is paramount to maximizing yield, boosting inventory turn, and optimizing plant health. Soil/growing media and tissue samples can be important guides to which nutrients and how much to apply.

Since plants accept nutrients at different pH levels, you can also consider electrical conductivity (EC) and total dissolved solids (TDS) for finding optimal plant nutrition.

Best Practices for Greenhouse Factors

Worker Entry

Workers entering can unknowingly bring pests into a facility through their shoes and clothing. Clothing, hair, and other items introduced from the outside environment can easily spread insects like mites, aphids, and diseases such as Botrytis and powdery mildew.

BEST PRACTICES FOR WORKER ENTRY INCLUDE:

- Construct a clean room area for worker entry
  - Remove boots, hats and other items that could contaminate crops
  - Wear bodysuits, gloves, hair nets, and shoe coverings
- Deploy sanitizing show and boot bath areas at the entry of each CEA area
- Install a fan system between doors as you enter the greenhouse so that a burst of air in between the two doors ventilated to the outside will remove pathogens and insects from the workers' clothing/shoes

Pruning

High-density planting in CEA requires growers to know how to pinch, prune, trim and de-leaf a crop. These techniques increase the efficiency of the crop and reduce insect and disease pressure by providing improved air circulation, reduced humidity levels, and potentially improving the photosynthetic efficiency of plants.

Sanitation

Perhaps the most important aspect of designing and implementing a successful IPM program in CEA is sanitation. Understanding how pests enter and spread in a CEA facility is paramount. If pests cannot enter the CEA facility, they cannot spread. Once in the facility, pests can spread, and you must develop a control strategy.

SANITATION INVOLVES A MULTI-LEVEL UNDERSTANDING OF THE OPERATION:

- Worker practices: facility entry and workplace hygiene
- Exterior facility pest barriers and management
- Interior facility practices
- Understanding pest life cycles and how pests spread

Use of Beneficial Insects

The use of insects as predators to harmful pests has been well documented. An effective IPM approach helps to deploy these parasitoids before they are needed so that if insects do enter the CEA environment, these predators are already present.

When released in a CEA environment before damaging insect populations are high, parasitoids are very effective. However, if populations of damaging insects are elevated, parasitoids are less effective. To ensure the effectiveness of this practice, follow consistent scouting and action thresholds.

Interior Facility Practices

Cleaning and sterilization are very important in maintaining a proper CEA facility sanitation program. Anything that touches the plants, containers, pruning scissors/sheers, growing media, emitters, etc. must be considered a vector for pests to spread.

EXAMPLES OF THE LEVEL OF INTERIOR HYGIENE REQUIRED ARE:

- Sanitization of scissors/pruners using isopropyl alcohol or other sanitizing agent between EACH cut.
- Debris removal, scrubbing, soaking and sterilization of emitters, containers, benches, shelving, etc. with hydrogen peroxide.
- If planting from cuttings, be sure to thoroughly inspect and eliminate pests prior to planting. Also, ensure the mother plant that the cutting came from is not infested. Lastly, the control of personnel can reduce the spread. Restrict the movement of people and supplies between infested and pest free areas.
- Crop free period: In severe cases of pest outbreaks, a crop-free period may be necessary to eliminate the host plant to break the pest life cycle and thoroughly clean and disinfect the facility.

Cultivar, Variety or Strain Selection

In all crops, different varieties exist with specific characteristics. These characteristics may be related to yield, growth habit, appearance and pest resistance or tolerance. Some varieties have been bred to ***resist*** diseases or insects, while others have characteristics that make them ***tolerant*** of diseases or insects.

Planning a CEA crop cycle should include selecting the right plant varieties that will do well in your facility and market. Selecting plants with resistance to pests will help reduce the overall pest pressure in the facility. Build a scheduled spray program based upon the pests prevalent throughout your crop cycle to improve success.

Exterior Facility Pest Barriers & Management

Keep weeds, shrubs, and other vegetation away from the CEA facility as this attracts pests that can enter the facility via ventilation, cracks, or when workers brush against them.

BEST PRACTICES FOR THE MAINTENANCE OF EXTERIOR FACILITIES INCLUDE:

- A minimum 20’ vegetation-free barrier around a CEA facility.
- Use of gravel (along with Homeplate® herbicide) around the CEA structure to eliminate habitat for insects and diseases.
- Use of screens on vents to provide a physical barrier against insects.
- Locate compost and other organic debris areas at least 50’ away from the CEA facility.
- Weekly inspection of facility exterior to determine potential pest entry points.
    - Caulk and seal areas
    - Use of high-density mesh screening

Scouting

Scouting is the essential **first step** of an effective and sustainable IPM program. It is essential for pest management decisions and will save time and money in the long run by the ability to correct problems before they get out of control.

Early intervention of problems is critical for success. Growers should have a daily scouting routine to systematically gather information, then identify and document problems. Effective management of a CEA environment requires that growers identify problems early, deploy control measures, and document the information for each CEA house or growing environment. Collecting and managing this information will provide the grower with a database to help develop a predictive model in managing production.

Tools Used in CEA IPM

Trapped fungus gnats and beetles (glue panel)

Essential monitoring tools include:

- IPM Scouting Form (Inspector, Date, Time, House or Location, Findings)
  - Form should include a map of house(s) crops and conditions: ventilation, lighting, watering, appearance and notes for all major pests and conditions.
  - Forms turned in each day: reviewed and catalogued (database or file)
  - Thresholds/ Pest Counts/ Recommended Actions
- Trained Personnel
- Hand lens of at least 10x (20x is best)
- Yellow sticky cards/stakes/pins
- Flagging tape
- Clipboard
- Waterproof marker

Other monitoring tools:

- Soil Thermometer
- Potato slices placed in catch containers with growing media (no plants)
  - Fungus gnat monitor

A scout monitoring spider mite with a hand lens on a tomato crop.

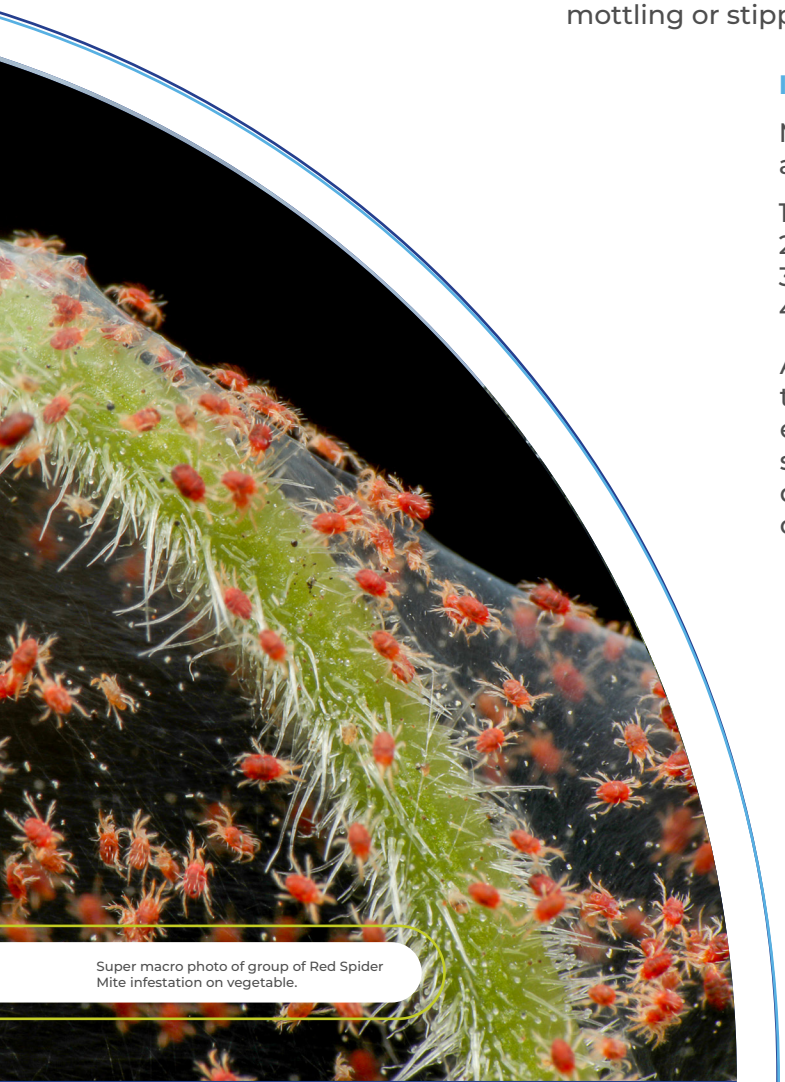
Bio-Controls & Product Selection

The decision to deploy organic control measures should be based on scouting, proper identification of the pest, and selection of the correct bio-pesticide. Growers should also utilize other measures, such as cultural control and proper sanitation, as bio-pesticide applications alone are a temporary solution.

Common Mite & Insect Pests

Common Mite Pests

Spider mites are not true insects but members of the Acari (mite) family *Tetranychidae*, which includes about 1,200 species. Spider mites damage plants by piercing plants and sucking nutrients. They generally live on the undersides of plant leaves, which makes them hard to identify before significant populations exist. Damage will first be visible on the lower 1/3 of the plant and will generally appear as mottling or stippling of leaves.



Super macro photo of group of Red Spider Mite infestation on vegetable.

IDENTIFICATION AND LIFE CYCLE

Mites usually measure about 1⁄8 inch or less in length and their life cycle has four basic stages:

1. Egg
2. Larva
3. Nymph
4. Adult

Applications of bio-controls must be very thorough, treating ALL plant parts: upper and lower leaf surfaces, emerging leaves, and folds between petioles. Since some mite species pupate in the soil, it is also wise to direct bio-controls to the base of plants, thoroughly covering the media.

Red mite on plant

PRODUCT NAME	APPLICATION		REGULATORY		MITES			
	Foliar (F)	Drench (D)	Approved for Hemp	OMRI	Red mite	Broad mite	Russet mites	2-spot mite
Sil-Matrix® LC	F		✓	✓	✓	✓	✓	✓
BotaniGard® ES	F	D	✓	✓	✓	✓	✓	✓
Ancora®	F	D	✓	✓	✓	✓	✓	✓
Triact®	F			✓	✓	✓	✓	✓

Hemp Russet Mite (*Aculops cannabicola*)

The hemp russet mite is an eriophyid mite, which does not produce a web and has only been observed on hemp. They have an elongated body, are a pale color and can be a major pest in CEA. It is an extremely small mite; it is much smaller than the two-spotted spider mite, and individual mites cannot be observed without substantial magnification (15-20X).

Infested plants will exhibit a slight upward curling along the edges of leaves, but this is not a consistent symptom and may only develop on some cultivars. Plants often respond by having a general dullness of leaves (russeting) and as infestations progress, small areas of leaves may have visible yellow or brown spotting. Foliage also may become more brittle and may sometimes break at the leaf petiole. Russet mites also develop on stems, which may cause stems to have a slight bronze/golden color. Heavy infestations on developing flower buds may suppress bud growth and size.

Chili broad mite and Chill thrips are major insect pests in Chili plants. The both insect make curly leaf and shoot in Chili.

Broad Mite (*Polyphagotarsonemus latus*)

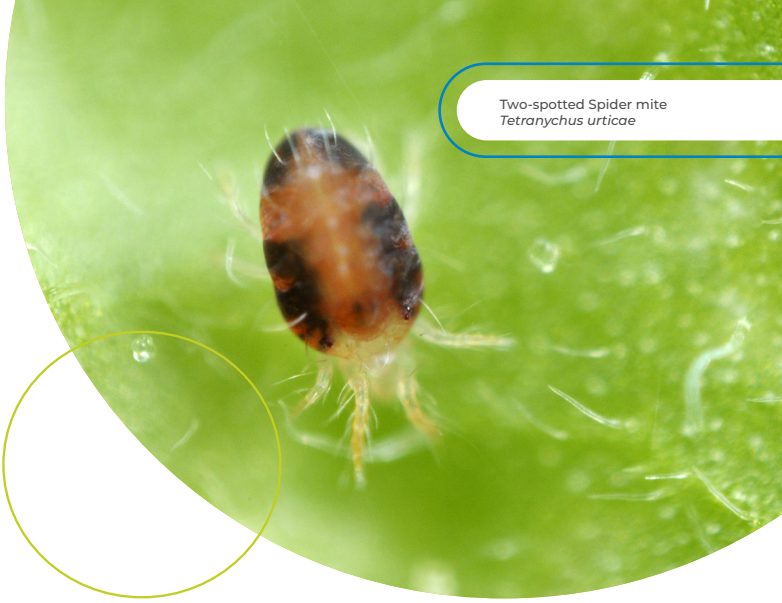
The broad mite can be a major CEA pest and has a wide host range. Like the hemp russet mite, these are microscopic and difficult to identify, even with magnification. Broad mites are often imported in CEA facilities through soil, as females pupate and wait until an appropriate host is introduced.

Broad mites also have distinctive eggs that are translucent and oval-shaped with a geometric cross-hatched pattern of white dots on the surface. The eggs are very hard to see but are usually found on the undersides of leaves and are sometimes also found on the upper leaf surface as well. Adults tuck into folds of emerging leaf tissue, so applications of bio-controls must be thorough. Broad mite damage may resemble a virus. Leaves may be curled , gnarled, and brittle or hard looking. Another common symptom is stunting of tender growing tissue.

Two-Spotted Spider Mite (*Tetranychus urticae*)

Two spotted spider mites can cause serious damage to wide range of CEA crops. Some growers may refer to this mite as red spider mite or greenhouse mite. It gets its name because it typically has at least two spots, one on each side of its body, just behind the eyes. Adults and nymphs typically have a yellow or greenish color and hairs or spines on the body. The adult female is visible to the naked eye and is about 1/60 of an inch long, but will be bigger than the male and more oval shaped.

In a CEA environment, there is not an over-wintering part of the life cycle. However, when exposed to colder temperatures, the two-spotted spider mite adult female will change to an orange color and overwinter in places like underneath bark scales or ground cover around the base of plants and trees. As with other mites, they pierce the leaves of the host and extract plant juices. When they extract the sap, the feeding site collapses in the punctured area. Chlorotic spots form at each feeding site, and in heavy infestations, an entire plant may become yellowed, bronzed, or killed completely. Two-spotted mites produce webs.


Two-spotted Spider mite
Tetranychus urticae

ROTATIONAL PROGRAMS TO CONSIDER:

- Ancora® as a preventative weekly,
- Sil-Matrix® LC applied weekly under low mite pressure, and
- BotaniGard® ES as a rescue under heavy mite pressure applied every 2-5 days.

Good spray coverage is essential, but do not spray to run off.

CERTIS BIOLOGICALS RECOMMENDATIONS FOR MITE CONTROL

PRODUCT NAME	RATE	INTERVAL	NOTES
Ancora®	14-28 oz/100 gal	3-10 days	Most effective when it is applied before or at the first sign of insect presence. Apply late evening or early morning under low light conditions. Keep product refrigerated at approximately 40-50o F in a dry place. Use in a fogger will require following a mixing protocol.
Sil-MATRIX® LC	0.5-1 gal/100 gal	5-7 days	Sensitive to low pH materials. Dilute before adding other materials to tank. Target pH for Sil-MATRIX solution should be 4-5 or 7-8. Avoid pH of 6. Use of spreader sticker will enhance efficacy.
BotaniGard® ES	1-2 qts/100 gal	2-5 days	Repeat applications for as long as pest pressure persists. There is no limit on the number of applications or total amount that can be applied in one season. Store in a cool environment.

Common Insect Pests

PRODUCT NAME	APPLICATION		REGULATORY		PESTS							
	Foliar (F)	Drench (D)	Approved for Hemp	OMRI	Aphid	Fungus gnat larvae	Fungus gnat adult	Thrips	Caterpillar	Mealy Bug	Root aphids	Whitefly
Sil-MATRIX® LC	F		✓	✓	✓							✓
BotaniGard® ES	F	D	✓	✓	✓			✓	✓			✓
Ancora®	F	D	✓	✓	✓			✓	✓	✓		✓
Agree® WG	F		✓	✓					✓			
Gemstar® *	F		✓	✓					✓			
Javelin® WG	F		✓	✓					✓			
Deliver®	F		✓	✓					✓			
Azatin® O	F	D		✓	✓	✓		✓	✓	✓		✓
Triact®	F			✓	✓					✓		✓

* Gemstar is only effective on caterpillar species within the Helicoverpa and Heliothis genus.

Aphids

Aphids are a common CEA pest. They are soft-bodied insects which can appear white, green, yellow, black, brown, and red, depending on their stage of life. Aphids have an incomplete life cycle; there are winged and wingless adults, eggs, and nymphs. An aphid becomes a reproducing adult within about a week and then can produce up to 5 offspring per day for up to 30 days.

Adults are usually small and oval-shaped and may have visible wings or antennae. Nymph aphids are thin/long and usually white or pale. Because nymphs are so small, they may look like little white specks or eggs. Both wingless and winged forms occur. Some dark spotting occurs on winged forms. Wingless forms lack this patterning but may have pale striping running along the top of the body.

Aphids pierce leaves and stems with their sucking mouthparts and feed on the juices inside. They usually occur in colonies located mainly on the undersides of stems and leaves. If a plant becomes heavily infested, leaves can turn yellow and/or wilt due to the excessive stress and leaf damage. A telltale sign of aphids is the accumulation of “honeydew,” which is a sticky fluid that they drop onto leaf surfaces that appears as small shiny spots after aphids feed. Honeydew can be an excellent diagnostic sign for detecting CEA aphid infestations.

Colony of Cotton aphid (also called melon aphid and cotton aphid) - Aphis gossypii on a leaf

Aphid close up on a green leaf. Crop harvests, insecticidal treatment. Damaged plant leaves, devouring.

CERTIS BIOLOGICALS RECOMMENDATIONS FOR APHID CONTROL

PRODUCT NAME	RATE	INTERVAL	NOTES
Ancora®	14-28 oz/ 100 gal	3-10 days	Most effective when it is applied before or at the first sign of insect presence. Apply late evening or early morning under low light conditions. Keep product refrigerated at approximately 40-50o F in a dry place. Use in a fogger will require following a mixing protocol.
Sil-MATRIX® LC	0.5-1 gal/ 100 gal	5-7 days	Sensitive to low pH materials. Dilute before adding other materials to tank. Target pH for Sil-MATRIX solution should be 4-5 or 7-8. Avoid pH of 6. Use of spreader sticker will enhance efficacy.
Triact®	.5-1 gal/ 100 gal	5-7 days	Contact activity: SDR: Suffocant/Desiccant/Repellent activity, coverage is important.
Azatin® O	10-16 fl oz/100 gal	7-10 days	Azatin O is translaminar but will not translocate to new growth.
BotaniGard® ES	1-2 qts/ 100 gal	7-10 days	Repeat applications for as long as pest pressure persists. There is no limit on the number of applications or total amount that can be applied in one season. Store in a cool environment.

Root Aphids

The root aphid is often confused with mealybugs. However, as the name suggests, they feed on roots and damage plants by piercing the roots and other underground plant parts by sucking out carbohydrate rich fluids. Common root aphids that infest CEA crops are: Sugarbeet root aphid (*Pemphigus populivenae*) and Rice root aphid (*Rhopalosiphum rufiabdominalis*).

Root aphids can be identified by their teardrop shape and a pair of pointy protrusions on their hind ends. They range in color from brownish-orange, yellowish- green, pinkish-white, and brown and are often misidentified as mealybugs because masses are covered in a white waxy cast (molted) skin that they leave behind. They are aggressive and will grow in clusters and cover plant roots with soft, tissue-like masses. Like other above ground aphids, honeydew is produced and often attracts ants near the soil line.

The first sign of root aphids is lack of plant vigor. Plants appear withered, curled, and the leaves will start to yellow. Damage is often mistaken for nutrient deficiency and is often misdiagnosed as a magnesium or iron deficiency. Plant roots will turn yellow, swell, and then harden in the spots where the root aphids feed.

Root aphids develop almost entirely below ground. Most stages found on above-ground parts of plants are winged forms, but these are often dead, stuck to the leaf surface. Some colonization of foliage occurs, but most offspring produced on foliage by migrant winged forms migrate to the roots. The root aphid will reproduce asexually year-round in CEA, which means unmated adult female aphids will give birth to live young, all of which are female. Females give birth to 60-100 nymphs in their 30-day lifespan.

CULTURAL CONTROL PRACTICES INCLUDE:

- Moisture management: wet soil is attractive to root aphids.
- Using only clean soil mixes and compost.
- Sanitation: dispose of discarded soil and plant material properly.
- Isolate new plants and thoroughly inspect.

CERTIS BIOLOGICALS RECOMMENDATIONS FOR ROOT APHID CONTROL

PRODUCT NAME	RATE	INTERVAL	NOTES
BotaniGard®22WP	0.5-2.0 lb/100 gal	5-10 days	There is no limit on the total amount of product applied per season.

Fungus Gnats
(*Orfelia and Bradysia*)

Fungus gnats can be a significant problem in CEA, causing damage to root tissues of crops. They have also been implicated in the transmission of plant diseases, including black root rot, Pythium blight, Verticillium wilt, Botrytis blight, and Fusarium wilt.

Adult fungus gnats are dark, winged, and fragile insects, similar in appearance to a small mosquito. Both larvae and adults can spread plant pathogens and may promote disease. Fungus gnats develop through four life stages: **1)** egg, **2)** larvae (four larval stages or instars), **3)** pupa, and **4)** adult, producing many generations a year. Adult females deposit eggs (up to 200) in crevices or cracks on the surface of growing media, and in moist, organic debris. They do not like high temperatures and prefer to lay eggs in high organic matter areas.

Fungus gnat larva, Mycetophilidae on boletus mushroom

The larvae of fungus gnats are plant-damaging. Small infestations cause minor plant damage, but large infestations can destroy roots and stunt plant growth. A large population will slow down root growth and greatly reduce plant vigor. Young plants, seedlings, and unrooted cuttings are more vulnerable.

CERTIS BIOLOGICALS RECOMMENDATIONS FOR FUNGUS GNAT CONTROL

PRODUCT NAME	RATE	INTERVAL	NOTES
Azatin® O	8-16 fl oz/100 gal	14 days	Azatin O is used to control the larval stage of fungus gnats.

Worm on corn cob. Organic maize. Corn Harvest Affected By Worms.

Caterpillars

One of the most easily identified insect pests in CEA are the caterpillars. They belong to a large group of insects known as Lepidoptera (which includes moths and butterflies) and many species attack and damage a wide range of crops. Left unchecked, one caterpillar can do a great deal of damage in a single 24-hour period.

Caterpillars have a complete life cycle: eggs, larvae (caterpillar worms), pupae, and adult (moth or butterfly). Several species are considered borers and damage plant stems and stalks, while others feed entirely on foliage or flowers. Damage can range from a few small holes in foliage to total devastation of a specimen and subsequent loss of yield. Typical damage may be irregular holes, stem damage, chewed leaves and flowers, and yellowing of foliage. Since they have a relatively long life cycle, they are easy to control in most CEA situations.

CERTIS BIOLOGICALS RECOMMENDATIONS FOR CATERPILLAR CONTROL

PRODUCT NAME	RATE	INTERVAL	NOTES
Javelin® WG	0.25-1.5 lb/100 gal	5-7 days depending on pest pressure	Must be ingested by the worm; kill is not immediate. Do not use if worms are greater than 1.5 inches in length.
Azatin® O	4-16 fl oz/100 gal	7-10 days	Azatin O is translaminar but will not translocate to new growth.
Gemstar® LC	4-10 fl oz./100 gal	3-5 days	Only for corn earworm or other *Helicoverpa* or *Heliothis* species.
BotaniGard® ES	1-2 qt/100 gal	7-10 days	Repeat applications for as long as pest pressure persists. There is no limit on the number of applications or total amount which can be applied in one season. Store in a cool environment.

Mealybugs (*Pseudococcidae*)

Mealybugs are insects characterized by having a protective shell that varies in color depending on the species. This shell acts as a protective shield against other insects and against insecticide treatments. They are rarely a problem in CEA, but can occasionally cause significant damage. These pests are usually brought into the CEA environment on propagation material or on purchased plants. They feed by piercing the plant tissues and sucking sap from leaves, stems, and fruits. Mealybugs excrete sugary honeydew, which can lead to the growth of a fungus called sooty mold.

There can be one or more generations during the year, depending on the species and the climate of the area. They leave the egg as nymphs, then they transform into an adult mealybug, which lays new eggs that will generate more larvae again. Nymphs and females extract the sap from the plant, stunting growth and causing deformation and / or yellowing of leaves, sometimes followed by defoliation. The overall effect is a reduction of photosynthesis, plant vigor, and yield.

CERTIS BIOLOGICALS RECOMMENDATIONS FOR MEALY BUG CONTROL

PRODUCT NAME	RATE	INTERVAL	NOTES
Azatin® O	4-16 fl oz/100 gal	7-10 days	Azatin O is translaminar but will not translocate to new growth.
BotaniGard® ES	1-2 qts/100 gal	7-10 days	Repeat applications for as long as pest pressure persists. There is no limit on the number of applications or total amount that can be applied in one season. Store in a cool environment.

Thrips (*Thysanoptera*)

Leaf curl tomato/Thrips symptoms destroying tomatoes/ Crinkled leaves from thrips destroying tomatoes

Thrips are regularly found on CEA crops because they have a high reproductive capacity and are inconspicuous. There are many varieties of thrips, but onion thrips (*tabaci*) and western flower thrips (*Frankliniella occidentalis*) are common species found in CEA environments. In CEA production, thrips can cause serious foliar damage. Both larvae and adults cause damage by piercing and sucking plant juices and are usually found on the underside of the leaves. Blue sticky cards are a great tool to determine the level of infestations.

Larval thrips feed on pollen and are usually found in the flower. Thrips will react and move in the presence of CO2. Blowing into blooms at very close range will provide an idea of the level of thrips infestation as they attempt to leave the area. They inhabit near the flower ovule, before resting to molt in 1–2 weeks. Adults emerge and resume feeding on flowers, buds, and terminal foliage. The entire life cycle from egg laying to adult emergence can take 12 weeks in CEA environments.

The thrips life cycle goes from egg, larvae, pre-pupa, pupa, and adult. The pupal stages are found in the soil and do not feed. Thrips adults are small (1.5 mm), long yellowish-white insects. They are fast-moving and may fly, crawl, or hop from plant to plant, making them difficult to see until populations are high. Female thrips can reproduce sexually or asexually without a mate. They lay their eggs in the soft tissue of plants in areas of new growth. The eggs hatch after 3–5 days, and the nymphs then feed for 1–3 weeks.

CERTIS BIOLOGICALS RECOMMENDATIONS FOR THRIPS CONTROL

PRODUCT NAME	RATE	INTERVAL	NOTES
Ancora®	14-28 oz/100 gal	3-10 days	Most effective when it is applied before or at the first sign of insect presence. Apply late evening or early morning under low light conditions. Keep product refrigerated at approximately 40-50o F in a dry place. Use in a fogger will require following a mixing protocol.
Azatin® O	4-16 fl oz/100 gal	7-10 days	Azatin O is translaminar but will not translocate to new growth.
BotaniGard® ES	1-2 qts/100 gal	7-10 days	Repeat applications for as long as pest pressure persists. There is no limit on the number of applications or total amount that can be applied in one season. Store in a cool environment.

The western flower thrips: *Frankliniella occidentalis* and damage caused on the bean leaf by this pest. It is an important pest insect in agriculture.

Whitefly Aleyrodes proletella agricultural pest on cabbage leaf.

Whitefly (*Aleyrodidae*)

There are over 1500 species of whitefly, most of which are inconspicuous and never reach densities high enough to cause damage to their host plants. However, a few species are major CEA pests. The most common are the sweetpotato whitefly (*Bemisia tabaci*) and greenhouse whitefly (*Trialeurodes vaporarorium*).

Whiteflies are piercing and sucking insects that feed on plant sap, much like aphids. They have an incomplete life cycle: egg, nymph, and adult. Adults are very small (1/16 - 1/10 inch) with white wings, hence the name “white fly.” Females lay eggs directly on the undersides of plant leaves. The eggs hatch into nymphs or crawlers that move a short distance before settling at a feeding location. Nymphs soon lose the ability to walk and remain in the same location for the rest of their development until they pupate and emerge as winged adults. The entire whitefly life cycle takes about 3 weeks, allowing populations to build quickly. Whiteflies do not have a dormant stage in CEA and are year-round pests.

Whiteflies are sap feeders that reduce the overall vigor of plants through their feeding. As infestations become severe, plants yellow and lose their leaves prematurely. They also produce large amounts of sticky, sugary honeydew, which in turn is colonized by black sooty mold, reducing the attractiveness and marketability of whitefly-infested crops. A yellow sticky card is often the best measurement that growers can take to determine the level of whitefly infestation. More importantly, whiteflies are vectors that transmit over a hundred different plant viruses. The viruses are taken up by whiteflies feeding on an infected plant. When the whitefly moves to a new plant and starts feeding, viral particles enter the plant and start a new infection cycle. Most CEA growers will not tolerate any level of whitefly infestation because of the potential virus transmission.

CERTIS BIOLOGICALS RECOMMENDATIONS FOR WHITEFLY CONTROL

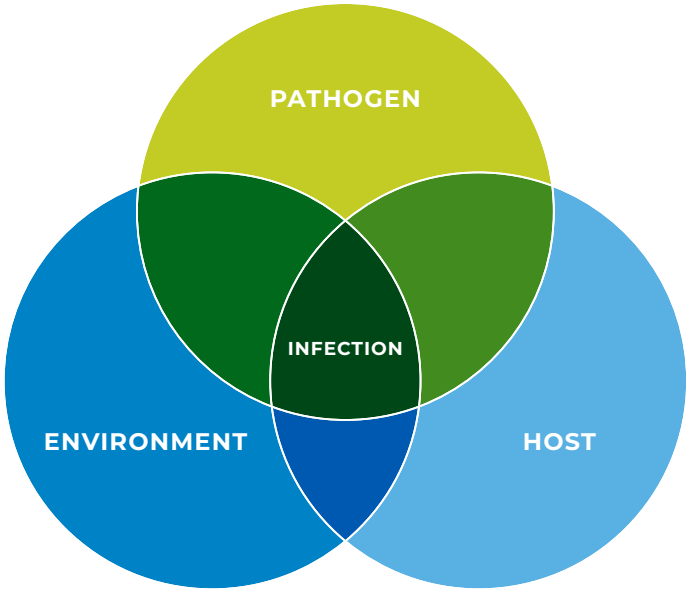
PRODUCT NAME	RATE	INTERVAL	NOTES
Ancora®	14-28 oz/100 gal	3-10 days	Most effective when it is applied before or at the first sign of insect presence. Apply late evening or early morning under low light conditions. Keep product refrigerated at approximately 40-50o F in a dry place. Use in a fogger will require following a mixing protocol.
Sil-MATRIX® LC	0.5-1 gal/100 gal	5-7 days	Sensitive to low pH materials. Dilute before adding other materials to tank. Target pH for Sil-MATRIX solution should be 4-5 or 7-8. Avoid pH of 6. Use of spreader sticker will enhance efficacy.
Azatin® O	4-16 fl oz/100 gal	7-10 days	Azatin O is only effective against immature whiteflies, not adults.
BotaniGard® ES	1-2 qts/100 gal	7-10 days	Repeat applications for as long as pest pressure persists. There is no limit on the number of applications or total amount that can be applied in one season. Store in a cool environment.

The glasshouse whitefly or greenhouse whitefly - Trialeurodes vaporariorum. It is important pest of many plants

Principles of Disease Control in CEA Environments

The most important factor in disease prevention and control is to understand how and why diseases attack plants in CEA production. Plant disease occurrence and severity results from the impact of three factors: the host plant, the pathogen, and the environmental conditions.

1. The **HOST** Plant
   - Is the cultivar, variety, or strain resistant, tolerant, or susceptible?
2. The **ENVIRONMENT**
   - Are environmental conditions favorable for disease development?
     - Temperature, moisture, RH, ventilation, lighting, canopy density, etc.
3. The **PATHOGEN** or **DISEASE**
   - Is the disease present?
     - Assume that spores and other reproductive structures are present.



The three individual parts of the disease triangle need to come to gether in order for disease out breaks to occur. This includes a susceptible host, favorable environment, and presence of the pathogen.

Watermelon cultivation in the greenhouse of Almeria

Common Disease Pests

PRODUCT NAME	APPLICATION		REGULATORY		DISEASE				
	Foliar (F)	Drench (D)	Approved for Hemp	OMRI	Powdery mildew	Downy mildew	Fusarium	Pythium	Botrytis
Carb-O-Nator®	F		✓	✓	✓				✓
LifeGard® WG	F		✓	✓	✓	✓			✓
Triathlon® BA	F	D	✓	✓	✓	✓	✓	✓	✓
Sil-MATRIX® LC	F		✓	✓	✓				✓
Triact®	F			✓	✓				✓

Powdery Mildew

Powdery mildew is a common fungal disease encountered in CEA crop production. Many growers struggle with controlling the disease and they are often caught off guard. Once powdery mildew infects a CEA environment, it is nearly impossible to eliminate.

Symptoms of powdery mildew include patches of white powdery growth on the upper and lower leaves and stems. Disease severity depends upon variety, age and overall condition of the plant, as well as microclimate conditions. Older leaves and mature plants are usually affected first and become chlorotic and deformed, limiting plant growth and marketable yield. Severely affected tissue may turn necrotic and die.

CEA environments provide ideal conditions for development of powdery mildew. Mildew spores are spread by air currents, infected plant debris, touching and examining infected plants, clothing, and infected tools.

CONDITIONS FAVORING DEVELOPMENT OF POWDERY MILDEW ARE:

- Dense canopy
- Low plant vigor
- Reduced air flow
- Temperatures between 64-77 °F (18-25 °C)
- Humidity ~50% or higher

Monitor and scout for powdery mildew every day, especially in sections with reduced air flow, dense plant canopies, or standing water. Examine both the upper and lower side of leaves. Powdery mildew forming on the underside of leaves can go undetected and move quickly through the environment before it is noticed.

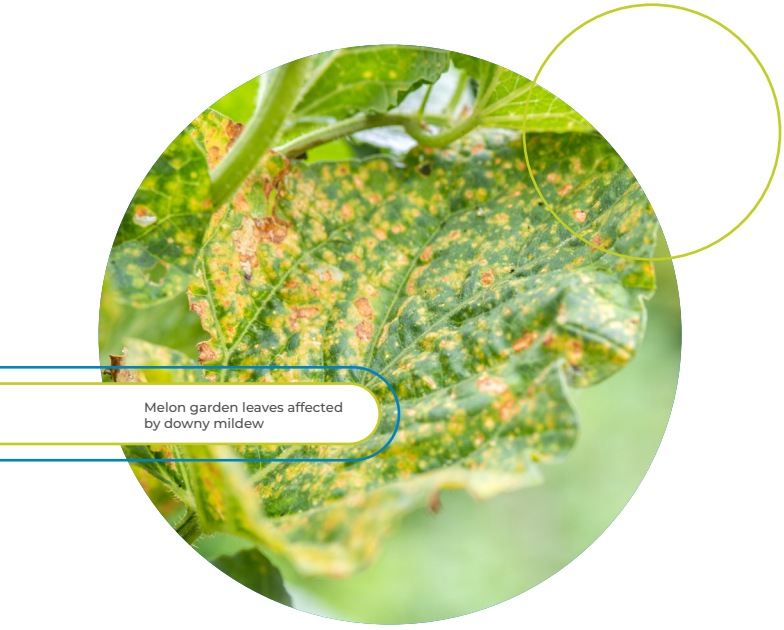
CERTIS BIOLOGICALS RECOMMENDATIONS FOR POWDERY MILDEW CONTROL

PRODUCT NAME	RATE	INTERVAL	NOTES
Carb-O-Nator®	2.5-5 lbs./100 gallons	10-14 days	Can be used to control early infestations of PM. Must be used consistently.
Triathlon® BA	.5-6 qts/100 gal	7-10 days	Applications should start when conditions are conducive for disease development.
LifeGard® WG	4.5 oz /100 gallons	3-14 days	Applications should start when conditions are conducive for disease development.
Sil-MATRIX® LC	.5-1 gallon/100 gallons	5-7 days	Sensitive to low pH materials. Dilute before adding other materials to tank. Target pH for Sil-MATRIX solution should be 4-5 or 7-8. Avoid pH of 6. Use of spreader sticker will enhance efficacy.

Downy Mildew

Although they have a similar name, downy mildews are completely different than powdery mildews. Powdery mildews are true fungal pathogens that produce white, flour-like colonies, usually on upper leaf surfaces. Downy mildews, on the other hand, are more closely related to algae. Downy mildews produce grayish, fuzzy looking spores and mycelium on the lower leaf surfaces. The difference between powdery mildews and downy mildews is important because control strategies are very different between these two diseases.

Understanding the disease cycle is critical to managing any disease. The fungus overwinters in or on plant parts and debris as mycelium or hardened spores. Downy mildew outbreaks under cool (50-75 °F), wet conditions with high relative humidity (85% or higher). Free water is required for spores to infect susceptible plants. Prolonged periods of leaf wetness promote spore germination and spread, so keeping plants dry minimizes the spread of this disease. Increasing air circulation around the plant by thinning and pruning it reduces humidity and minimizes infection.



Melon garden leaves affected by downy mildew

Cabbage downy mildew.Cabbage and Cauliflower (Brassica sp.)

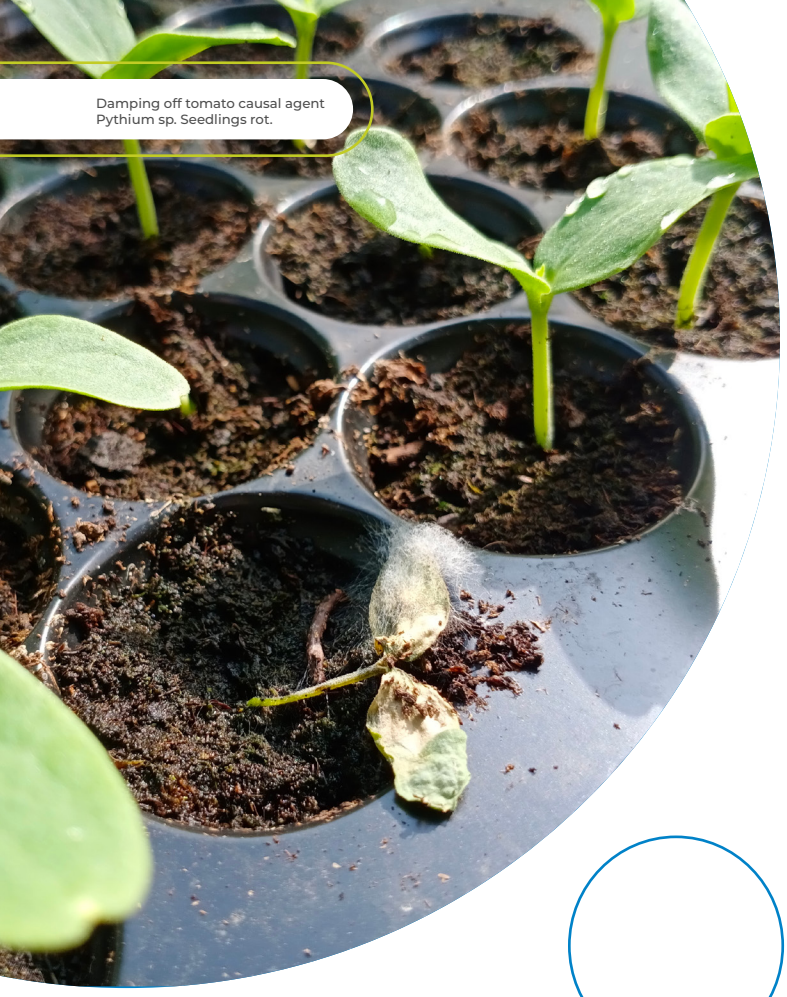
Downy mildew attacks a wide range of crops, and symptoms vary significantly between plants and even varieties. Downy mildew may first appear as yellow/white patches on the upper surfaces of older leaves. On the undersides, these areas are covered with white to grayish cotton-like fungi. These “downy” masses are most often noticed early in the morning in CEA environments when moisture is high and the light cycle has just begun. Soon after the light cycle or sunlight begins, signs of the mildew disappear. As the disease progresses, leaves may eventually turn crisp and brown and fall off even though the plant has ample water.

PRINCIPALS OF CONTROL:

- Prune plants to improve air circulation
- Water early enough in the day to allow for complete drying of the foliage before the dark cycle
- Keep ground under benches free of old leaves and infected plant debris
- Remove and destroy infected plant: do not use in composting
- Choose resistant varieties
- Scout daily and apply bio-controls before significant disease outbreak occurs

CERTIS BIOLOGICALS RECOMMENDATIONS FOR DOWNY MILDEW CONTROL

PRODUCT NAME	RATE	INTERVAL	NOTES
Triathlon® BA	0.5-6 qts/100 gal	7-10 days	Applications should start when conditions are conducive for disease development.
LifeGard® WG	4.5 oz /100 gallons	3-14 days	Applications should be made preventively and then made every 14 days when disease conditions become favorable.



Damping off tomato causal agent
Pythium sp. Seedlings rot.

Damping off tomato causal agent
Pythium sp. Seedlings rot.

Pythium

Pythium is one of the most common diseases found in CEA crop production. It is a soilborne pathogen that can cause wilt, decline, and death.

Like downy mildew, Pythium is a water mold and spreads by water movement, infected soil, and plant debris. Insects such as fungus gnats and shore flies can also spread Pythium. Pythium, or “damping-off,” is especially a concern in CEA environments that use recirculating water systems and/or stock tank solutions. Once in a CEA environment, pythium can become a permanent disease that hibernates on dirty plant containers, water equipment, stock tank solutions, fallen debris, benches, hoses, and walkways. It remains dormant and ready to become activated by the right plant and environmental conditions.

When conditions favor Pythium, it spreads by releasing swimming zoospores that migrate to plant root surfaces to infect and colonize root tissue. The disease infects root tissue and the vascular system of established plants and eventually causes plant collapse. Pythium can affect seedling emergence or attack mature plant material. Pre-emergence damping-off causes seeds and young seedlings to rot before they emerge, and post-emergence damping off kills newly emerged seedlings. In postemergence damping-off, the pathogen causes a water-soaked, soft brown lesion at the stem base, near the soil line, that pinches off the stem, causing the seedling to topple over and die. In mature plants, Pythium causes crown and root rot, where plants suddenly wilt. Often, upper leaves of infected plants wilt in the day and recover overnight, but plants eventually die. Symptoms may be confused with excessive nutrient levels, ammonium toxicity, heat stress, or water stress.

Sanitation practices are extremely important in the control of Pythium. Follow a strict sanitation program: clean and disinfect all interior surfaces and equipment including tools, hoses, walkways, carts, totes, troughs, tanks, and water supply lines. Use sterile propagating media and equipment. Remove dying plants by placing them directly into plastic bags for disposal away from the CEA environment.

CERTIS BIOLOGICALS RECOMMENDATIONS FOR PYTHIUM CONTROL

PRODUCT NAME	RATE	INTERVAL	NOTES
Triathlon® BA	0.5-4.5 pt/100 gal- drench 0.5-6qts/100 gal- foliar application	7-10 days	Drenches can start after germination or sticking.

Fusarium

Fusarium is a soilborne pathogen that can cause wilt, decline, and death. Fusarium spreads in contaminated soil and infected cuttings and is favored by warm temperatures, high relative humidity, overwatering, and poor drainage. Fusarium spores move easily with water and can be splashed from one plant to another.

Fusarium causes a wide range of symptoms. The first signs of the disease are yellowing of foliage, stunting, and wilting, often along one side of plant. Look closely at stems near the base of plant and soil line. Dark, sunken areas called cankers visible on stems and are the tell-tale sign of a Fusarium infection. There can also be reddish streaking in petioles near the plant crown, and sometimes pinkish or white masses of mycelium growing on the base of cuttings or in the crown of a plant. Plants may appear water stressed, and foliage may brown and die.

As with other soilborne diseases, proper sanitation is a key to control. Cuttings should be quarantined and treated, and growing media should be free of disease.

Fusarium wilt disease on tomato

CERTIS BIOLOGICALS RECOMMENDATIONS FOR FUSARIUM CONTROL

PRODUCT NAME	RATE	INTERVAL	NOTES
Triathlon® BA	0.5-4.5 pt/100 gal- drench 0.5-6qts/100 gal- foliar application	7-10 days	Drenches can start after germination or sticking.

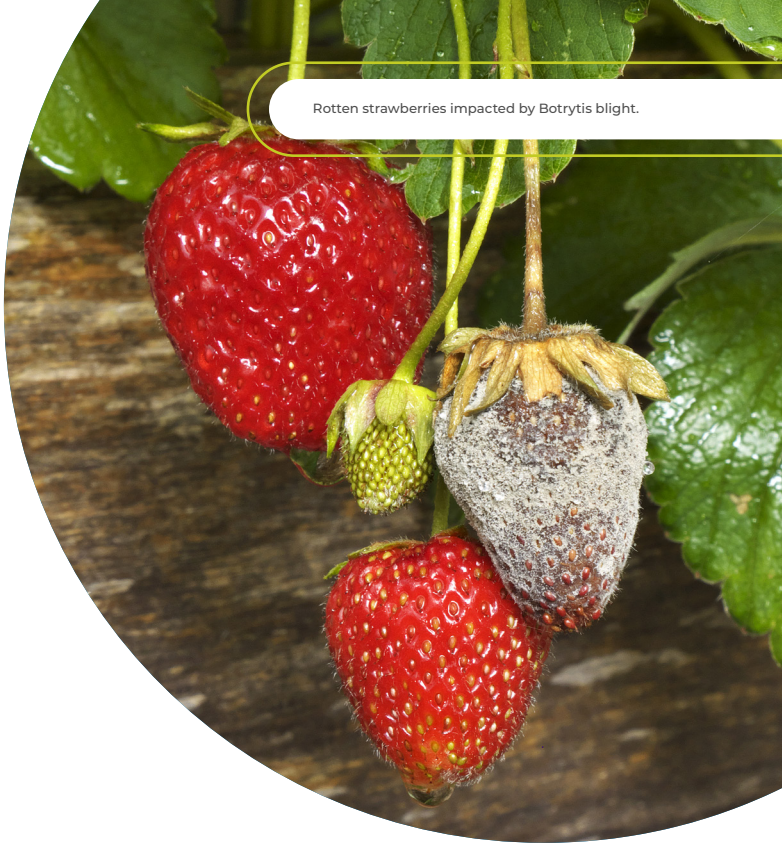
Fusarium wilt disease on tomato. damaged by disease and pests of tomato leaves

Botrytis

Botrytis blight one of the most common fungal diseases of CEA crops. The disease is often referred to as gray mold because it produces abundant fuzzy gray spores on the surfaces of infected tissues. Botrytis blight is most often caused by Botrytis cinerea, but other species may also be problematic. A sound IPM program is necessary to control this disease. Like other diseases, Botrytis has a specific range of temperature and relative humidity that is necessary for spore germination, infection, and disease development.

The disease takes place at a wide range of temperatures, but 60-75°F is optimum. Spores move easily by air currents and splashing water. Botrytis will also produce hardened reproductive structures that can survive in soil for extended periods of time.

Depending on the host and environmental conditions, Botrytis can cause leaf and flower blight, fruit rot, cankers, damping-off, and root rot. Plants may be attacked at any stage, but tender new growth, freshly injured tissues, and aging or senescent tissues are preferred. Fuzzy gray spore masses may be visible to the naked eye or observed with a hand lens. Copious spores are produced on lesions as well as on plant debris left on benches, the greenhouse floor, and cull piles.



Rotten strawberries impacted by Botrytis blight.

CONDITIONS THAT FAVOR THE DISEASE:

- Film of moisture for 8 to 12 hours
- Relative humidity 85% or greater
- Temperatures 55-75 °F

CERTIS BIOLOGICALS RECOMMENDATIONS FOR BOTRYTIS CONTROL

PRODUCT NAME	RATE	INTERVAL	NOTES
Carb-O-Nator®	2.5-5 lbs./100 gallons	10-14 days	Can be used to control early infestations of PM. Must be used consistently.
Triathlon® BA	0.5-6qts/100 gal- foliar application	7-10 days	Applications should start when conditions are conducive for disease development.
LifeGard® WG	4.5 oz /100 gallons	3-14 days	Applications should be made preventively and then made every 14 days when disease conditions become favorable.

Certis Biologicals understands the challenges of growers, and our portfolio of OMRI-Listed® products fits perfectly into both traditional and Controlled Environment Agriculture IPM programs. Please contact us to discuss how our product recommendations suggested throughout this guide could be included in your program this year.

Glossary

	TERM	DEFINITION
ACRONYMS	**CEA**	Controlled Environment Agriculture
	IPM	Integrated Pest Management
	OMRI	Organic Materials Review Institute
TERMS	**Color spectrum of light**	The visible spectrum that is always the same for a rainbow or the separated light from a prism.
	CO2 Enrichment	Utilized in greenhouses, it allows crops to meet their photosynthetic potential. Enriching the air with CO2 can be done by means of combustion of natural gas or liquid CO2. Adding CO2 makes it possible to increase the photosynthesis potential of crops, especially on sunny days.
	Cultivar	A plant variety that has been produced in cultivation by selective breeding.
	Diurnal	Behavior of a plant that is active in the daytime.
	Electrical conductivity (EC)	Measures the ability of soil water to carry electrical current. EC has been primarily used as a measure of soil salinity.
	Environmental Engineer	Application of scientific and engineering principals to improve and maintain the environment to protect human health, protect nature's beneficial ecosystems, and improve environmental-related enhancement of the quality of human life.
	Facility Architect	A facility designer that specializes in developing establishment plans according to project requirements.
	Fungus gnat monitor	Visual inspection for adults and the use of yellow sticky traps to trap adults. Chunks of raw potato placed in pots with the cuts sides down can be used to monitor for larvae.
	General Contractor	Esponsible for the day-to-day oversight of a construction site, management of vendors and trades, and the communication of information to all involved parties throughout the course of a building project.
	IPM Scouting Form	A document that is crop specific and corresponds with threshold counts of crop specific pests and diseases, which can be used as a guide to the control method used.
	Lepidoptera	Order of insects that include butterflies and moths.

TERMS	**Mechanical Engineer**	Engineer that combines engineering physics and mathematics principles with materials science to design, analyze, manufacture, and maintain mechanical systems.
	Petioles	The stalk that joins a leaf to a stem; leafstalk.
	Russeting	An abnormality of fruit skin which manifests in russet-colored (brown) patches that are rougher than healthy skin.
	Structural Engineer	Responsible to analyze, design, plan and research structural components and structural systems to achieve design goals and ensure the safety and comfort of users or occupants.
	Tensiometers	Measures water potential or tension. Tensiometers are used for irrigation scheduling to help farmers and other irrigation managers to determine when to water.
	Tetranychidae (spider mites)	Family of medium-sized soft-bodied mites that have the movable chela of each chelicera modified into a long piercing organ, tenant hairs on the claws, and no genital suckers, that feed on plants and usually spin silken webs over the foliage.
	Total dissolved solids (TCS)	Measure of the dissolved combined content of all inorganic and organic substances present in liquid in molecular, ionized, or micro-granular suspended form.
	Vector	A living organism or plant that transmits an infectious agent from an infected animal/plant to a human or another animal/plant.
PRODUCTS & DISTRIBUTORS	**AgSil® 16H**	Helps plants to resist toxicity from phosphorous, manganese, aluminum, iron and increases tolerance to salt. AgSil also aids in resistance to drought by reducing water loss, and in some cases, it may increase growth and yield. The product also helps to reduce certain diseases.
	Ancora®	A microbial insecticide containing a naturally occurring fungus that infects both foliage and soil insect pests. Ancora is compatible with beneficial arthropods and is labeled for use on herbs, vegetables and ornamentals.
	Azatin® O	A biological insect growth regulator (IGR) used to control the larval stage of a broad spectrum of greenhouse and nursery pests. Azatin O contains the active ingredient azadirachtin.
	Bug-N-Sluggo®	Broad-spectrum bait that controls ants, earwigs, cutworms, sowbugs, pill bugs, slugs, and snails. The active ingredients are iron phosphate, an active ingredient that originates in the soil, and Spinosad, which is derived from a soil dwelling bacterium.
	Defguard®	Biofungicide/Bactericide, an IPM foundational product, this broad spectrum biofungicide has been extensively tested and used across many plant types. Multiple modes of action work to protect against various foliar and soil pathogens of CBD Hemp.

PRODUCTS & DISTRIBUTORS		
	Griffin Greenhouse Supply	Founded in 1947 by Charles J. Griffin, and headquartered in Tewksbury, Massachusetts, it is one of the largest suppliers to growers in the Greenhouse and CEA industries; with personnel covering 49 of the 50 states (HI is not covered).
	Grotto®	OHP, Inc. fungicide/bactericide provides effective, broad-spectrum prevention and control of key diseases on a variety of plants and crops. Active ingredient: copper octanoate.
	Hawthorne Gardening Company	Formed in October 2014, it is The Scotts Miracle-Gro Company's subsidiary for cannabis growers and one of the first major investments by a major United States corporation in the cannabis industry.
	Kalmor®	OHP, Inc. fungicide/bactericide is an effective broad-spectrum agent for prevention and control of diseases in a variety of plants and crops. Active ingredient: copper hydroxide.
	OHP, Inc.	Originally Olympic Horticultural Products, it is a privately owned company founded with the goal of becoming the leading provider of technology-based pesticide solutions for the greenhouse and nursery production markets.
	Sil-MATRIX® LC	Preventative fungicide and a contact miticide/insecticide. Forms a physical barrier within the leaf cuticle that prevents penetration of fungal diseases.
	Soilgard® 12G	*G. virens*, the active ingredient in SoilGard is a naturally occurring soil fungus, which is antagonistic to plant pathogenic fungi such as Pythium and Rhizoctonia, thereby aiding in control of these damping-off and root rot pathogens.
	Triact®	OHP, Inc. clarified hydrophobic extract of Neem oil, a broad spectrum fungicide, miticide, and insecticide (OMRI-Listed)®. Triact 70 is preventative as well as a curative.
	Triathlon® BA	OHP, Inc. OMRI-Listed® broad-spectrum preventative biofungicide and bactericide for use on a wider variety of ornamentals, fruits, vegetables, and herbs grown in greenhouses, nursery, and shade houses. Active ingredient: *Bacillus amyloliquefaciens*.

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