Using UV-C: How Close are We to Implementing it and What We Need to Move Forward

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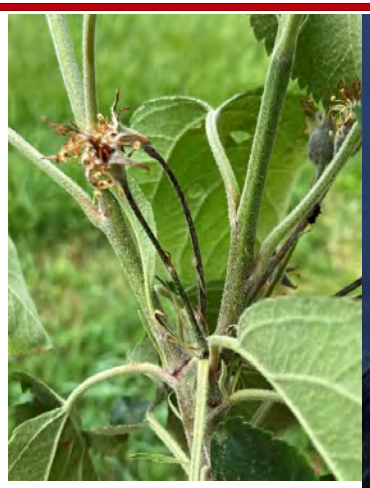
Suppression of fire blight w/UV light

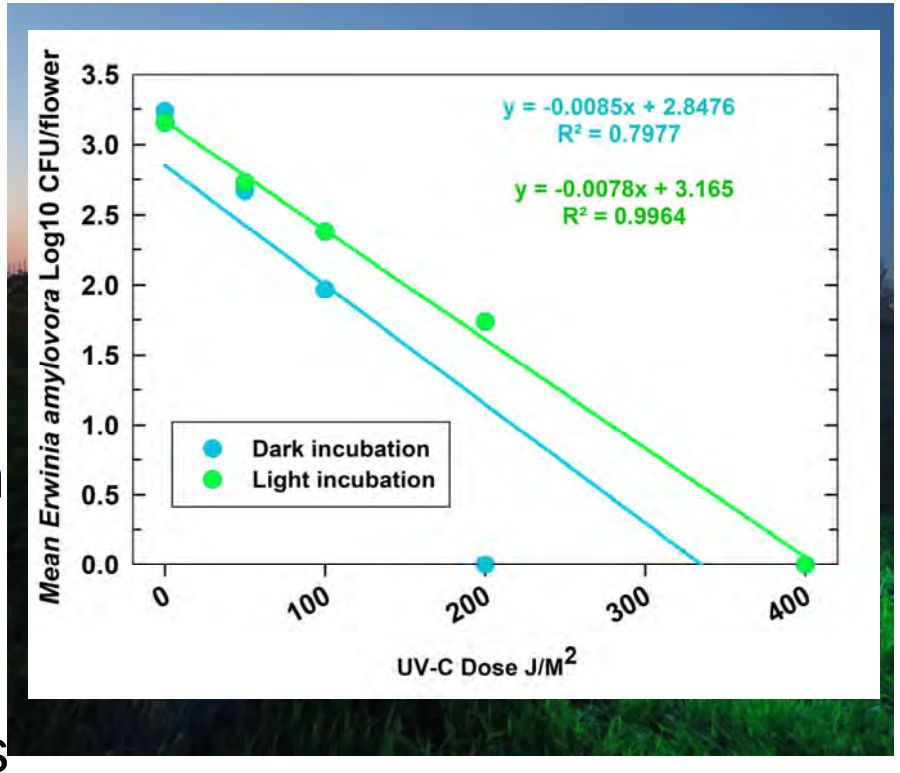
Suppression of fire blight using UV light

- Infections at bloom initiate fire blight epidemics > devastating shoot blight
- Preventing blossom blight requires precise applications of antibiotics > resistance & lack consumer appeal
- Germicidal (UV-C) light is effective against transparent bacteria, algae
  - Medicine, aquaculture, & agriculture
  - Organic approved
  - No residue



Suppression of fire blight using UV light

- Some pathogens & microbes can repair UV damage in sunlight (even *Erwinia amylovora*) – Use at night
- Some crops like Hemp can be injured by UV light & if dose “too low”, not effective
- Works **REALLY** well on natural inoculum levels or organisms multiplying on surfaces (like *Erwinia amylovora)*
- Difficult to conduct natural inoculum tests with fire blight



UVC Trial Site at Cornell AgriTech

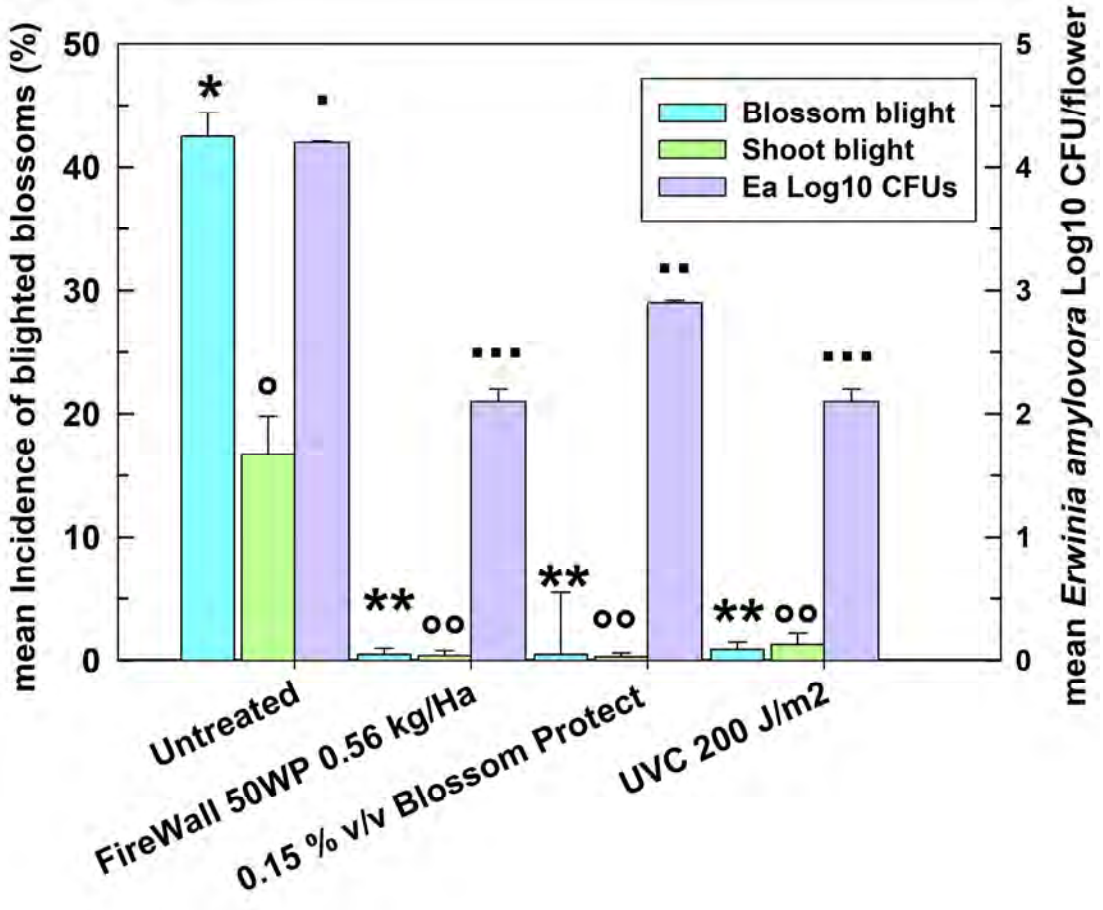
- Orchard sites (High Density Super Spindle)
- ‘Evercrisp’ on G.41 planted in 2019
- Reduced trellis (96”) to accommodate UV-C unit for grapes
- Replicated plot panels (RCB): 4 reps w/ ten trees each: V1 and V2

UVC -Blossom Blight Trials

- At 80% bloom
  - Streptomycin (Firewall 50 WP 0.56kg/Ha)
  - Aureobasidium pullulans (1.05% buffer protect + 0.15% blossom protect)
- Ea 273 at $1x10^6$ $CFUml^{-1}$
- That evening > UVC $200J/m^2$
- 100% Bloom: Strep, Aureo, UVC $200J/m^2$
- Blossom blight & shoot blight incidence
- Ea populations & leaf shape and shoot growth (possible UVC injury)

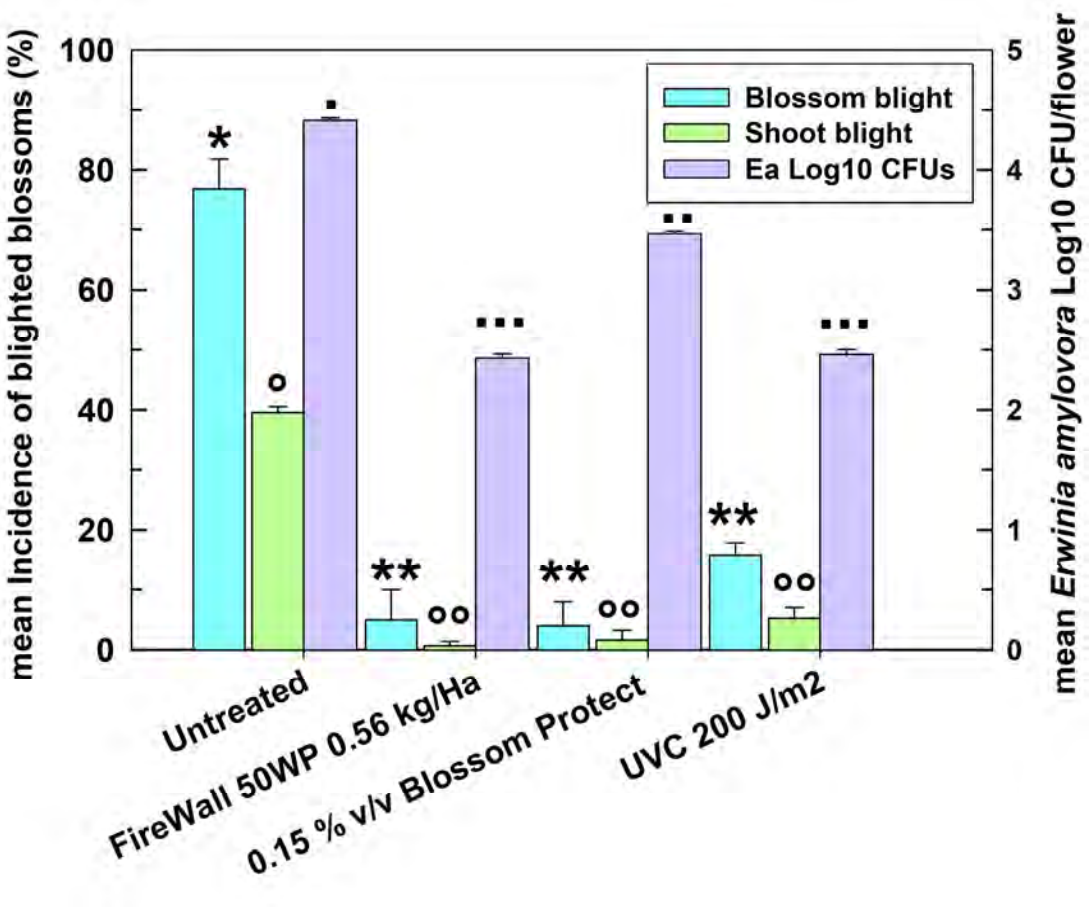
UVC Fire Blight trials (2021) – ‘Evercrisp’

- **Exceptionally cold bloom – low levels of infection on ‘Evercrisp’**
- Reduced Ea populations on flowers
- Excellent control of blossom and shoot blight in this cool season



UVC Fire Blight trials (2022) – ‘Evercrisp’

- **Exceptionally warm wet year – high levels of infection on ‘Evercrisp’**
- Reduced Ea populations on flowers, but higher than 2021
- Excellent control of blossom and shoot blight, but still high



UVC Fire Blight trials (2021) – ‘Evercrisp’

No differences in leaf shape & internode length

Treatment programs (amt./100 gal)	Leaf length (mm)*	Leaf width (mm)*	Internode length on 1st year shoots (%)
Over both inoculum doses			
Untreated	82.5 ± 0.1 a	56.3 ± 0.1 a	39.4 ± 0.1 a
Streptomycin (Firewall 50 WP 0.56kg/Ha)	83.2 ± 0.8 a	56.2 ± 0.5 a	41.1 ± 2.3 a
Aureobasidium pullulans (1.05% buffer protect + 0.15% blossom protect)	82.6 ± 0.7 a	56.4 ± 0.7 a	39.6 ± 0.6 a
UVC 200 J/m^2	82.6 ± 0.1 a	56.3 ± 0.1 a	39.6 ± 0.1 a

UVC Fire Blight trials (2022) – ‘Evercrisp’

No differences in leaf shape & internode length

Treatment programs (amt./100 gal)	Leaf length (mm)*	Leaf width (mm)*	Internode length on 1st year shoots (%)
Over both inoculum doses			
Untreated	82.8 ± 0.1 a	59.8 ± 0.2 a	45.5 ± 0.6 a
Streptomycin (Firewall 50 WP 0.56kg/Ha)	82.5 ± 2.3 a	59.1 ± 1.3 a	44.4 ± 2.9 a
Aureobasidium pullulans (1.05% buffer protect + 0.15% blossom protect)	81.7 ± 0.6 a	60.1 ± 0.3 a	44.4 ± 1.0 a
UVC 200 J/m^2	82.1 ± 1.0 a	59.9 ± 0.1 a	46.9 ± 0.9 a

UVC Horticultural impacts Trial at Cornell AgriTech

- ‘Buckeye Gala’, ‘Lady in Red’, ‘Royal Red’ Honeycrisp’ on M.9-337 planted in 2021
- Orchard sites (High Density Super Spindle)
- Reduced trellis (96”) to accommodate UV-C unit for grapes
- Replicated plot panels (RCB): 4 reps w/ five trees

UVC Horticultural impacts Trial at Cornell AgriTech

- At 80% and 100% bloom
  - Streptomycin (Firewall 50 WP 0.56kg/Ha)
  - Aureobasidium pullulans (1.05% buffer protect + 0.15% blossom protect)
- No inoculation with Ea 273
- Weekly and Bi-weekly UVC 200J/m^2
- Blossom blight & shoot blight incidence **(none)**
- Ea populations & leaf shape and shoot and tree growth (possible UVC injury)


Līga Astra Kalniņa

UVC Horticultural impacts (2022) – ‘Gala’

No impact of UV applications on growth and development

Treatment programs (amt./100 gal)	Log10 CFU/mL	Leaf length (mm)*	Leaf width (mm)*	Internode length on 1st year shoots (%)	1st year shoot length (cm)	Canopy Height (cm)
Untreated	1.5 ± 0.0 a	91.3 ± 0.3 a	78.7 ± 0.1 a	49.9 ± 0.6 a	22.0 ± 0.3 a	189.6 ± 0.5 a
Streptomycin (Firewall 50 WP 0.56kg/Ha)	0.0 ± 0.0 b	92.2 ± 1.4 a	79.0 ± 1.0 a	47.0 ± 0.9 a	20.3 ± 0.4 a	189.7 ± 1.6 a
Aureobasidium pullulans (1.05% buffer protect + 0.15% blossom protect)	0.0 ± 0.0 b	92.7 ± 0.8 a	77.3 ± 0.2 a	49.1 ± 1.4 a	21.4 ± 0.3 a	189.8 ± 1.4 a
UVC 200 J/m^2 1/week	0.0 ± 0.0 b	93.5 ± 0.4 a	78.4 ± 0.3 a	49.3 ± 0.7 a	21.2 ± 0.5 a	192.4 ± 0.7 a
UVC 200 J/m^2 2/week	0.0 ± 0.0 b	91.2 ± 0.2 a	79.4 ± 0.3 a	49.4 ± 0.7 a	21.9 ± 0.3 a	190.1 ± 0.3 a

UVC Horticultural impacts (2022) – ‘Lady in Red’

No impact of UV applications on growth and development

Treatment programs (amt./100 gal)	Log10 CFU/mL	Leaf length (mm)*	Leaf width (mm)*	Internode length on 1st year shoots (%)	1st year shoot length (cm)	Canopy Height (cm)
Untreated	1.5 ± 0.0 a	92.5 ± 0.6 a	70.3 ± 0.1 a	55.9 ± 0.5 a	20.1 ± 0.2 a	180.4 ± 0.4 a
Streptomycin (Firewall 50 WP 0.56kg/Ha)	0.0 ± 0.0 b	92.6 ± 3.6 a	69.1 ± 0.2 a	51.3 ± 2.3 a	20.1 ± 0.2 a	177.5 ± 1.9 a
Aureobasidium pullulans (1.05% buffer protect + 0.15% blossom protect)	0.0 ± 0.0 b	91.7 ± 1.1 a	70.7 ± 0.6 a	50.9 ± 0.7 a	20.0 ± 0.3 a	180.5 ± 0.5 a
UVC 200 J/m^2 1/week	0.0 ± 0.0 b	93.3 ± 0.4 a	69.8 ± 0.4 a	55.4 ± 0.6 a	20.4 ± 0.3 a	179.3 ± 0.4 a
UVC 200 J/m^2 2/week	0.0 ± 0.0 b	93.1 ± 0.1 a	70.2 ± 0.2 a	55.0 ± 0.9 a	19.9 ± 0.1 a	180.4 ± 0.4 a

UVC Horticultural impacts (2022) – ‘Royal Red Honeycrisp’

No impact of UV applications on growth and development

Treatment programs (amt./100 gal)	Log10 CFU/mL	Leaf length (mm)*	Leaf width (mm)*	Internode length on 1st year shoots (%)	1st year shoot length (cm)	Canopy Height (cm)
Untreated	1.5 ± 0.0 a	67.7 ± 0.6 a	50.1 ± 0.2 a	34.9 ± 0.3 a	17.5 ± 0.2 a	160.0 ± 0.8 a
Streptomycin (Firewall 50 WP 0.56kg/Ha)	0.0 ± 0.0 b	67.6 ± 1.1 a	48.6 ± 0.7 a	33.7 ± 2.2 a	18.0 ± 0.2 a	157.8 ± 2.2 a
Aureobasidium pullulans (1.05% buffer protect + 0.15% blossom protect)	0.0 ± 0.0 b	68.0 ± 0.7 a	48.1 ± 0.4 a	35.0 ± 2.3 a	17.1 ± 0.3 a	160.2 ± 1.3 a
UVC 200 J/m^2 1/week	0.0 ± 0.0 b	67.2 ± 0.7 a	50.7 ± 0.4 a	34.7 ± 2.9 a	17.3 ± 0.4 a	159.3 ± 0.8 a
UVC 200 J/m^2 2/week	0.0 ± 0.0 b	67.4 ± 0.2 a	50.2 ± 0.3 a	34.6 ± 0.7 a	17.8 ± 0.2 a	159.8 ± 0.6 a

UVC summary and takeaways

- UVC was effective at 200 J/m^2 against high and low inoculum
- Cold & warm bloom seasons, comparable to conventional (strep) & organic (*Aureobasidium*) standards
- Reduced populations on surface of flowers greatly, no apparent damage, or impacts on the development of young trees
- No residue, potential for frequent use & robotic automation

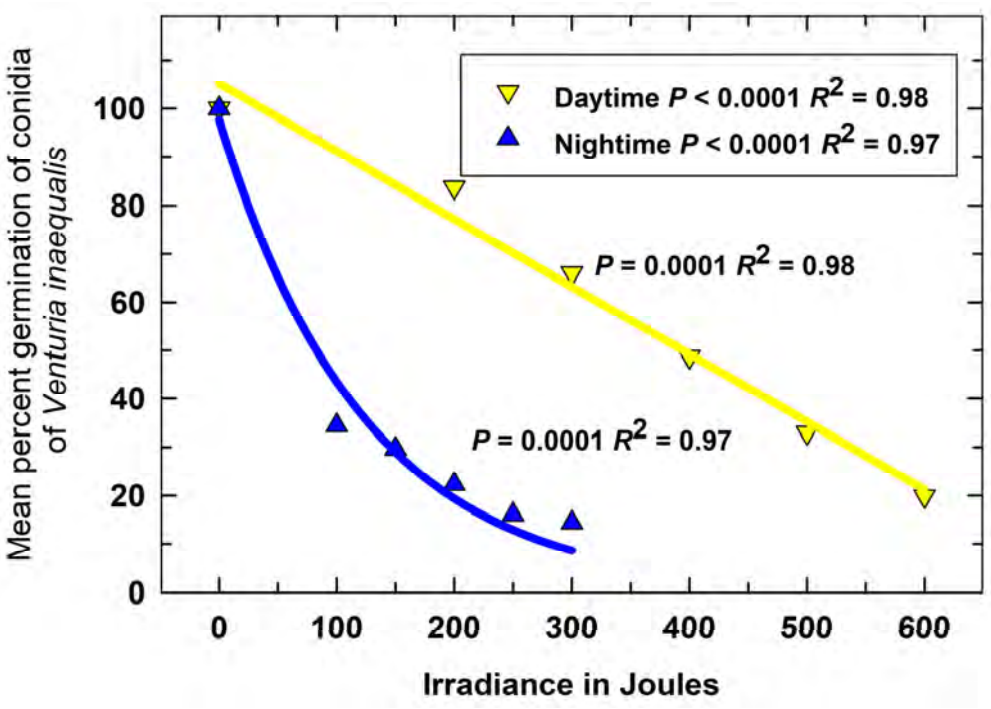
Suppression of fungal diseases of apple w/UV light

Suppression of apple scab using UV light

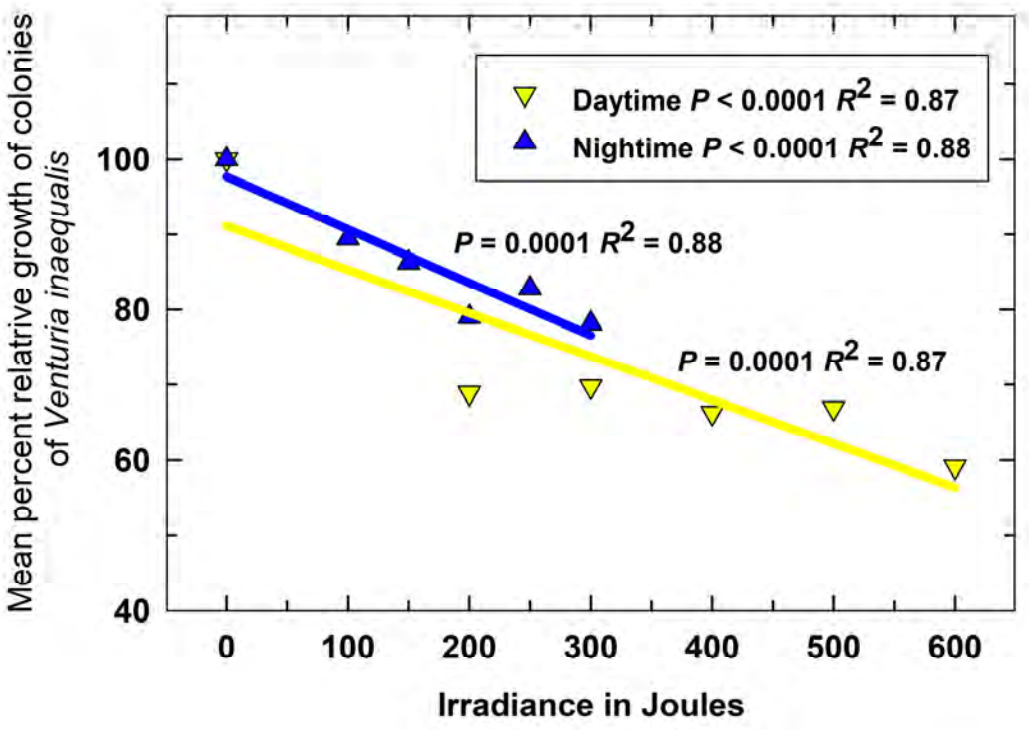
- UV-C could be used to manage fire blight of apple, a bacterial disease.
- Apple Trees can tolerate season long weekly applications 2 weeks/harvest w/no impacts
- Impacts on other apple diseases such as apple scab?
- Venturia inaequalis is darkly pigmented > needs higher dose
- Orchard inoculum levels lower than that of fire blight

Suppression of apple scab using UV light

Spore germination



Colony growth after 72 hrs



Field Trial at Cornell AgriTech

- High Density Super Spindle planting
- ‘Evercrisp’ on G.41 planted in Aug 2022
- Reduced trellis (96”) to accommodate UV-C unit for grapes
- Replicated plot panels (RCB): 4 reps w/ ten trees each

Field Trial at Cornell AgriTech 2023

Treatment	Program
1	Untreated Control (no fungicides)
2	**Manzate Max + Captec** rotated biweekly with Aprovia, Flint Extra or Cevya
3	**Double Nickel** rotated biweekly with Aprovia, Flint Extra or Cevya
4	**UV-C 200 J/m^2 at Night**
5	**UV-C 400 J/m^2 During the Day**

Simplified conventional standard program

Experimental Biopesticide programs

Objective 1: Calendar timing (7-10 days; 8 applications)

Field Trial at Cornell AgriTech 2023

Treatment	Program
1	Untreated Control (no fungicides)
2	**Manzate Max + Captec** rotated biweekly with Aprovia, Flint Extra or Cevya
3	**Double Nickel** rotated biweekly with Aprovia, Flint Extra or Cevya
4	**UV-C 200 J/m^2 at Night**
5	**UV-C 400 J/m^2 During the Day**

Simplified conventional standard program

Experimental Biopesticide programs

Objective 2: Forecast timing NEWA & rimpro germination timing (8 applications)

Field Trial at Cornell AgriTech 2024

Treatment	Program
1	Untreated Control (no fungicides)
2	**Manzate Max + Captec** rotated biweekly with Aprovia, Flint Extra or Cevya
3	**Double Nickel** rotated biweekly with Aprovia, Flint Extra or Cevya
4	**UV-C 200 J/m^2 at Night**
5	**UV-C 400 J/m^2 During the Day**

Simplified conventional standard program

Experimental Biopesticide programs

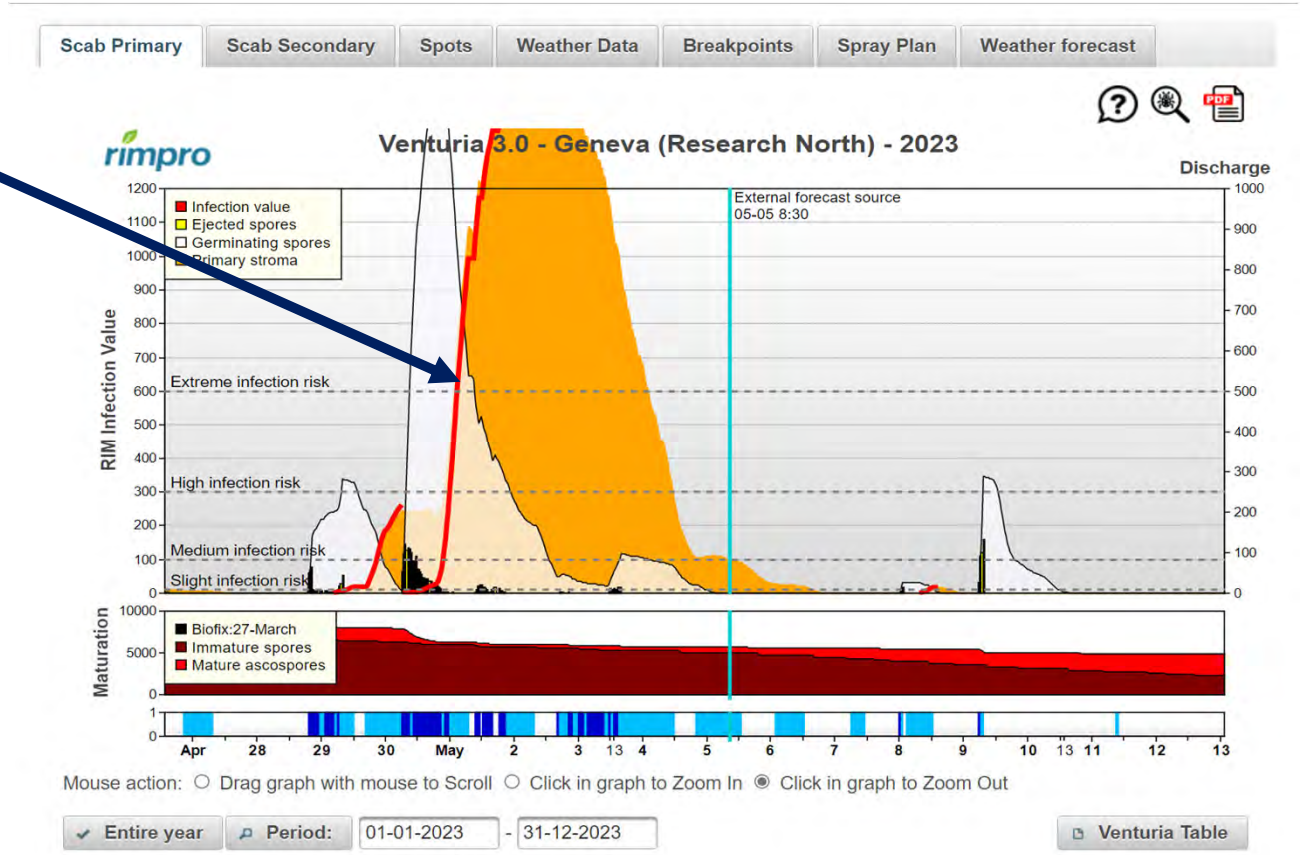
Forecast timing NEWA & rimpro germination timing (16 applications)

Field Trial at Cornell AgriTech

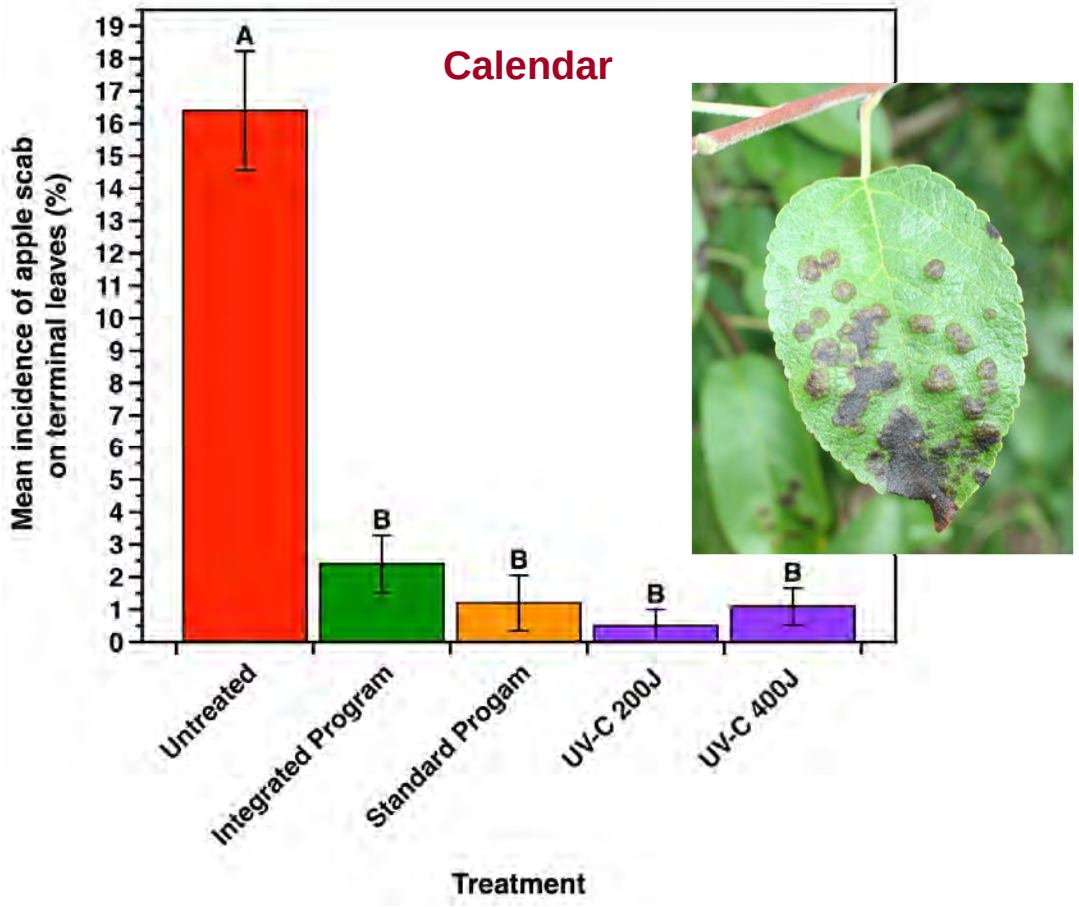
Objective 2: Forecast timing NEWA & rimpro germination timing

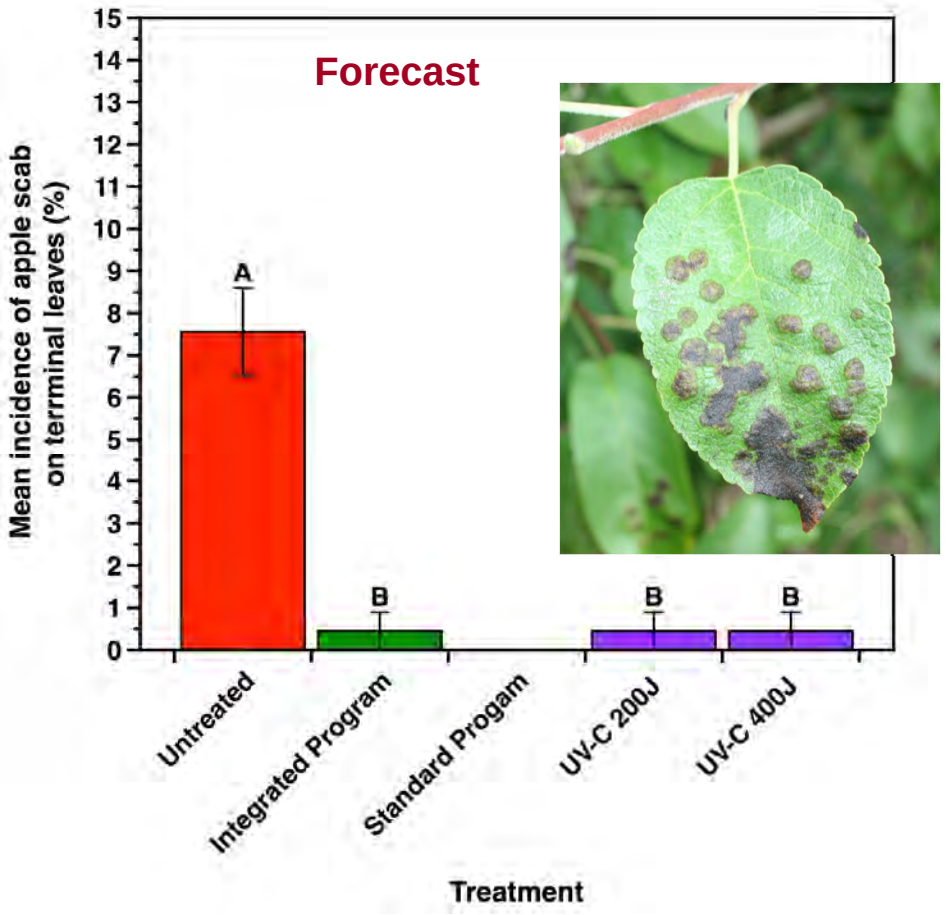
Infection Events Summary

Date (2023)	Infection Events
Apr 26	no
Apr 27	no
Apr 28 Forecast	combined
Apr 29 Forecast	combined
Apr 30 Forecast	combined
May 1 Forecast	yes
May 2 Forecast	no
May 3 Forecast	no

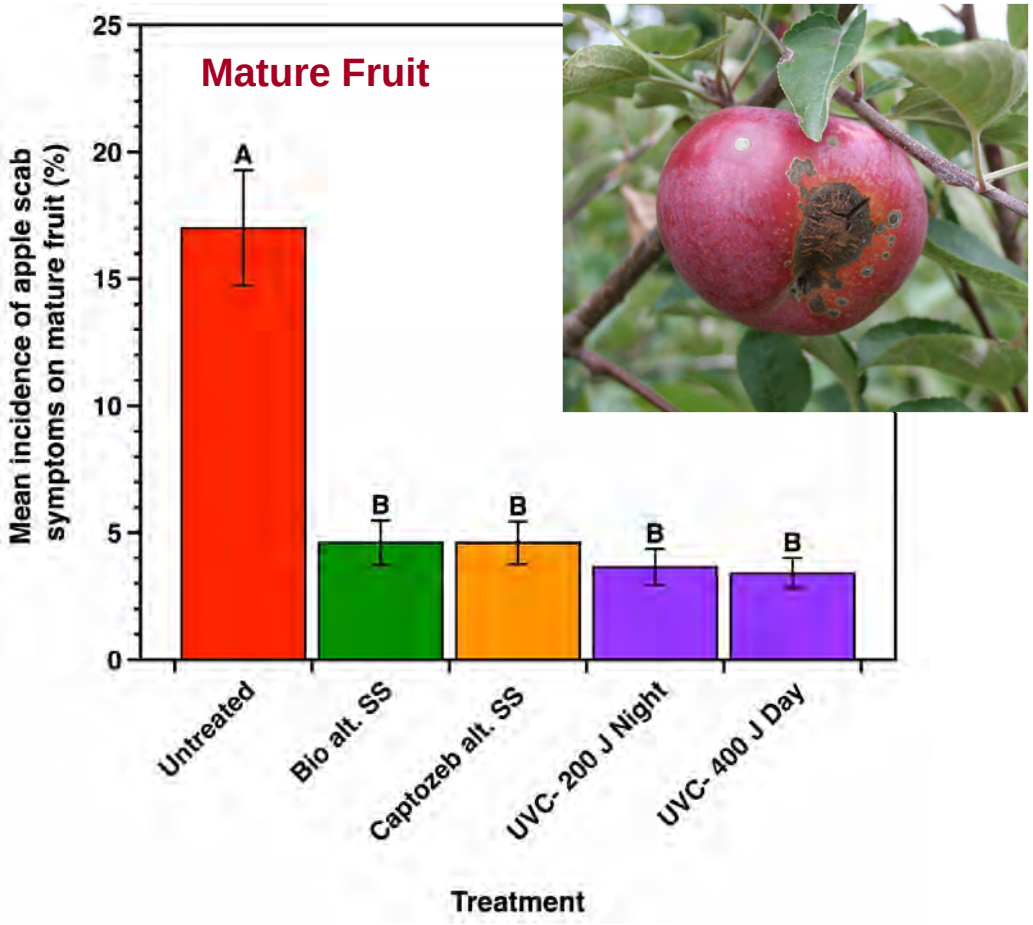


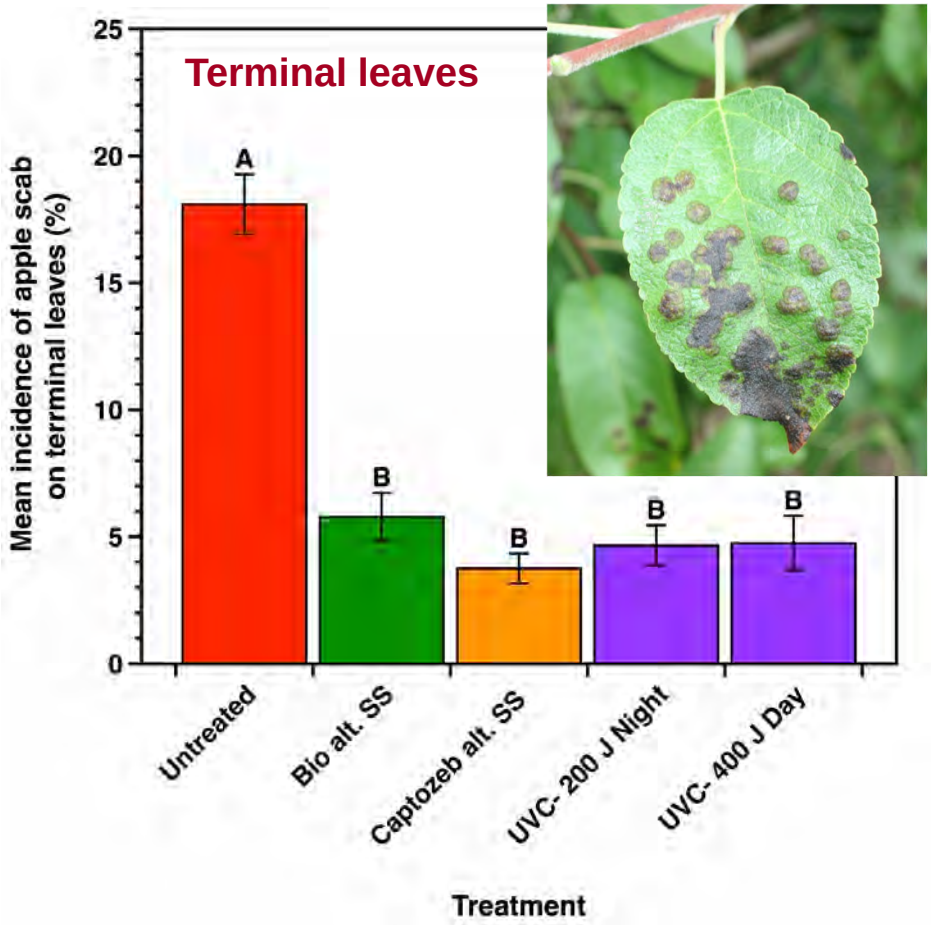
Apple Scab ‘Evercrisp’ (2023)



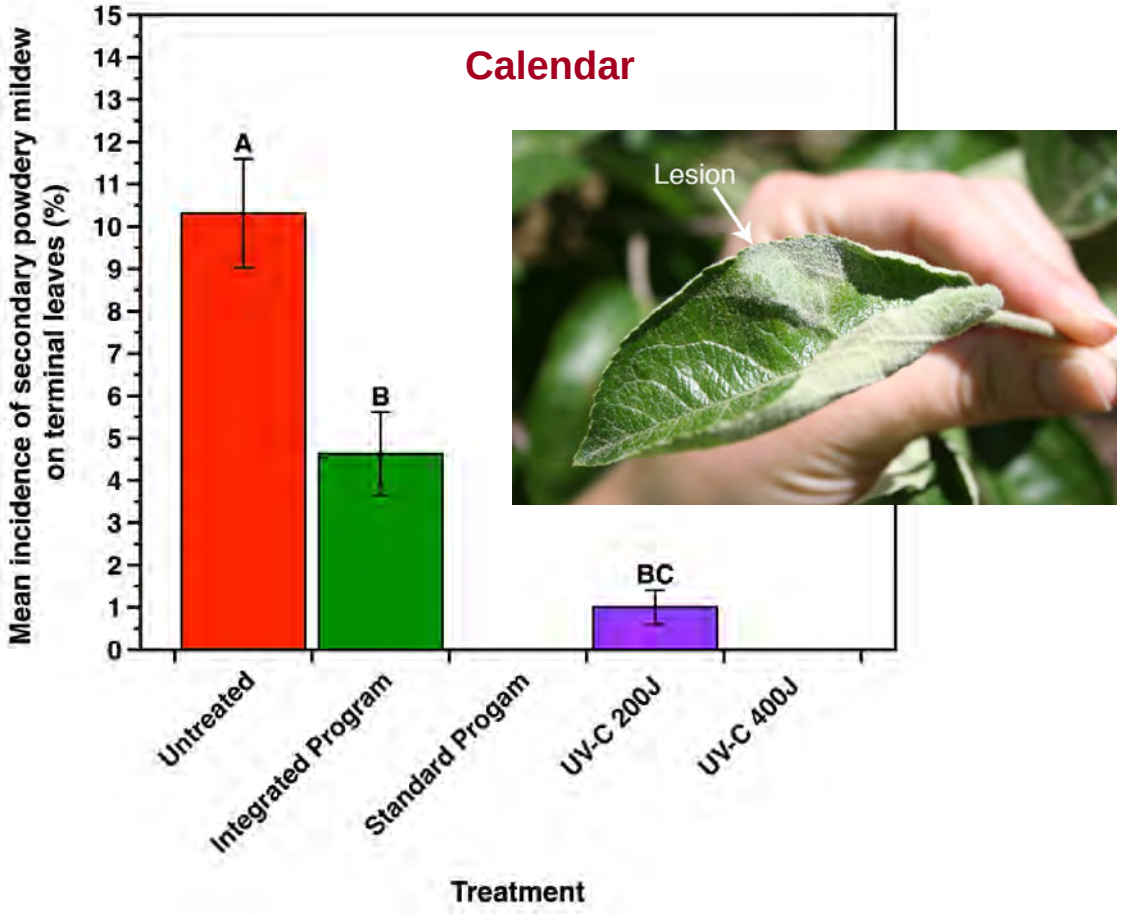


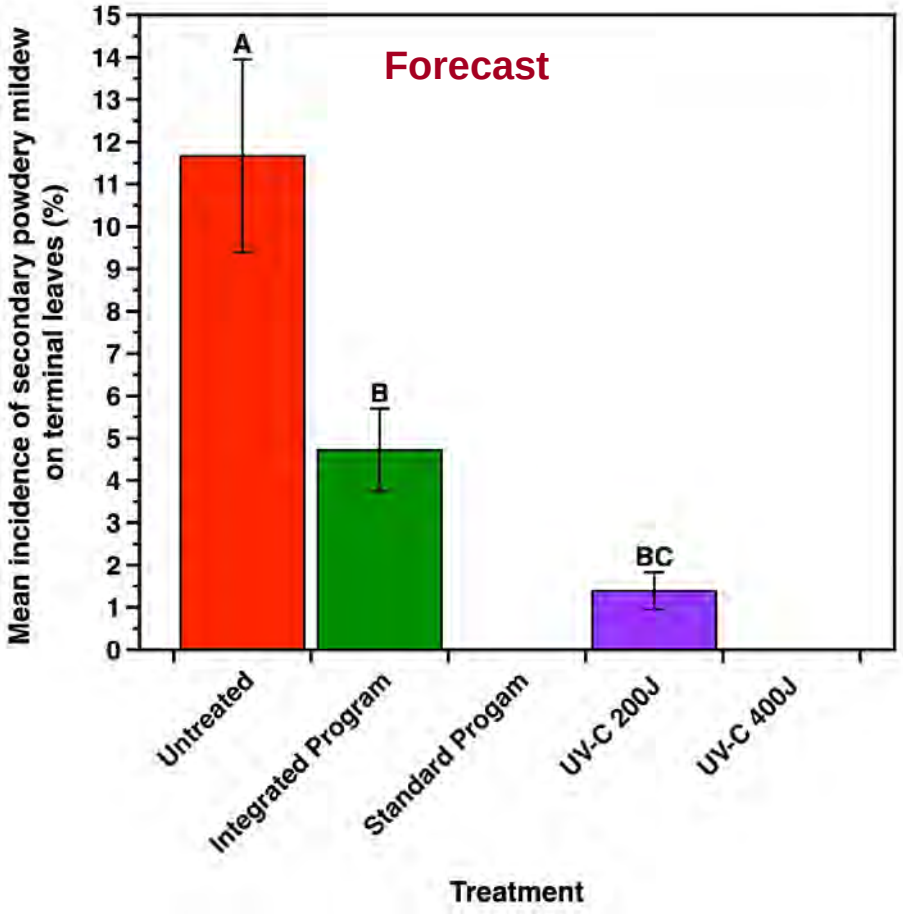
Apple Scab ‘Evercrisp’ (2024)



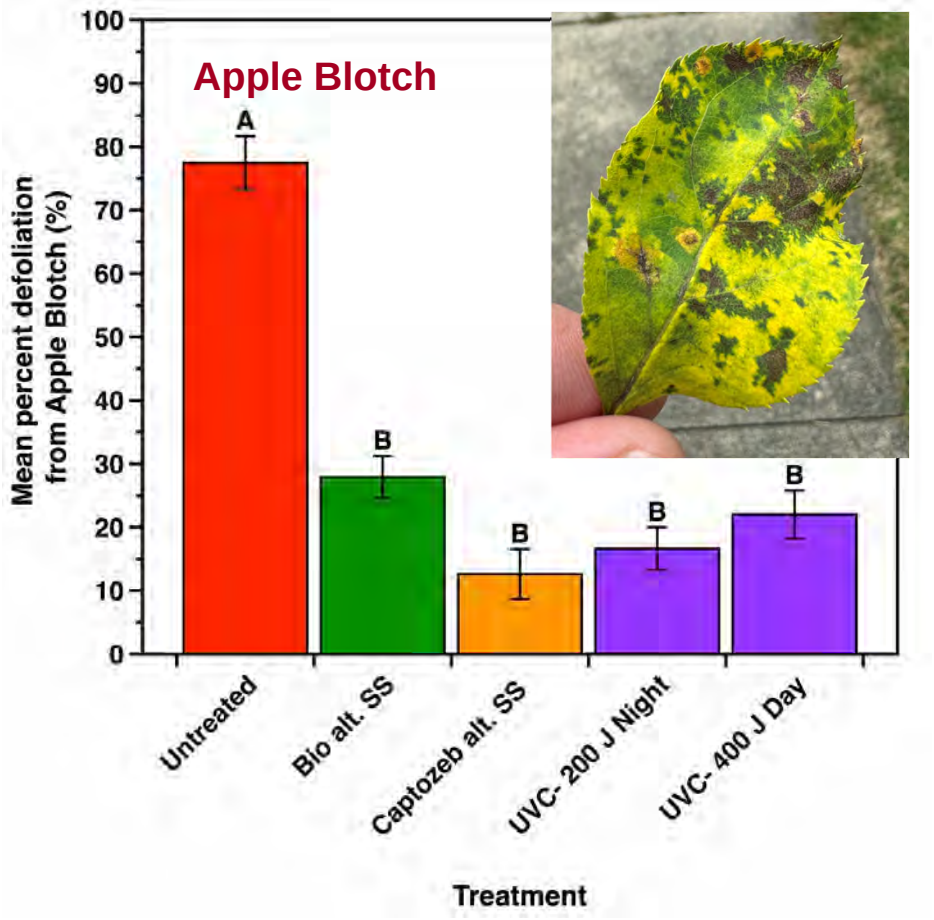


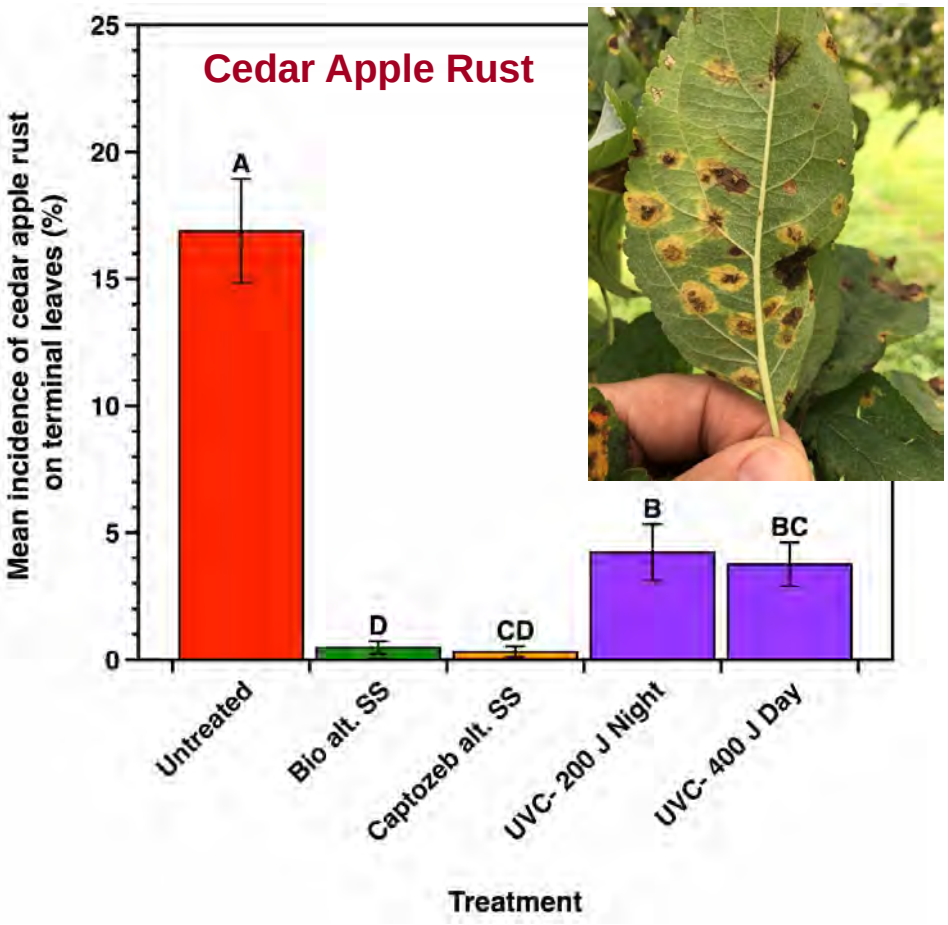
Terminal Powdery Mildew ‘Evercrisp’ (2023)





Apple Blotch & Cedar Apple Rust ‘Evercrisp’ (2024)





Summary: Apple Scab

- **2023: Exceptionally cold dry early spring 2nd leaf 'Evercrisp' (establishment)**
- **2024: Exceptionally cold wet spring and summer (high pressure)**
- High-density planting: excellent aeration
- No difference between calendar or forecast timing in 2023

Summary: Powdery Mildew, CAR, & Apple Blotch

- Powdery mildew: 2023 cold dry early spring & 2024 cold wet spring and summer (no mildew on ‘Evercrisp’)
- Cedar apple rust; low pressure > some control
- Apple Blotch High pressure > excellent control

UVC summary and takeaways

- Nightly time UVC was effective at for apple scab and mildew 200 J/m^2 : low inoculum, dry season, establishment years
- UVC 400 or higher J/m^2 may allow for daytime applications
- No appreciable difference between calendar and forecast timing, but for forecast timing less risky
- No impacts on tree vigor or fruit quality even after 16 applications

How do we move forward

- Consistent performance from a design apple growers can use
- We may need a covered system, but these are incompatible with modern plantings – fruiting wall
- At least 3 years of data, on orchards > 3rd leaf, warmer production regions

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