Production Systems for Leafy Greens and Herbs

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Cornell Controlled Environment Agriculture

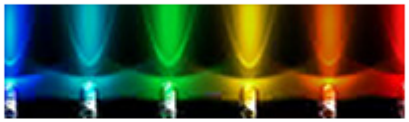
Controlled Environment Agriculture or CEA facilities can range from the very low-tech such as row covers and high/low plastic covered tunnels, to fully automated glass greenhouses with computer controls. There have even been some CEA facilities on the international space station where astronauts have grown leafy greens both to eat and to advance scientific knowledge. The Cornell CEA program has worked with many different types of CEA facilities through the years. We developed a greenhouse hydroponic production method geared toward local food production. A prototype facility was built in Ithaca in the late 1990's and continues to function today producing more than 1000 heads of lettuce every day of the year. We continue to do research in the areas of supplemental lighting and commercial hydroponic vegetable production. Learn more about the CEA...

Thinking About Starting Your Own Company?

Here are some things you should consider:

- Hot Topics

GLASE



The Greenhouse Lighting and Systems Engineering (GLASE) consortium is a public-private partnership led by Cornell University and Rensselaer Polytechnic Institute to integrate advanced energy-efficient LED lighting with improved environmental controls for more efficient and sustainable greenhouse production.

Cornell CEA on Instagram

Instagram

GLASE

GREENHOUSE LIGHTING & SYSTEMS ENGINEERING

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www.glase.org

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Outline

- Propagation
- Production Systems and Environmental Management
  - Deep water culture (raft/pond)
  - Nutrient film technique (channels)
  - Specialty systems (aeroponics, vertical towers)
- Common problems

Common crops

Leafy greens

- Lettuce
- Kale
- Arugula
- Swiss chard
- Pak choi
- Spinach
- Mustard
- Baby leaf greens

Herbs

- Basil
- Cilantro
- Parsley
- Chives
- Dill
- Mint

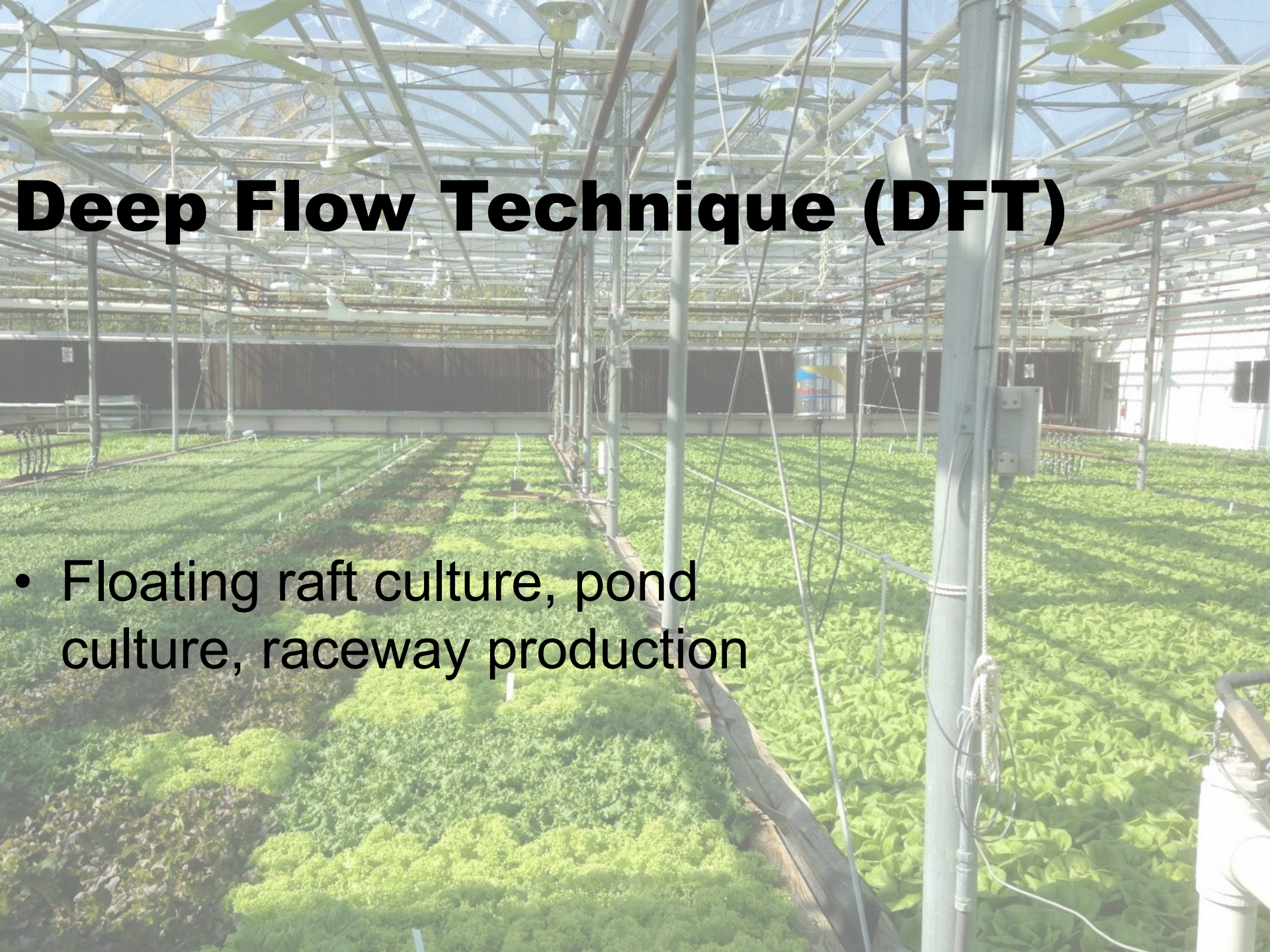
Seedlings in Rockwool/Oasis

Lettuce seedling culture

- 1-inch cubes (Rockwool, Oasis, Jiffy, etc.)
- Presoak cubes with tapwater
- Temperature 68 – 72 °F (20-22 C)
- Irrigate on ebb and flood trays (or by hand)
- Complete fertilizer solution at 100-150 ppm N
  - EC about 1.5 mhos/cm
  - pH 5.4 – 5.8
- Transplant when 3-4 true leaves (10 – 21 d)


PROP LAB

Deep Flow Technique (DFT)



- Floating raft culture, pond culture, raceway production

Cornell CEA Float Pond System

- Designed originally for ‘Ostinata’ butterhead lettuce
  - Subsequently used ‘Flandria’
- Seedling stage (11 days in rockwool blocks) then transplant to rafts
- Initial raft spacing at 9 plants per square foot until day 21 (90 plants/m^2)
- Then respaced to 3.5 plants per square foot (35/m^2) until day 35
- Daily light integral 17 mol / m^2 / d
- Produces 1200 5 ounce (150 g) heads a day in 6,000 square feet (600 m^2) of pond

Day 11 – transplant to raft

- 90 plants/m^2

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Day 21 – transplant to wider spacing

- 35 plants/m^2

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Day 35 - Harvest

- Heads about 5 oz. (150 g) if everything went according to plan
- Package and store at 33-38 °F (1-3 C)

Greenhouse Set Points

- Air Temperature 75 F Day / 65 F Night (24/18 C)
- Water Temperature: 75 – 78 F (24-26 C)
- Relative Humidity: 50-70%
- Carbon Dioxide: Enrichment to 1500 ppm is beneficial
- Light 17 mol m^{-2} d^{-1} combination of solar and supplemental light
- Dissolved Oxygen 7 ppm (mg/L), crop failure if less than 3 ppm
- pH 5.6-6

Rafts

- 4’x8’x1” polystyrene boards
  - Cut into **4** 2’x4’ sections
  - 1” holes drilled
- Can buy premade
  - Ex: Beaver Plastics

Hydronov system

- Seeding in oasis cubes, trays floated on top of pond
- First transplanting at first true leaf (4-6 d after seeding)
  - 288 seedlings per 2'x4' board (36/sf)
- Second transplanting at third true leaf stage (10-12 d after seeding)
  - 72 seedlings per 2'x4' board (9/sf)
- Third transplanting at fourth true leaf stage (18-21 d after seeding
  - 18 plants per 2'x4' board (2.25/sf)
  - Grown on 24-30 d (harvested 45 d after seeding)

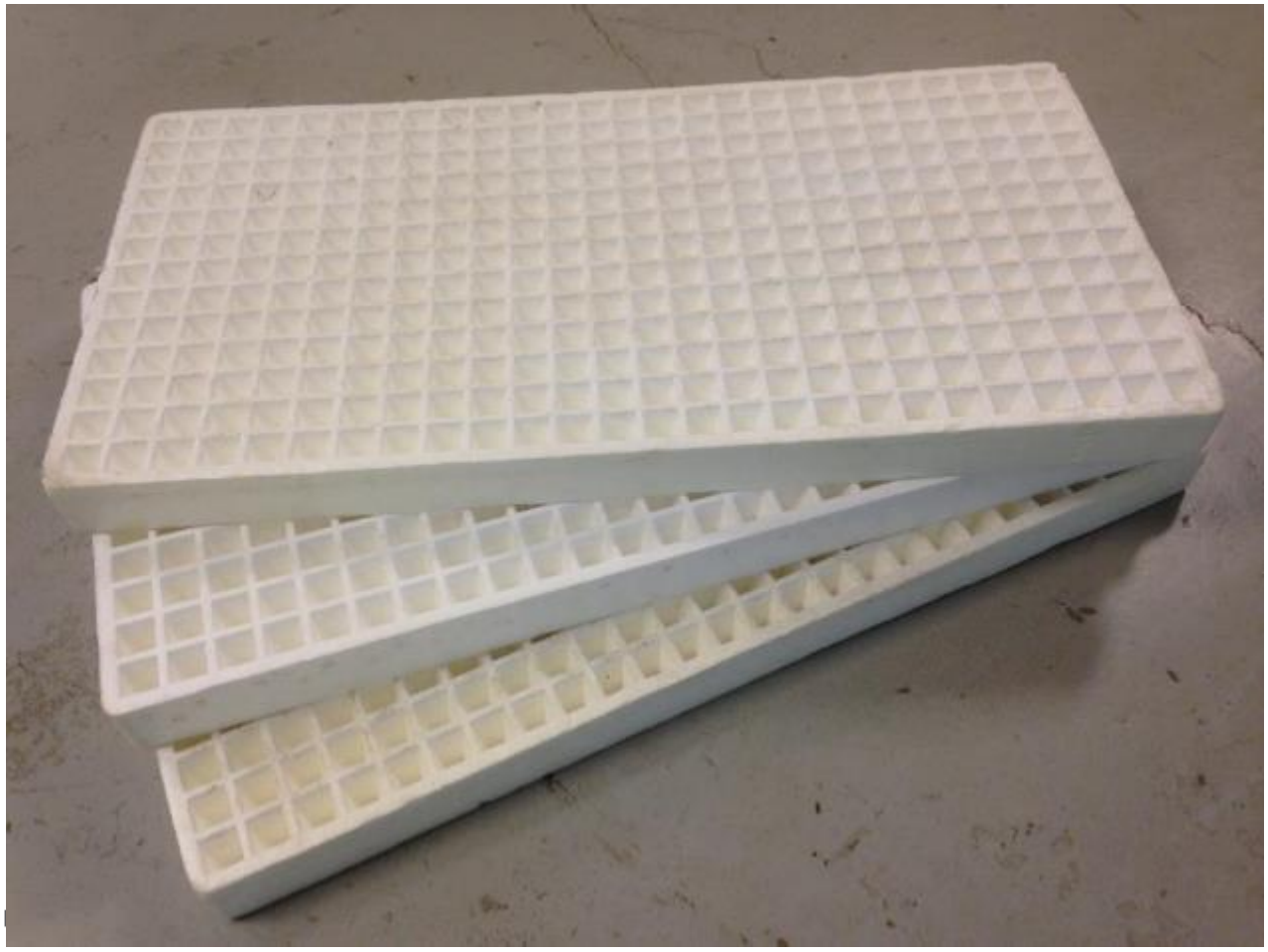
Baby leaf greens in float pond

- Styrofoam Speedling trays with soilless mix
- Germination chamber 1-3 days
- Float 14 days (17 mol DLI, 22/20°C (72/68°F) D/N)

Baby leaf greens in pond

Speedling Trays

336 cells (13 x 26), 13.625” x 26.625” x 1.75”
= 2.5 square feet



Timing/Yields Baby-Leaf Greens

	Germ. Dark (d)	Germ. Light (d)	Float (d)	Yield (oz./sf)	Yield (g/m^2)
Arugula	1	2	10	12	3,600
Kale	2	1	10	14	4,200
Lettuce	1	2	10	15	4,500
Spinach	3	0	13	9	2700

Data are examples from Cornell CEA trials with 72-74 F (22-24) air temperature and 17 mol/m2/d DLI

Pond temperature

- Use of in-line water chiller to maintain nutrient solution temperature
- Typically 65-75°F
  - Delays bolting 3-4 days (in warm climates)
  - Reduce *Pythium* infection

Why DFT?

Pros

- Low cost
  - Home built
  - Pre-formed ponds
- A simple system
  - Water + Nutrients + Oxygen (the only moving part)
- Large buffer
  - Nutrients
  - pH
  - Temperature
- Respacing

Cons

- Very heavy
- Large initial water use
- Large waste if deep cleaning is needed
  - Ex: Sanitation

Nutrient Film Technique (NFT)

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Manufacturers of Rigid PVC Extruded Growing channels, ex:

- CropKing
- American Hydroponics
- FarmTek
- Example Dimensions
  - 4” wide x 1.5” deep x 12 ft long

Ex: Automated systems with metal channels

- Greenhouse Automation

Spacing and NFT

Square foot weeks calculator (Lou Albright, 2014)

- Cornell Pond: 0.74 plants/sf/wk
- Crop King: 1.53 plants/sf/wk
- AmHydro: 0.86 plants/sf/wk

Plants harvested per week per 1000 square feet

- Cornell Pond: 1,351 plants/wk
- Crop King: 654 plants/wk
- AmHydro: 1,163 plants/wk

Why NFT?

Pros

- Small volume of water makes easy to drain and sanitize
- Lightweight (e.g. rooftop)
- Many turn-key systems available

Cons

- Clogging of emitters
- Leaks
- Biofilm/Algae
- Small volume of H_2O per plant
  - Rapid changes in nutrients, temperature, pH
- Shared nutrient solution means disease can spread rapidly

Pond/NFT Management

- pH/EC tested and adjusted at least daily
- NFT
  - Typically small volume water per plant
  - Nutrient imbalances can occur relatively quickly
  - Drain and replace nutrients every 10-14 days
    - Or laboratory analysis adjust
- Pond/Deep water culture
  - Larger volume of water
  - Start with reverse osmosis water
  - Use for several crop cycles
  - Laboratory analysis every 1-2 weeks and adjust

Herbs in container media with NFT channel irrigation

Aeroponics

Roots bathed with mist which oxygenates when in contact with air

What happens when mist nozzles clog or power goes out?


Vertical Towers
Drip irrigated with substrate (ex: Perlite)

Vertical Production

- What might be some issues?
  - Nutrient distribution
  - Uniformity in Light interception

Common Pests, Diseases, and Physiological Disorders

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Pythium root rot

Symptoms

- Brown/discolored roots
  - "rat tails"
- Poor rooting
- Leaf wilting, chlorosis

Crops

- Spinach
- Basil
- Lettuce

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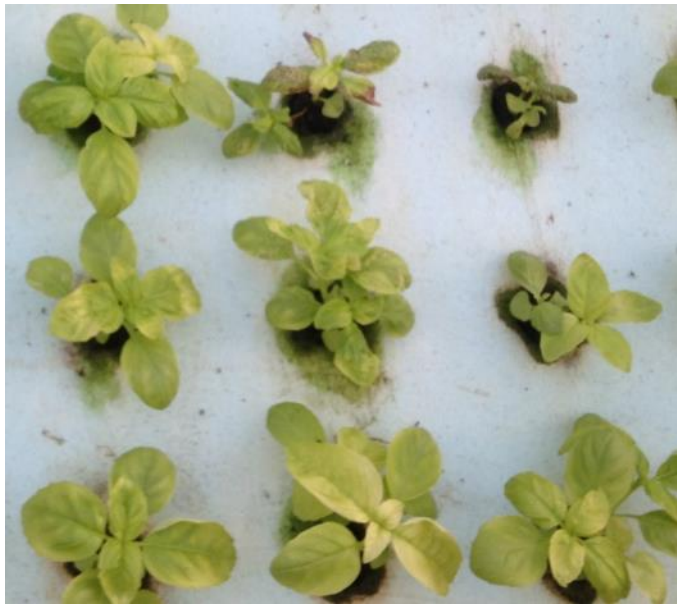
Pythium root rot

Control measures

- Sanitation / Exlusion
  - Ponds/troughs, tools
  - Remove root debris
  - Foot baths
- Cultural measures
  - *P. aphanidermatum* chiller to decrease water temperature (ex: 68 °F)
  - Keep dissolved oxygen near saturation
- Preventative drenches with Biofungicides at seedling stage

https://e-gro.org/pdf/E207.pdf



Powdery mildew

Symptoms

- Gray-white powdery growth on upper leaf surfaces

Crops

- Lettuce
- Rosemary
- Sage
- Mint

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Powdery mildew

Control measures

- Remove infected plants (bag up)
- Favored by humid nights, dry days
  - Ventilation and heating, esp. at night
- Cultivar selection

- Preventative fungicides, (not exhaustive)
  - Bacillus subtilis (ex: Cease), Potassium bicarbonate (ex: Milstop), Streptomyces (ex: Actinovate SP), hydrogen dioxide (Oxidate 2.0)

Leanne Pundt, Tina Smith
http://ipm.uconn.edu/documents/raw2/html/511.php?aid=511

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Aphids

Symptoms

- Soft bodied insects
- Lettuce aphid
- Green peach aphid
- Stunted plants, curled leaves, honey dew

Crops

- Lettuce
- Kale
- Basil
- Other herbs

Whitney Cranshaw, Colorado State University, Bugwood.org

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Aphids

Can transmit some viruses (LMV, CMV

Control measures

- Biocontrol, depends on aphid species
  - Predatory mites (*Amblyseius* spp. and *Phytoseiulus* spp.)
  - Parasitic wasps *(Aphidius)*

Thrips

Symptoms

- Slender insects 1 mm long
- Scarring / deformed leaves and flowers
- Black fecal specks

Crops

- Leafy greens, lettuce, kale, etc.
- Herbs

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Thrips

Control measures

- Prevention / Sanitation
  - Remove weeds
  - Inspect incoming plant material
- Biocontrols
  - Predatory mites
    - Hypoaspis
    - Cucumeris
    - Swirskii (also whitefly eggs)
  - Nematodes
    - Ex: Steinernema feltiae (against pupal stage thrips)
  - Orius (Pirate bug)

Shoreflies

Symptoms

- Small black fly
  - Short antennae
  - 5 white wing spots
- Feed on algae
- Frass on leaves may be a nuisance
- Adults can transmit Pythium

Crops

- Leafy greens
- Herbs

Shoreflies

Control measures

- Eliminate algae
- Remove wet spots under benches/channels
- Remove other organic matter/debris
- Biocontrols (not as effective as for fungus gnats)
  - rove beetle (*Atheta coriaria*

Leaf tip burn

Symptoms

- necrotic spots on the tips and edges of young leaves
- Center of the head is most affected

Crops

- Head Lettuce

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Leaf tip burn

Calcium deficiency, usually due to:

- poor transpiration or
- Plant growing too fast as head reaches maturity

Control

- Decrease relative humidity
- Air flow (Vertical fans)
- Decrease light levels (ex: < 17 mols/m^2/d)
  - Decrease light set points
  - Apply shading

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Outer leaf edge necrosis

Symptoms

- Necrotic spots on leaf edges at hydathodes
- Old leaves affected

Crops

- Head Lettuce

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Outer leaf edge necrosis

Causes

- Guttation (leakage of water and salts) at hydathodes
- High RH (or fluctuating high RH nights, low RH days)

Control

- Avoid high EC of nutrient solution
- Avoid high relative humidity at night

Bolting

Symptoms

- Premature development of flower stalk
- Poor head development

Crops

- Lettuce, spinach, arugula, herbs

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Bolting

Causes

- Excessive air temperature
- Photoperiods that promote flowering
  - Long days for spinach, lettuce, cilantro

Control

- Select resistant varieties
- Decrease air temperature < 80 °F (or chill pond, ex: 68 °F)

QUESTIONS? nsm47@cornell.edu

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