Meeting the Challenges of Losing Mancozeb and Captan: Past and Present and Future Research

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Reasons for regulatory changes on multi-site fungicide use

- Reduce soil microbial activity
- Reproductive & developmental toxicity mammals
- Probable human carcinogen (EPA 2005)
- Captan synergistic toxicity w/ insecticides on pollinators:
  - *Scientific Reports* **volume 14**,Article number: 15709 (2024)
  - EU high risk off target impacts to birds, mammals, aquatic organisms, bees and insects

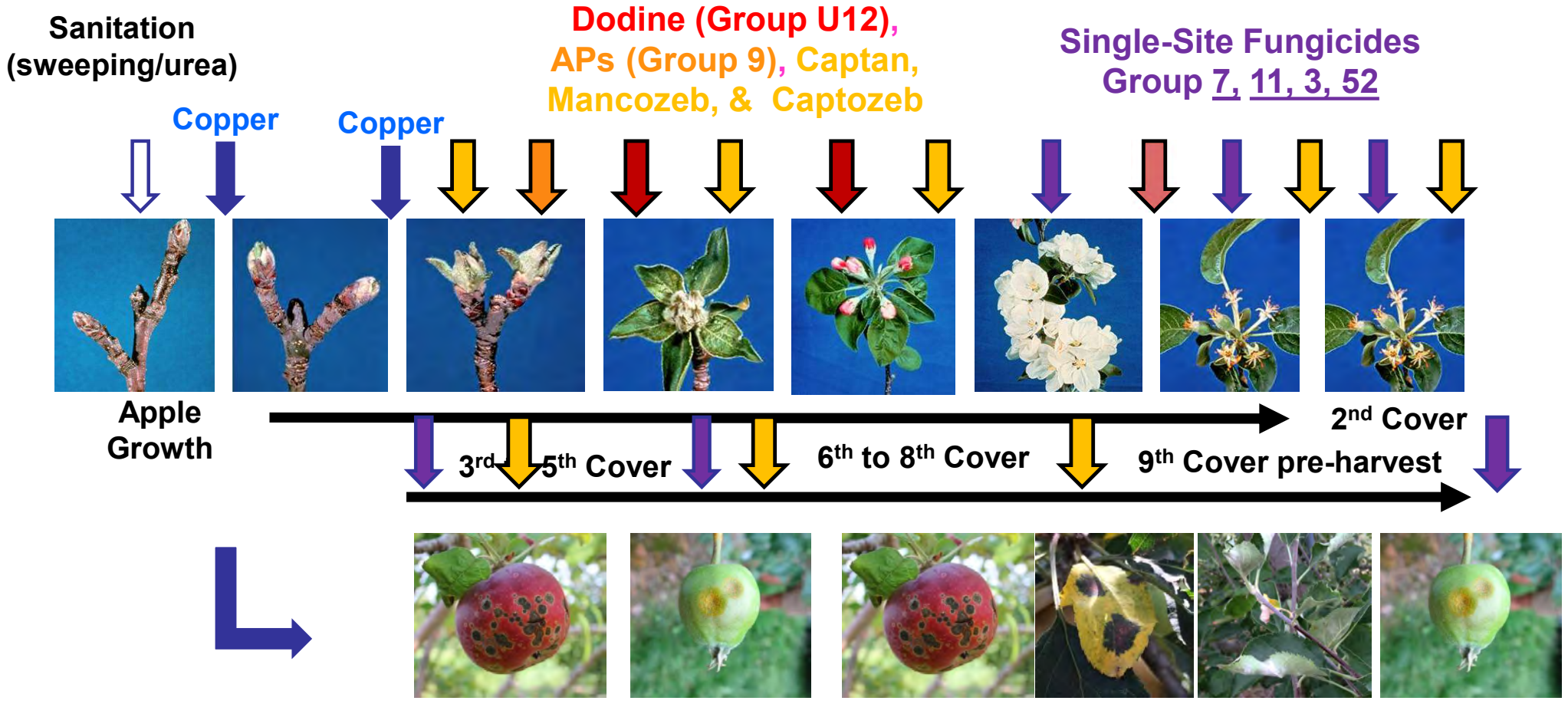
Regulatory changes for multi-site fungicide use

- 2018 Canada – removal of Metiram – subsequent captan use restrictions
- 2020 EU – removal of Mancozeb by July 2021
- 2023 – US EPA proposes cancelation of Ziram, Thiram and Ferbam
- 2024 – US EPA Captan Registration Review Decision (July) – Mancozeb Registration Review (Oct)

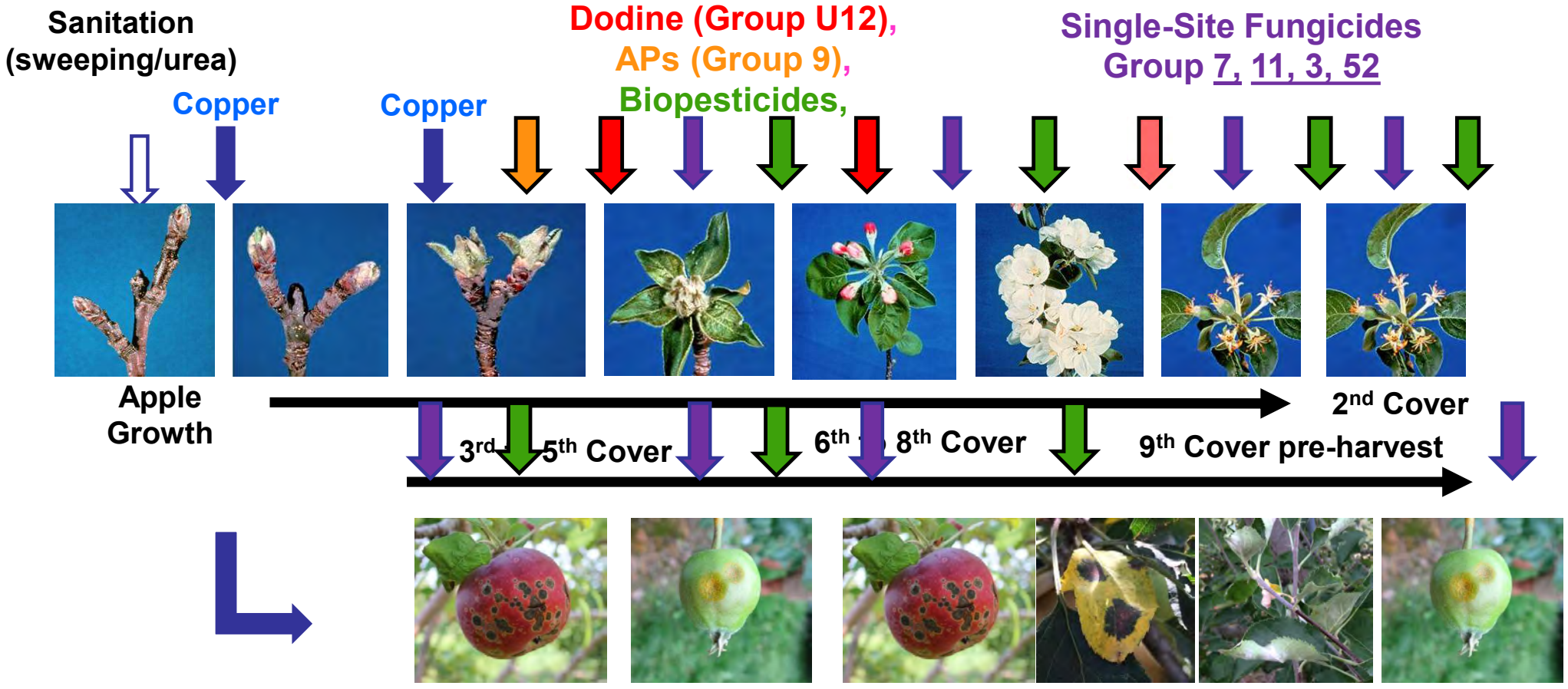
Regulatory changes for multi-site fungicide use

- 2025 – US EPA Mancozeb use restrictions in apple?
  - Aug 2024: Pesticide Registration Review: Proposed Decisions for Several Pesticides (Mancozeb and Malathion)
  - Nov 2024: Presented to EPA for an hour: PPE to allow hand thinning with mancozeb
  - Jan 2025 "We are currently reviewing public comments on the PID and plan to release an interim decision (ID) in late 2025 at the earliest.“ - Ben Tweed from EPA

2025: Fungal Disease Management Overview



2026: Fungal Disease Management Overview



2026 Full Season Disease Management

- Fall or Prior Spring: Urea application (40lbs/100) or Dolomitic lime (2.5 tons/Acre)
- Silver Tip: Delayed Dormant Copper (15% MCE)
- GT to HIG: Copper (15% MCE) (should be safe)
  - If > 15% ascospore ejection or 5 days of rain, use AP (Scala – Vanguard) or Dodine (Syllit FL)
  - These work well on apple scab, but not the other diseases that occur later

2026 Full Season Disease Management

- TC to Bloom:
  - If > 15% ascospore ejection or 5 days of rain, use AP (Scala – Vanguard) or Dodine (Syllit FL)
  - These work well on apple scab, but not the other diseases that occur later
  - If< 15% ascospore ejection or no rain. Use a biopesticide; liquid formulation products are easier to use (ex. Stargus, EcoSwing, Double Nickel LC)

2026 Full Season Disease Management

- PF to 2nd cover:
  - If > 15% ascospore ejection or 5 days or 1.5 inches of rain, use single site fungicide rotate groups: 7, 11, 3, 52 (Ex. Miravis, Flint Extra, Cevya, Axios)
  - Great on apple scab, powdery mildew, cedar apple rust
  - Key timings for managing Apple Blotch (*Diplocarpon an. Marssonina*) & initial inoculum for flyspeck sooty blotch and rots

Late Season Disease Management

- 3-5th cover:
  - 5 days or 1.5 inches of rain: apply a single-site fungicide SDHI/QOI//DMI/ should arrest Apple Blotch (*Diplocarpon an. Marssonina*) preventing it from defoliating pre-harvest
  - Less than 5 days or 1.5 inches of rain: captan 80 2.5 lb rate + Phos acid (low rate) Use a biopesticide; liquid formulation products are easier to use (ex. Stargus, EcoSwing, Double Nickel LC): **OSO (polyoxin D zinc) or Howler**

Late Season Disease Management

- 6-8th cover:
  - 5 days or 1.5 inches of rain: **OSO (polyoxin D zinc) or Howler: (*Pseudomonas chlororaphis* strain AFS009 > pyrrolnitrin (PRN) - chemical analogue of phenylpyrrole fludioxonil – a.i. in Scholar)**
  - Less than 5 days or 1.5 inches of rain: captan 80 2.5 lb rate + Phos acid (low rate) Use a biopesticide; liquid formulation products are easier to use (ex. Stargus, EcoSwing, Double Nickel LC)

Late Season Disease Management

- Final pre-harvest cover:
  - Finish Strong with low PHI single-site fungicide SDHI/QOI//DMI/ Merivon or Cevya (0) or Luna Sensation/Inspire Super (14)
  - Beneficial in reducing post harvest diseases down in storage – better color & firmness

Integrating biopesticide & single-site fungicides

Biopesticides, minimum-risk, & GRAS fungicides

- Naturally occurring/derived pesticidal substances: plant extracts, minerals, microcorganisms (or their products), & Plant-Incorporated Protectants (PIPs transgenes)
- Vary in type, cost, & efficacy | Low risk for resistance
- EPA list of biopesticides
- FDA Generally Recognized as Safe (GRAS) – food additives
- EPA minimum risk pesticides
  - FIFRA 25(b) exempted inert ingredients

Modes of action for biopesticides in fruit




Modes of Action:

Antibiotic Metabolites
Kill microbes by producing metabolites

Competitive Inhibition
Compete for niche on plant surface (flowers usually)

Defense inducers
Slow infection/invasion microbes by Boosting plant defense

Summary for biopesticides in fruit

- **Most Biologicals are protectants/eradicants:** will protect against new infections or eradicate pathogens on surface (limited persistence)
  - Double Nickel, Serenade, Serifel, Taegro, Blossom protect, Fracture, **Sytlet oil, Various Essential oils**, Polyoxin D
- **Defense inducers (ISR/SAR) +:** work internally to turn on plant defenses, natural defense inducers:
  - Actigard, Lifegard, Regalia, Employ (harpin) Vacciplant, **Apogee (Plant Growth Regulators)**

Succeeding with biopesticides

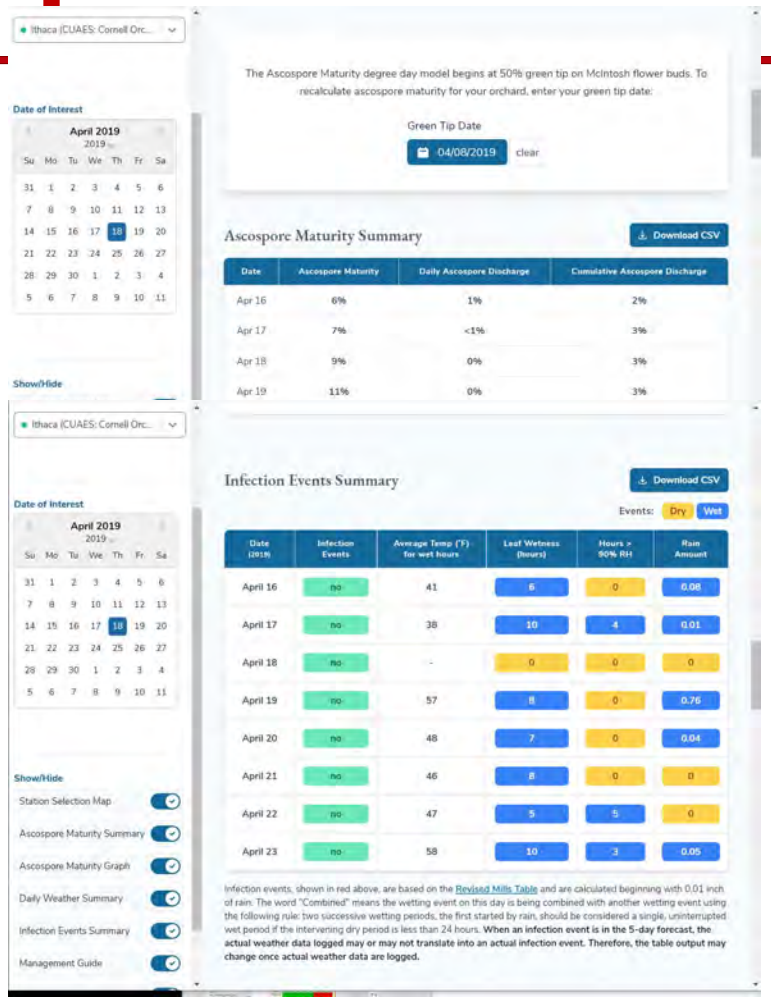
- **Implement the best horticultural practices**: high-density plantings are better for color, yield per acre, agrichemical applications, drying time & air circulation for disease protection

Tall spindle semi-dwarf 300/A

Tall spindle HD dwarf 1200/A

Succeeding with biopesticides

- **Use disease forecasting tools** – predict conditions pathogen maturity, dispersal, and infection
- Climate change > leading to erratic weather
- Increase precision and effectiveness of management applications over calendar schedule (erratic weather)
- DSS https://newa.cornell.edu/
- Local and satellite weather data: w/LW algorithms for satellite data



Could we use biopesticides and single-site fungicides in place of multi-sites?

- Increased regulatory, consumer, & market interest for fruit produced w/out multi-site fungicides & w/ biopesticides
- Published this study in apple (funded by NY apple growers): https://doi.org/10.1094/PDIS-02-21-0426-RE
- Multi-site mode of action of biopesticides could fill the role of resistance management for single-site fungicides

Could we use biopesticides and single-site fungicides in place of multi-sites?

Synthetic Multi-site Fungicides

- Effective (in large quantities)
- Fungicide resistance management

Multi-Site Biopesticides

- Environmentally sustainable
- Less effective under high disease pressure

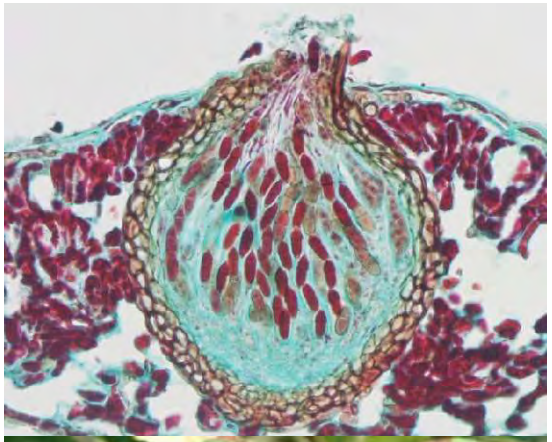
Single-site fungicides

- Highly effective
- Risk of resistance development

Captan and Mancozeb residue on leaves

Considerations for Apple Scab

- Apple scab overwinters and initiates infections from ascospores ejected from leaf litter > secondary infections produce conidia
- Spread is local & management is site-specific: High input system (10+ fungicide applications/year)
- Recent years: warmer winters (low snow cover) and springs > combined with intermittent dry periods in spring and early summer greatly impact apple scab epidemics



Use planting system to increase chance of success

I. Modern planting systems

Vertical Axis

Super Spindle

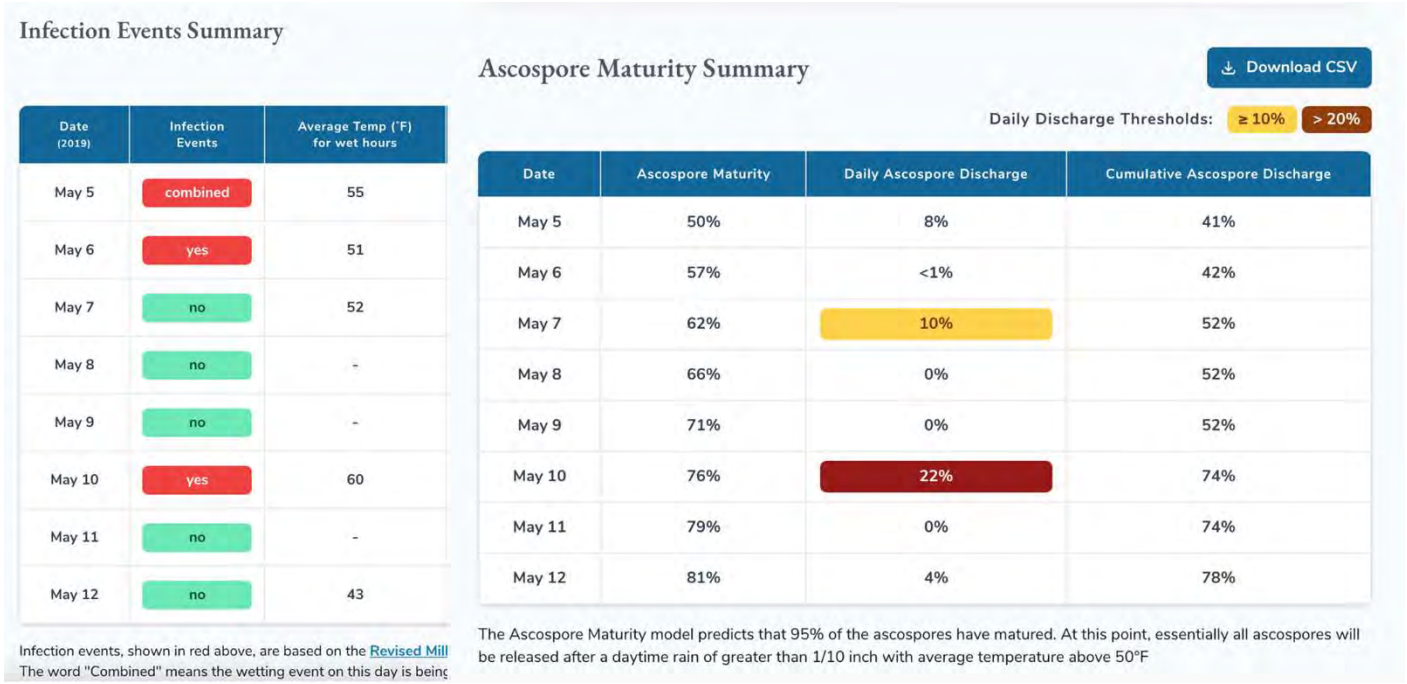
Super Spindle

- **Smaller trees**
- **Better fungicide coverage**
- **Faster drying time**
- **Less humid microclimate**
- **Less conducive to development of apple scab**

Use disease forecasting to increase chance of success

I. Modern planting systems

II. Using Decision Support Systems (DSS)



Infection Events Summary

Date (2019)	Infection Events	Average Temp (°F) for wet hours
May 5	combined	55
May 6	yes	51
May 7	no	52
May 8	no	-
May 9	no	-
May 10	yes	60
May 11	no	-
May 12	no	43

Infection events, shown in red above, are based on the Revised Mill
The word "Combined" means the wetting event on this day is being

Ascospore Maturity Summary

Download CSV

Daily Discharge Thresholds: ≥ 10% > 20%

Date	Ascospore Maturity	Daily Ascospore Discharge	Cumulative Ascospore Discharge
May 5	50%	8%	41%
May 6	57%	<1%	42%
May 7	62%	10%	52%
May 8	66%	0%	52%
May 9	71%	0%	52%
May 10	76%	22%	74%
May 11	79%	0%	74%
May 12	81%	4%	78%

The Ascospore Maturity model predicts that 95% of the ascospores have matured. At this point, essentially all ascospores will be released after a daytime rain of greater than 1/10 inch with average temperature above 50°F

Decision Support System

- **Aid by timing applications with to forecat infection events**
- **Infection threshold used to determine applications (15% ascospore release, >35 hours leaf wetness)**

Biopesticide Integration Field Trial at Cornell AgriTech 2019-2021

- Mature > 20 years Buckeye ’Gala’ on B.9 (VA)
  - Repeated Measures
    Randomized complete block (RCB): 4 single-tree reps
- 4-year Buckeye ’Gala’ on G.935 (SS
  - Repeated Measures
    RCB: 4 rep panels w/ five trees each

Vertical Axis

Super Spindle

Biopesticide Integration Field Trial at Cornell AgriTech 2019-2021

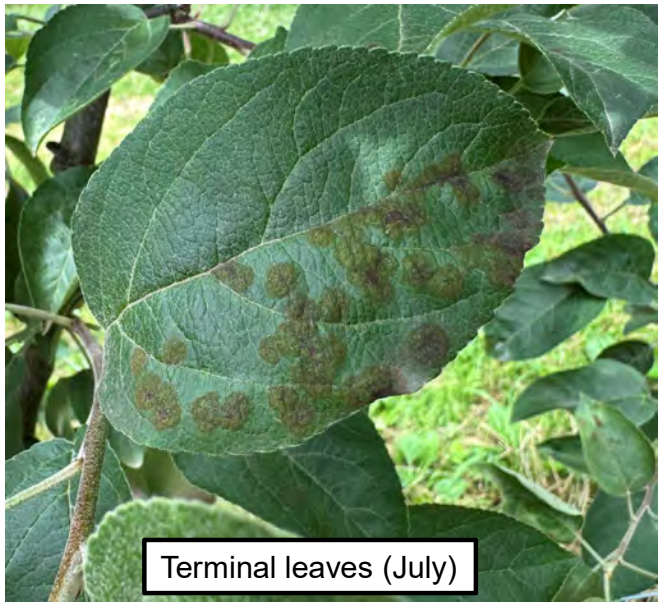
Program	Timing
Untreated Control (no fungicides)	-
Manzate Max (mancozeb) + Captec (captan) rotated biweekly with Aprovia (benzovindiflupyr)	**Calendar** timing (7-10 days)
Manzate Max + Captec rotated biweekly with Aprovia	**DSS Forecast** (15% ejection for single-site)
Serenade Opti rotated biweekly with Aprovia	**Calendar** timing (7-10 days; 8 applications)
Serenade Opti rotated biweekly with Aprovia	**DSS Forecast** (15% ejection for single-site)

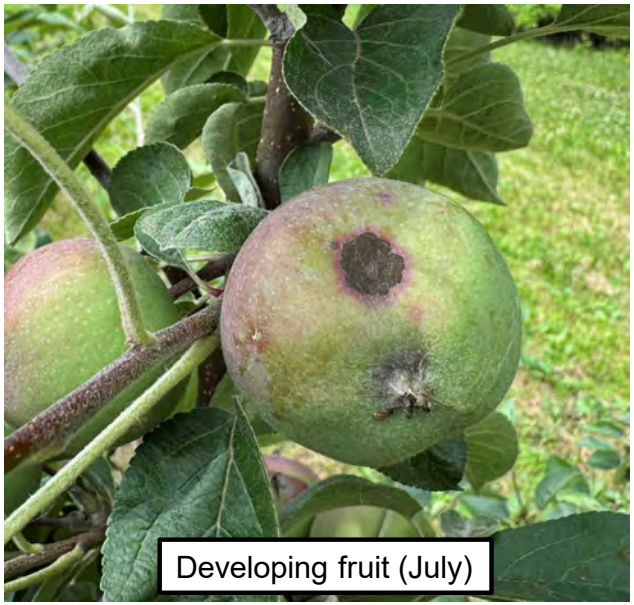
Simplified multi-site fungicide standard program

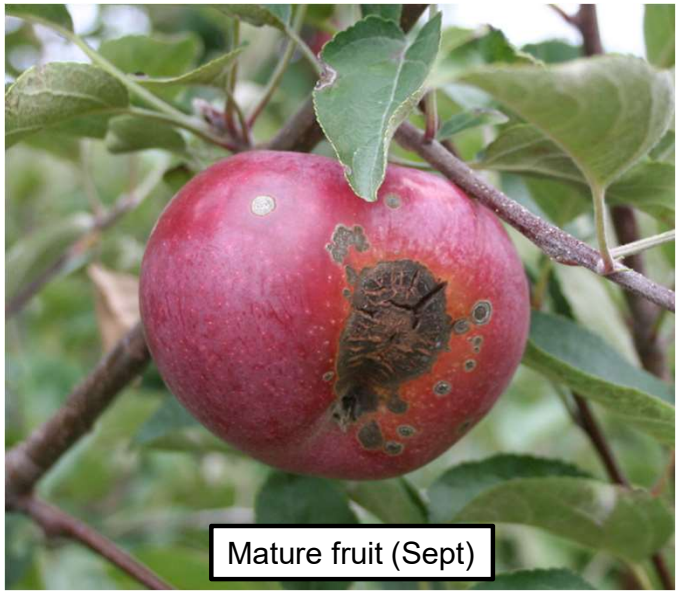
Experimental integrated biopesticide program

Apple Scab Assessment

AUDPC of Incidence (or incidence) of apple scab symptoms on terminal leaves or **fruit**


Terminal leaves (July)


Developing fruit (July)


Mature fruit (Sept)

Influence of Tree Architecture: Relative Humidity

> 90% Relative Humidity conducive to infection

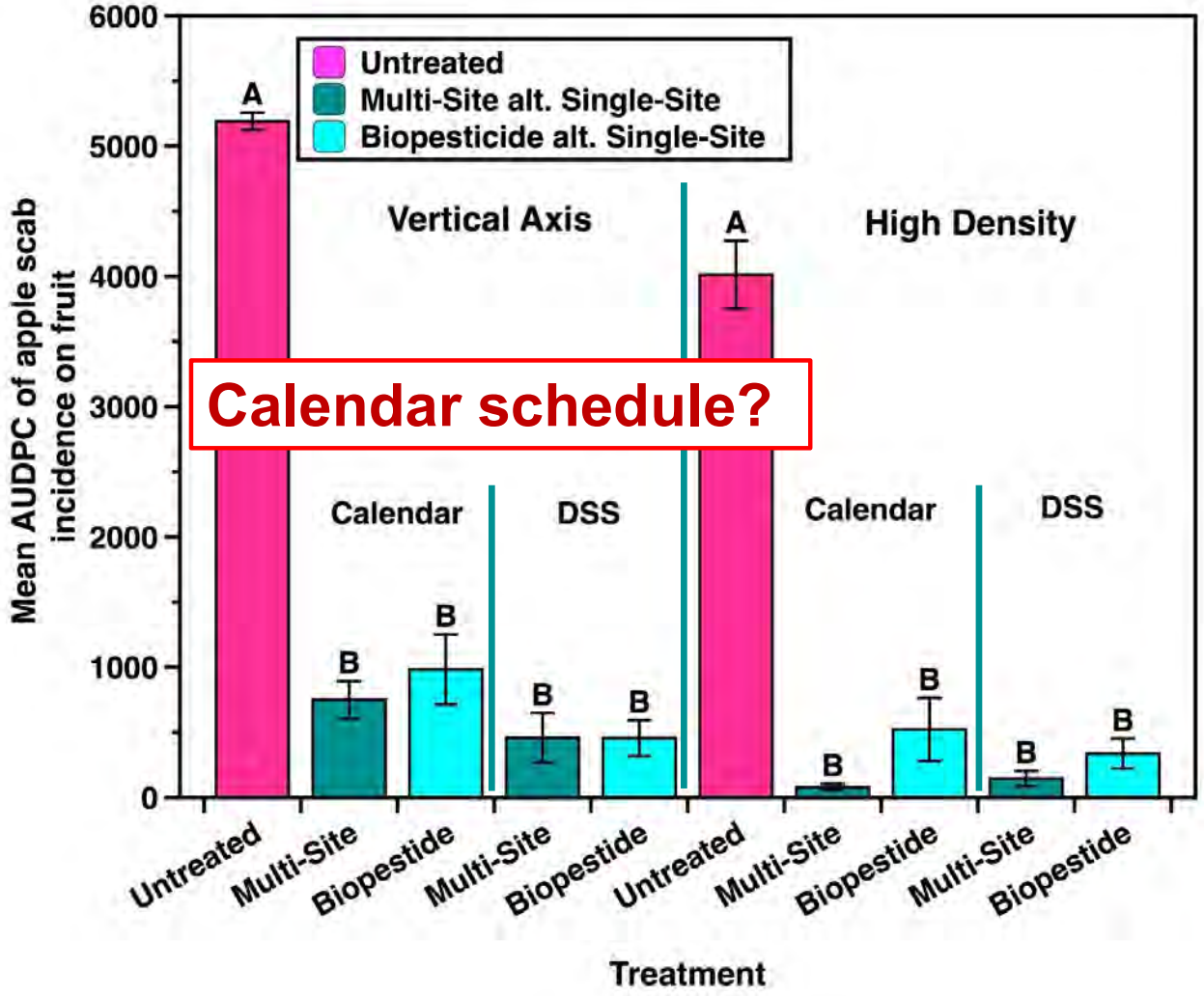
Weather sensors affixed to tree canopies Timeframe: April 1st- June 23rd

Vertical Axis

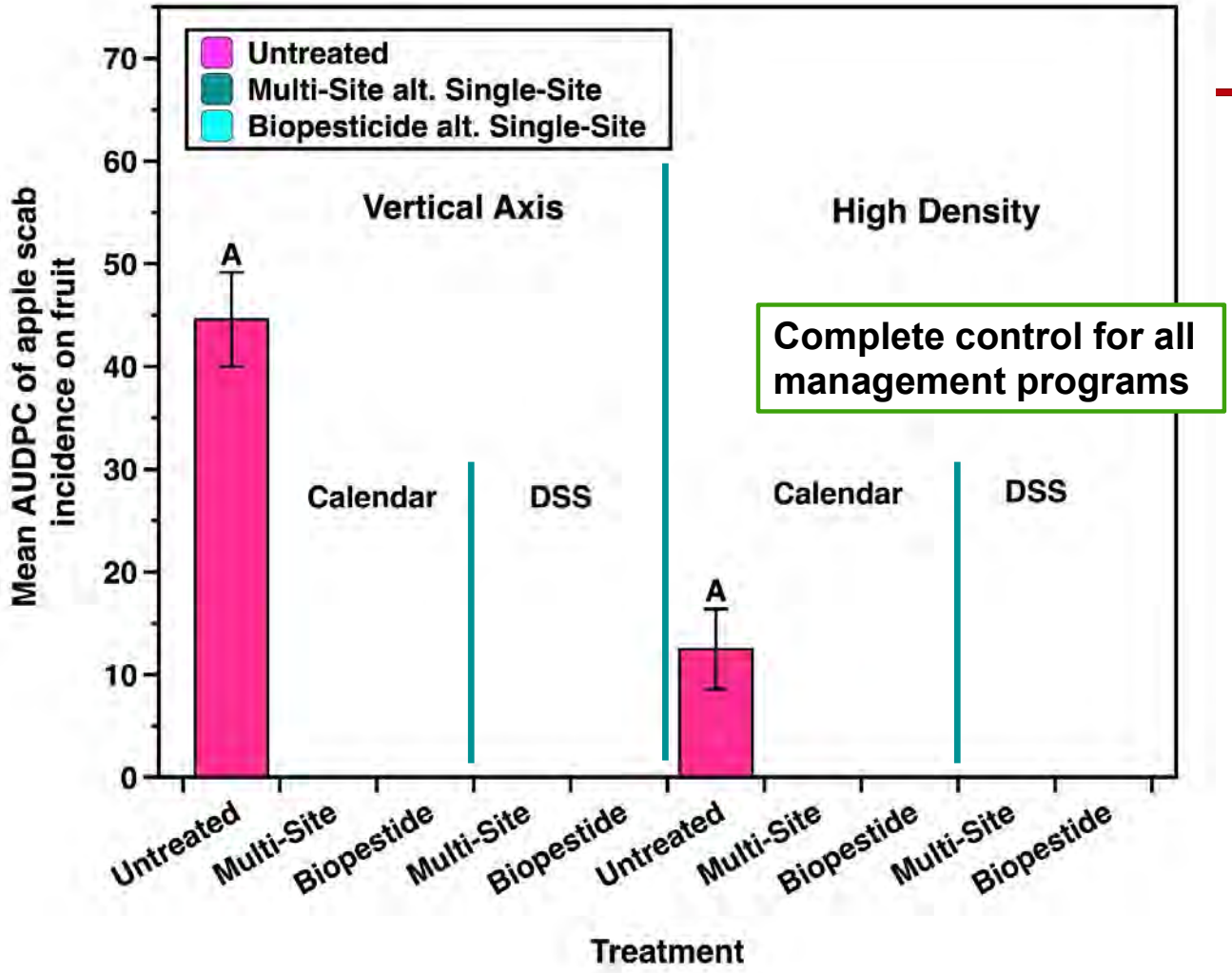
	Orchard	Mean %RH	Days over 90% mean RH
2019			
	Vertical axis	77.25% (+1.89%)	21 d (+4 days)
	Super spindle	75.36%	18 d
2020			
	vertical axis	73.96%	2 d
	super spindle	73.46%	2 d
2021			
	vertical axis	77.15% (+0.94%)	19 d (+3 days)
	super spindle	76.21%	17 d

Super Spindle

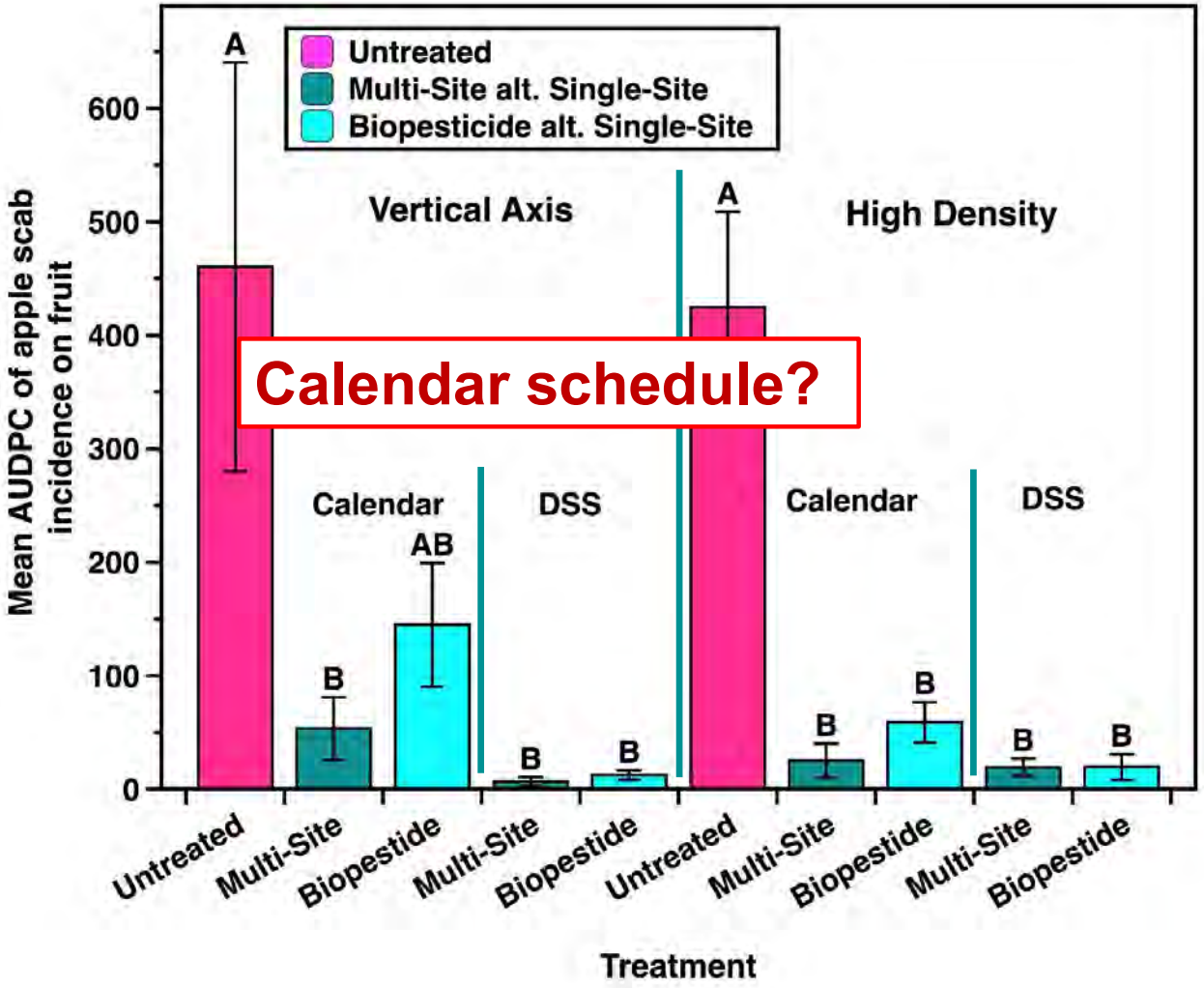
2019 Mean AUDPC of Incidence on Fruit



2020 Mean AUDPC of Incidence on Fruit

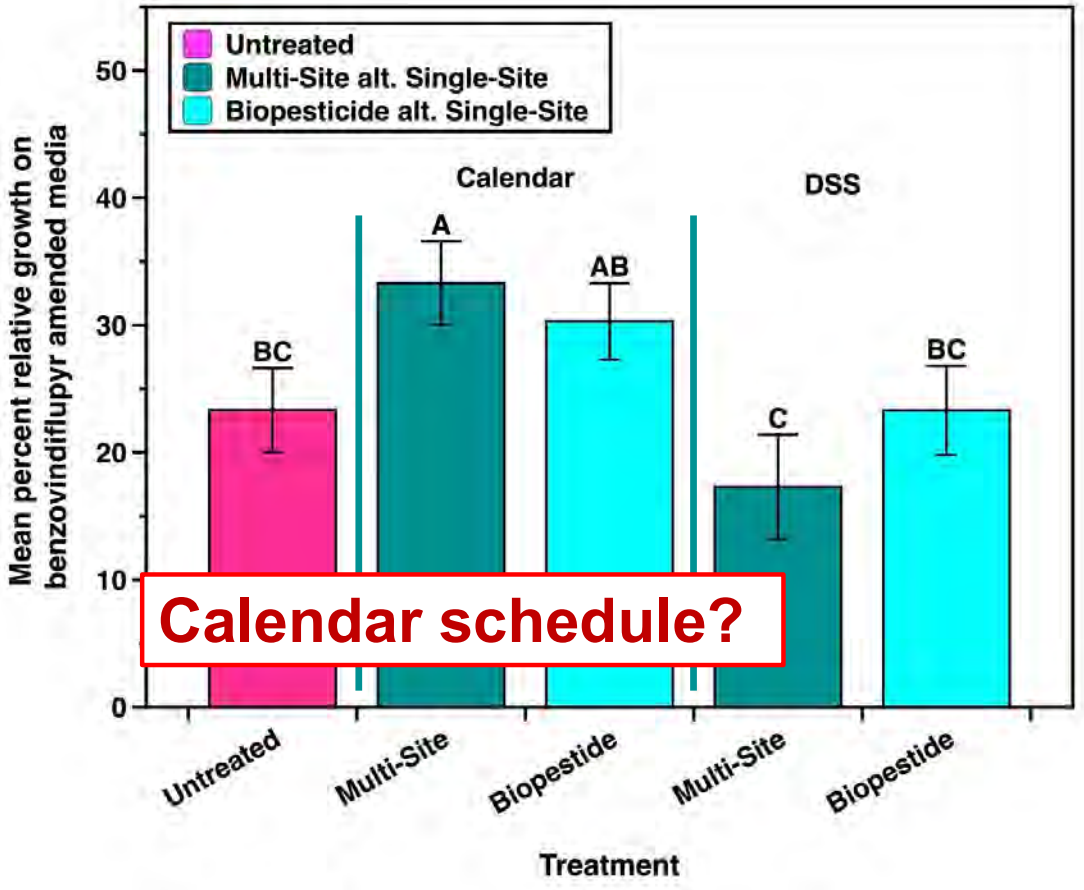


2021 Mean AUDPC of Incidence on Fruit



Selection of resistance to benzovindiflupyr

- Total of 10-30 Isolates per treatment replicate
  - Complete control limits available isolates
  - Selection not possible if population eliminated
- Relative growth assay: growth on benzovindiflupyr-amended media (10x mean baseline EC_{50} value)



Biopesticide Integration Field Trial at Cornell AgriTech 2022-2024

Program	Timing
Untreated Control (no fungicides)	-
Manzate Max (mancozeb) + Captec (captan) rotated biweekly with Aprovia (benzovindiflupyr), Flint Extra (trifloxystrobin) or Cevya (mefentrifluconazole)	**Calendar** timing (7-10 days)
Manzate Max + Captec rotated biweekly with Aprovia, Flint Extra or Cevya	**DSS Forecast** (15% ejection for single-site)
Double Nickel LC rotated biweekly with Aprovia, Flint Extra or Cevya	**Calendar** timing (7-10 days; 8 applications)
Double Nickel LC rotated biweekly with Aprovia, Flint Extra or Cevya	**DSS Forecast** (15% ejection for single-site)

Simplified multi-site fungicide standard program

Experimental integrated biopesticide program

Influence of Tree Architecture: Relative Humidity

> 90% Relative Humidity conducive to infection

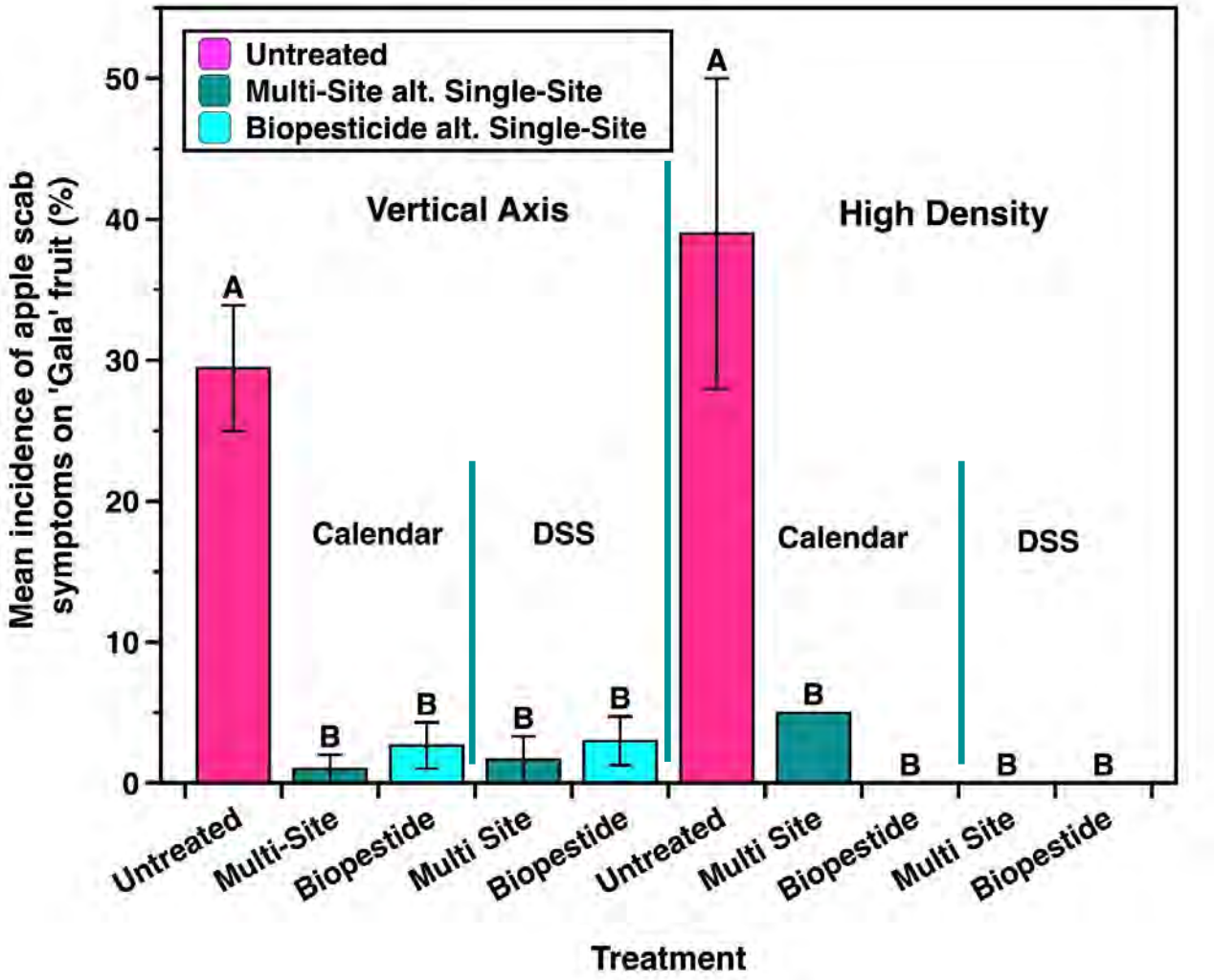
Weather sensors affixed to tree canopies Timeframe: April 12th- August 31st

Vertical Axis

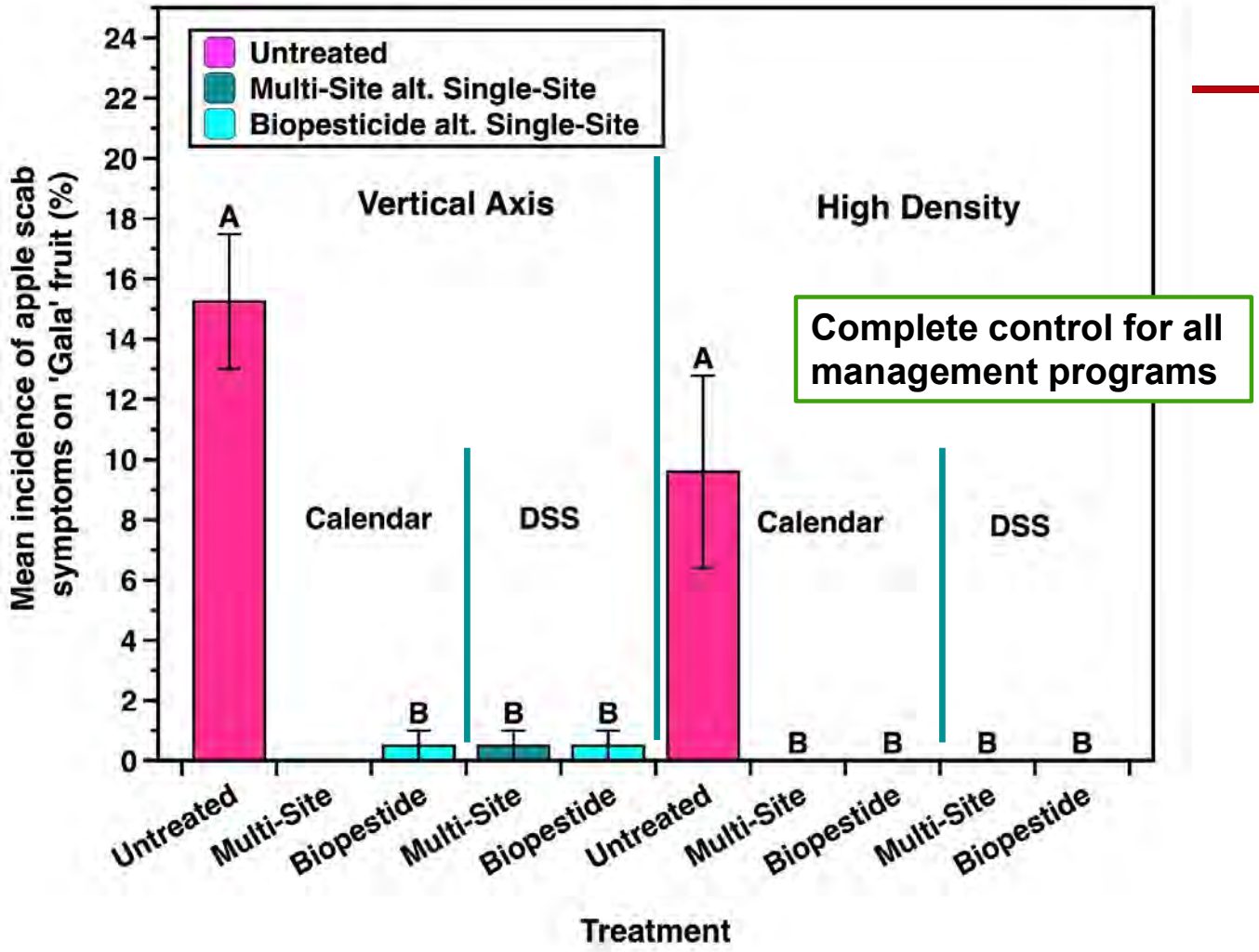
	Orchard	Mean %RH	Days over 90% mean RH
2022			
	Vertical axis	70.53%	84 d
	Super spindle	67.69%	66 d
		+2.84%	+18 days
2023			
	vertical axis	72.78%	89 d
	super spindle	68.95%	28 d
		+3.83%	+61 days
2024			
	vertical axis	77.33	119 d
	super spindle	69.79	44 d
		+7.54%	+75 days

Super Spindle

2022 Mean Incidence on Fruit

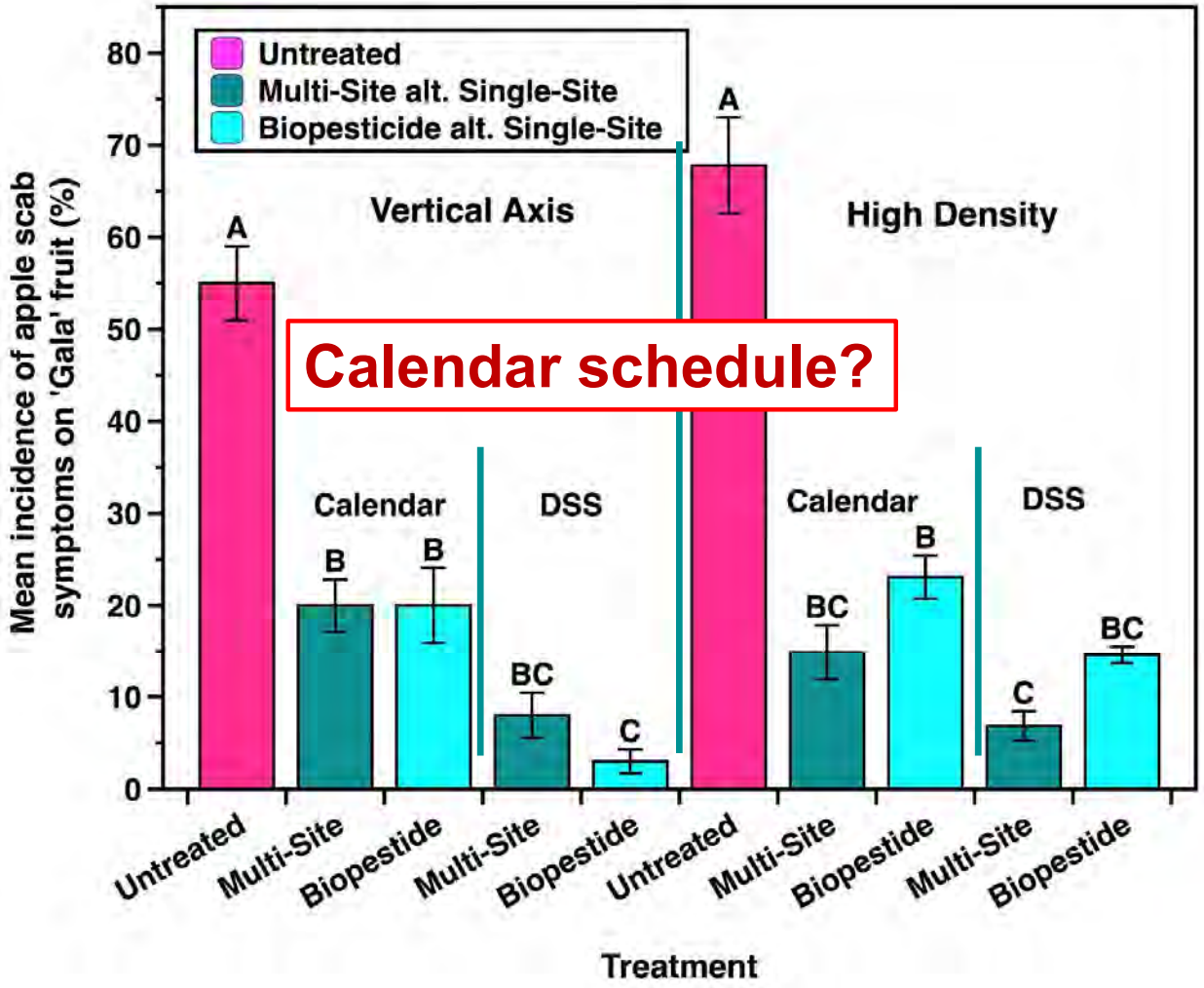


2023 Mean Incidence on Fruit



Complete control for all management programs

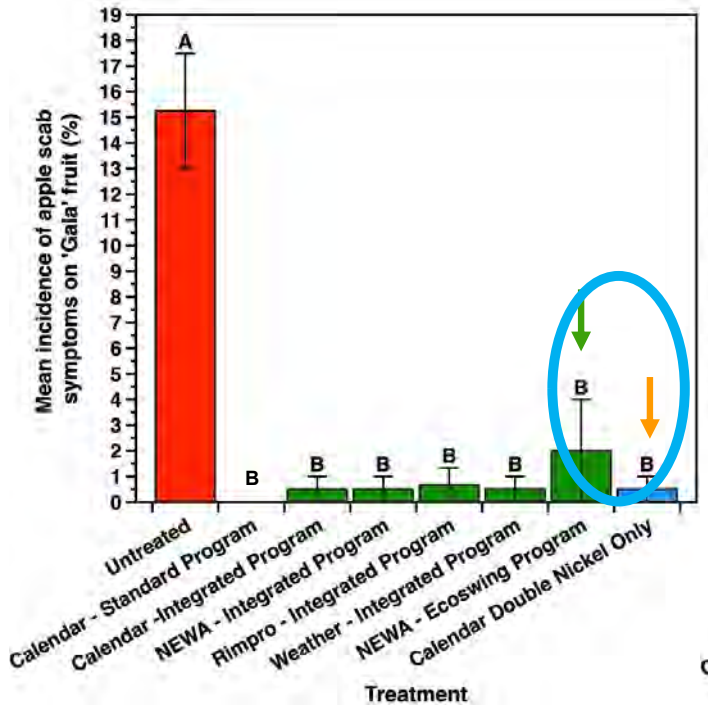
2024 Mean Incidence on Fruit



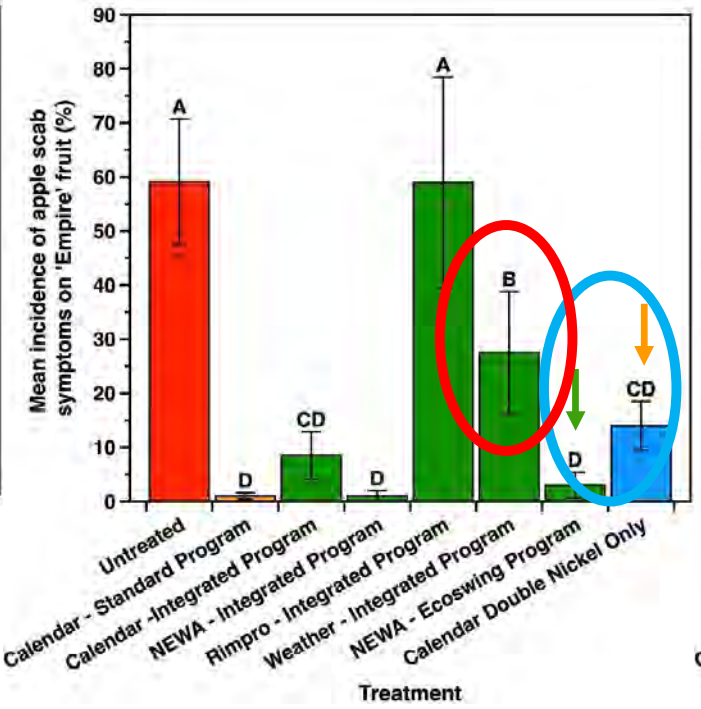
Using only biopesticides just more variable among plots/fields

2023 Mean Incidence on Fruit

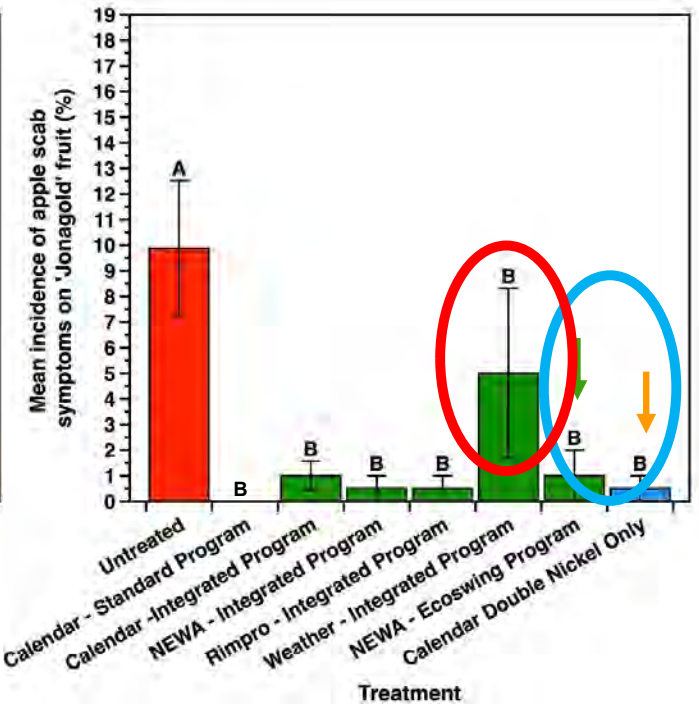
‘Gala’



‘Empire’

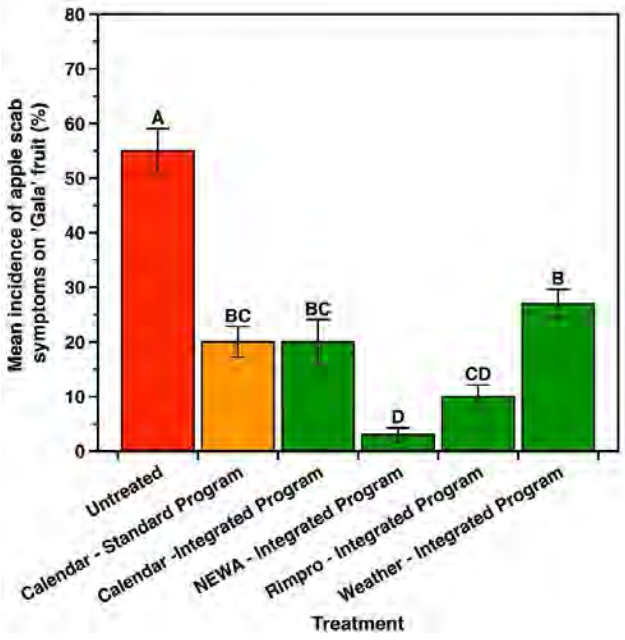


‘Jonagold’



Apple Scab Incidence on Fruit Extended Season Management 2024

‘Gala’



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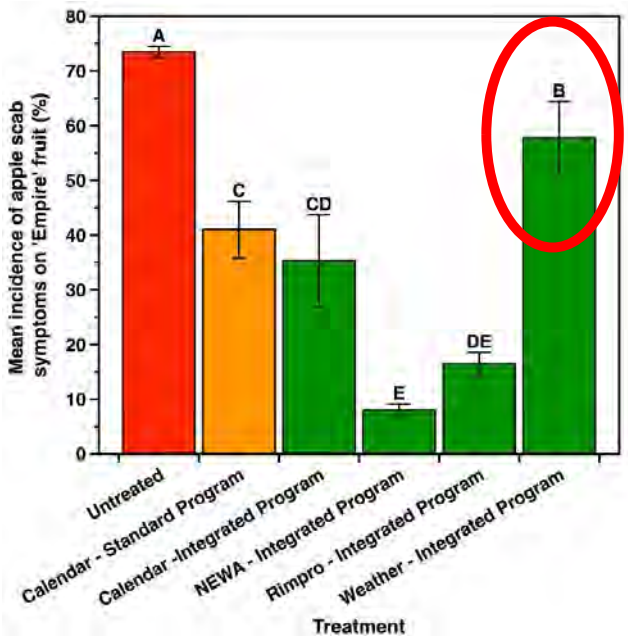

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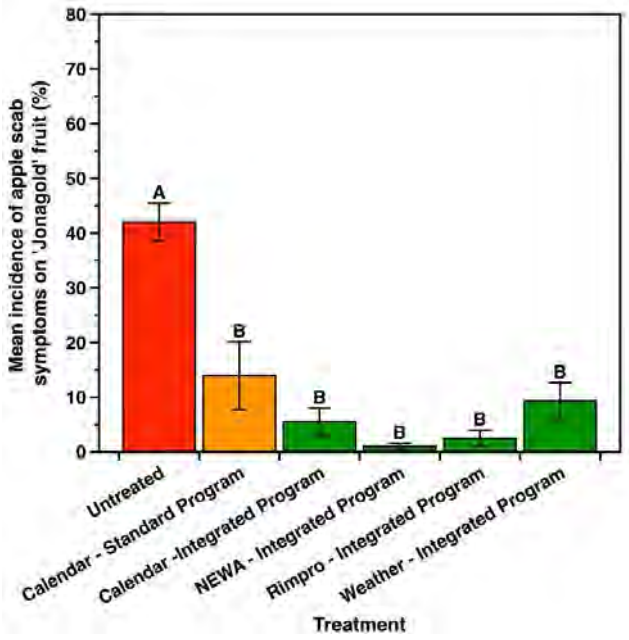


Fungicide application and Seasonal Weather Patterns 2019-2024

Year	Program	Single-Sites (Pink to 2nd)	Protectants (Pink to 2nd)	Seasonal Rain Fall (in)	Seasonal Leaf Wetness (hours)
2019	**Calendar**	**2**	**4**	**16.9**	**811**
2019	**Forecast**	**4**	**2**		
2020	Calendar	2	4	5.07	462
2020	Forecast	3	3		
2021	**Calendar**	**2**	**4**	**12.9**	**731**
2021	**Forecast**	**4**	**2**		
2022	Calendar	3	3	3.8	170
2022	Forecast	3	3		
2023	Calendar	3	3	4.76	212
2023	Forecast	3	3		
2024	**Calendar**	**3**	**3**	**15.62**	**938**
2024	**Forecast**	**4**	**2**		

- **Protectant are biopesticides (Serenade Opti or Double Nickel LC) or multisite fungicide (captan + mancozeb)**
- **In years with heavy rainfall > 12 in likely to require more single-site applications**

Summary and Takeaways

- Could use biopesticides in alternation with a strong single-site fungicide to replace multi-site fungicides in apple
- Greatest potential in systems & varieties (non-'McIntosh' relatives) less conducive to disease development (super spindle) & forecasting using a DSS
- Both the Vertical Axis & High-density planting: excellent aeration
- Low apple scab pressure (< 7 infection periods): complete control possible in high inoculum orchards

Summary and Takeaways

- In low pressure years and low risks systems: No appreciable difference between calendar and forecast timing
- NY industry: rely on biopesticides integrated with single-site fungicides once restrictions occur (e.g. Mancozeb)

Economic Considerations

- Rotational application practice doesn't mandate additional labor or applications: fewer is possible with forecasting

- Biopesticides not necessarily more expensive than single-site fungicides & high quality captan and mancozeb (premium liquid formulations) 35-40 $USD/A
  - Sulfur, bicarbonate, minerals, and oils least inexpensive
  - Fermented biological organisms and or other products in premium formulation most expensive
  - Adjuvants not often used with biopesticides

Economic Considerations

- Captan > injury on fruit w/ incompatible tank mixes, slow drying conditions, sensitive varieties
- Mixing single-site fungicides w/ biopesticides: greatly increase cost
- Biopesticides alone with increased frequency: greatly increase cost

Optimizing Disease Forecasting

Climatological Data for GENEVA RESEARCH FARM, NY - April 2023

Click column heading to sort ascending, click again to sort descending.

Date	Temperature				HDD	CDD	Precipitation
	Maximum	Minimum	Average	Departure			
2023-04-01	54	32	43.0	5.4	22	0	0.54
2023-04-02	69	24	46.5	8.4	18	0	0.05
2023-04-03	36	24	30.0	-8.5	35	0	0.00
2023-04-04	65	34	49.5	10.6	15	0	0.27
2023-04-05	53	38	45.5	6.1	19	0	T
2023-04-06	74	40	57.0	17.2	8	0	1.53
2023-04-07	58	37	47.5	7.2	17	0	0.00
2023-04-08	41	27	34.0	-6.8	31	0	0.00
2023-04-09	46	26	36.0	-5.2	29	0	0.00
2023-04-10	51	29	40.0	-1.7	25	0	0.00
2023-04-11	65	31	48.0	5.9	17	0	0.00
2023-04-12	70	50	60.0	17.4	5	0	0.00
2023-04-13	77	55	66.0	22.9	0	1	0.00
2023-04-14	83	52	67.5	23.9	0	3	0.00
2023-04-15	82	52	67.0	23.0	0	2	0.00
2023-04-16	81	51	66.0	21.5	0	1	0.00
2023-04-17	77	44	60.5	15.5	4	0	0.40
2023-04-18	54	37	45.5	0.1	19	0	0.01
2023-04-19	42	34	38.0	-7.9	27	0	T
2023-04-20	46	35	40.5	-5.9	24	0	0.00
2023-04-21	57	37	47.0	0.2	18	0	T
2023-04-22	85	50	67.5	20.2	0	3	0.18
2023-04-23	71	41	56.0	8.2	9	0	0.85
2023-04-24	48	35	41.5	-6.7	23	0	0.00
2023-04-25	48	32	40.0	-8.6	25	0	0.24
2023-04-26	48	35	41.5	-7.6	23	0	0.03
2023-04-27	51	32	41.5	-8.0	23	0	0.00
2023-04-28	57	34	45.5	-4.5	19	0	0.00
2023-04-29	58	42	50.0	-0.4	15	0	0.31
2023-04-30	54	42	48.0	-2.8	17	0	0.35
Sum	1801	1132	-	-	487	10	4.76
Average	60.0	37.7	48.9	4.7	-	-	-
Normal	53.7	34.8	44.2	-	625	3	2.76

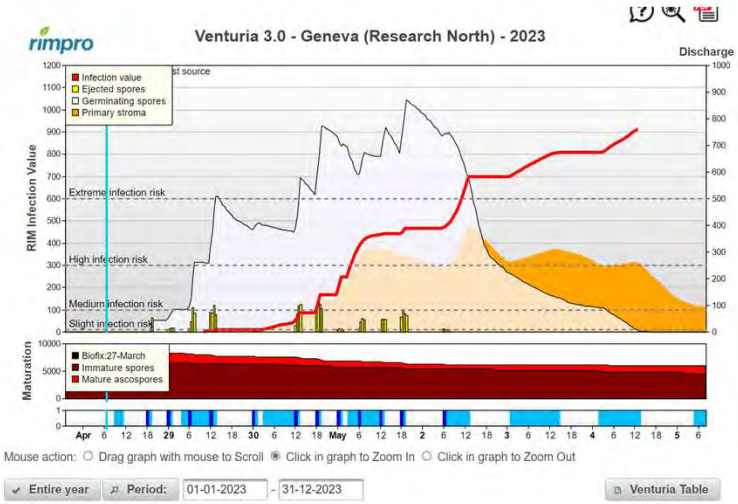
Infection Events Summary

Event:

Date (2019)	Infection Events	Ascospore Maturity	Daily Ascospore Discharge
May 5	combined	50%	8%
May 6	yes	57%	<1%
May 7	no	62%	10%
May 8	no	66%	0%
May 9	no	71%	0%
May 10	yes	76%	22%
May 11	no	79%	0%
May 12	no	81%	4%

Infection events, shown in red above, ar
The word "Combined" means the wetti

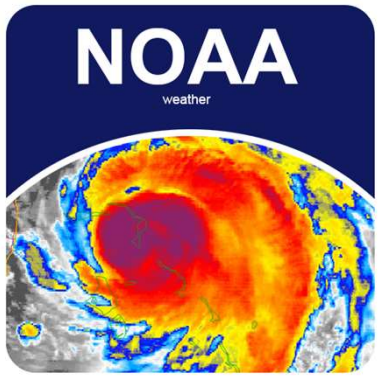
rity model predicts that 95% of the ascospores have matured. A
laytime rain of greater than 1/10 inch with average temperature



Forecasting systems differ in cost and ease of use

NYS IPM NEWA

RIMpro



NOAA Weather app

Forecasting systems differ in cost and ease of use

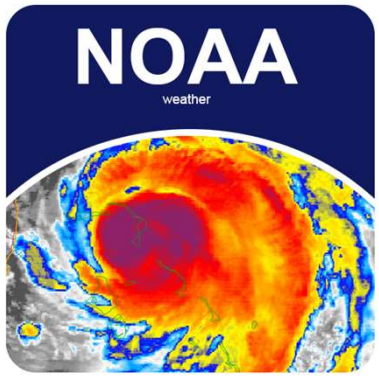
NYS IPM NEWA

- Free access
- Infection prediction
- Leaf Wetness
- Ascospore Release
- Weather data
- Relatively quick and easy to use

RIMpro

- Paid subscription service ~ € 250
- Infection prediction based on RIM value
- Primary and secondary Scab Models
- More complicated navigation and ease of use
- Uses NEWA & US Weather service data stream

NOAA Weather app



- Free
- Quick and easy to check on your phone/device
- Only weather data - rainfall

Forecasting Field Trials at Cornell AgriTech

- Mature (> 20 years) vertical axis planting
- Buckeye ’Gala’ on B.9
- ’Empire’ and ’Jonagold’ on M.9/M.111 interstems
- Randomized complete block (RCB): 4 single-tree reps

Buckeye ’Gala’ on B.9

’Jonagold’ on M.9/M.111 interstem

Forecasting Field Trial at Cornell AgriTech 2022-2023

Program	Timing
Untreated Control (no fungicides)	-
Manzate Max + Captec rotated biweekly with Aprovia, Flint Extra or Cevya	Calendar timing (7-10 days)
Double Nickel LC rotated biweekly with Aprovia, Flint Extra or Cevya	Calendar timing (7-10 days)
Double Nickel LC rotated biweekly with Aprovia, Flint Extra or Cevya	NEWA
Double Nickel LC rotated biweekly with Aprovia, Flint Extra or Cevya	RIMpro
Double Nickel LC rotated biweekly with Aprovia, Flint Extra or Cevya	Weather services

Simplified conventional standard program

Experimental Biopesticide programs

Single Site Application Threshold

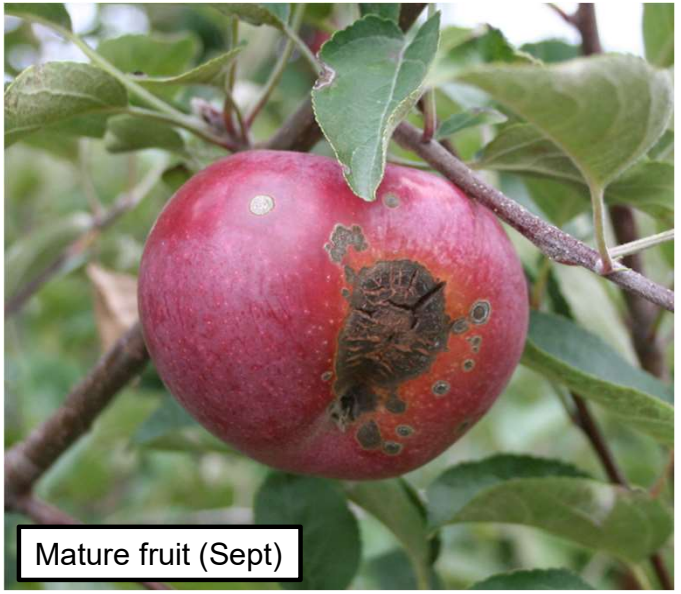
Timing	Application threshold for single-site fungicides
-	Untreated Control (no fungicides)
Calendar timing (7-10 days)	**None** – single-site fungicides will be rotated with biopesticides irrespective of the weather predictions.
NEWA	Single-site fungicides applied before an event where more than **15% ascospore ejection** is forecast, or when more than **1.5" in of rain** is predicted or has occurred in the last 7 days
RIMpro	Single-site fungicides applied before an event where a **RIM value greater than 300**, or when more than **1.5" in of rain** is predicted or has occurred in the last 7 days
Weather app	Single-site fungicides applied when more than **1.5" in of rain** is predicted or has occurred in the last 7 days

Apple Scab Assessment

Incidence of apple scab on terminal leaves (July), & or **fruit (Sept) with a lesion**

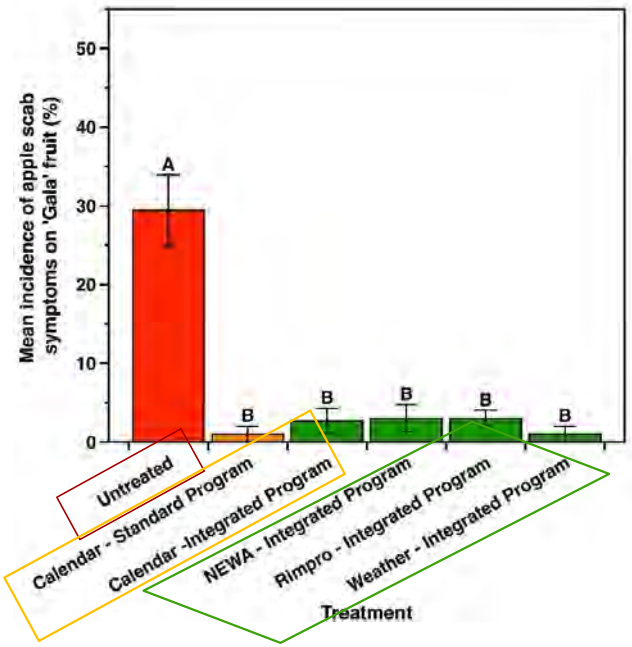
- 10 shoots per tree
- 10 clusters of (5) fruit per tree


Terminal leaves (July)

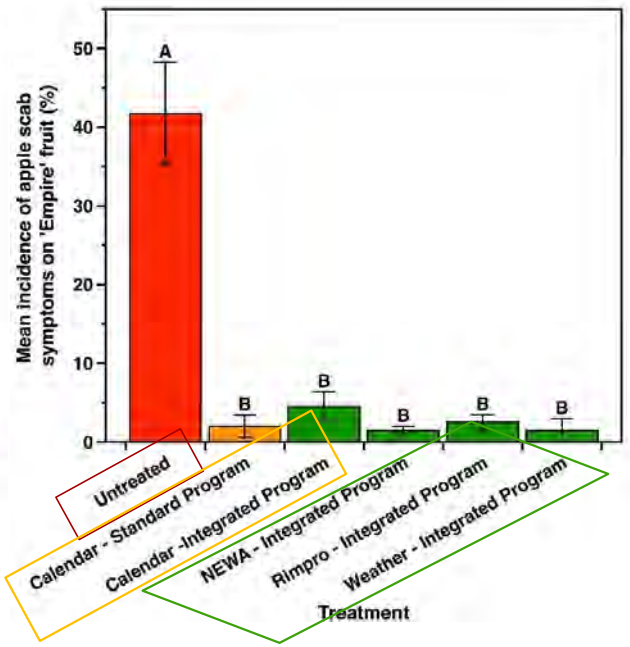

Mature fruit (Sept)

Forecasting Field Trial at Cornell AgriTech 2022

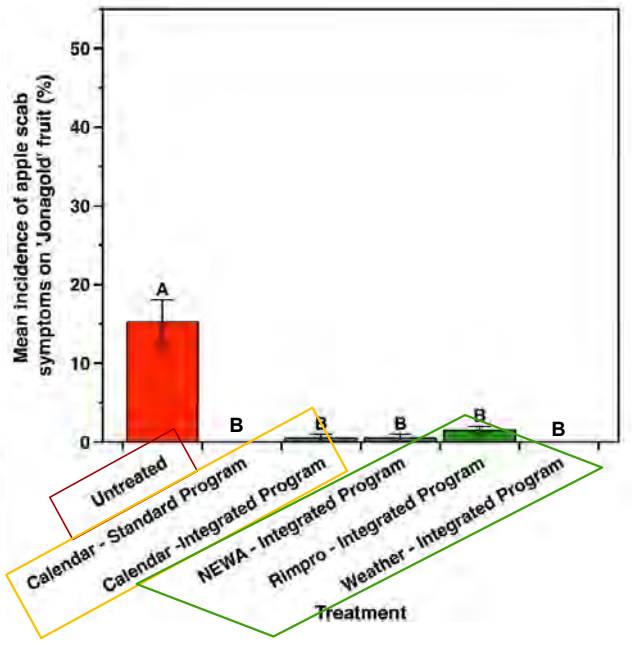
‘Gala’



‘Empire’



‘Jonagold’



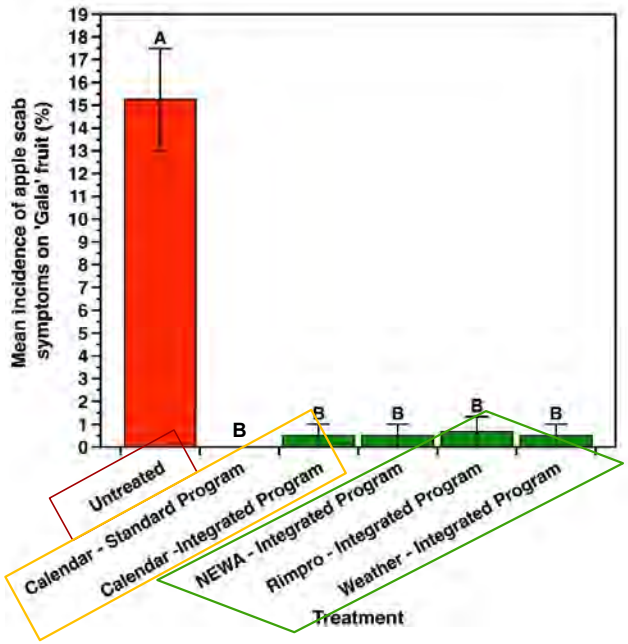
Forecasting Field Trial at Cornell AgriTech 2022

Cells shaded in a different color are where predictions were different among forecasting services

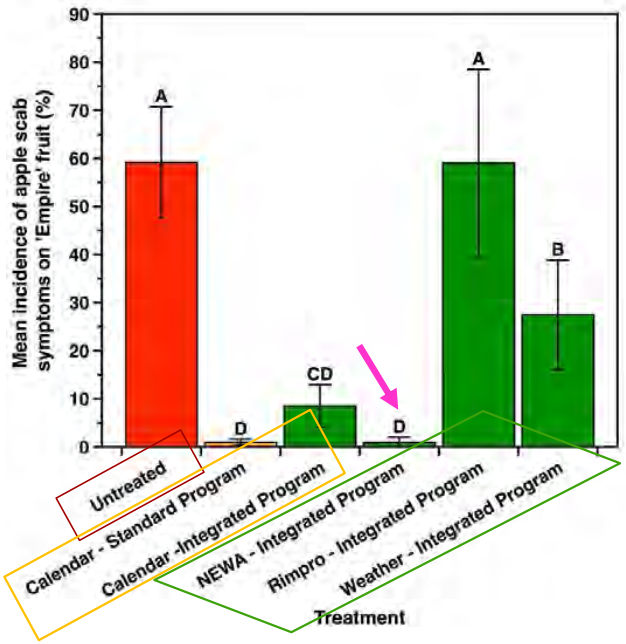
Stage	Date	Treatment	RIM Risk (value)	NEWA ejection	Weather (rain inches)	Material
GT	4/14/2022	All	Slight (4)	<1%	0.35	Biopesticide or Protectant
HIG	4/21/2022	All	None	<1%	0.37	Biopesticide or Protectant
TC	4/25/2022	NEWA + Weather	-	2%	0.33	Biopesticide or Protectant
TC	4/27/2022	RIMpro	Slight (25)	-	-	Biopesticide or Protectant
TC	4/28/2022	Calendar	-	-	-	Biopesticide or Protectant
Pink	5/1/2022	NEWA + Weather + RIMpro	Extreme (1435)	19%	1.20	Single Site
Pink	5/4/2022	Calendar	-	-	-	Single Site
Bloom	5/11/2022	Calendar	-	-	-	Biopesticide or Protectant
Bloom	5/14/2022	NEWA + Weather + RIMpro	High (495)	32%	1.35	Single Site
Petal Fall	5/18/2022	Calendar	-	-	-	Single Site
Petal Fall	5/21/2022	NEWA + Weather + RIMpro	Medium (126)	4%	0.36	Biopesticide or Protectant
1C	5/25/2022	Calendar	-	-	-	Biopesticide or Protectant
1C	5/26/2022	RIMpro	Slight (23)	-	-	Biopesticide or Protectant
1C	5/27/2022	NEWA + Weather	-	16%	1.15	Single Site
2C	6/2/2022	All	High (371)	20%	1.05	Single Site

Apple Scab Incidence for Standard Season Management 2023

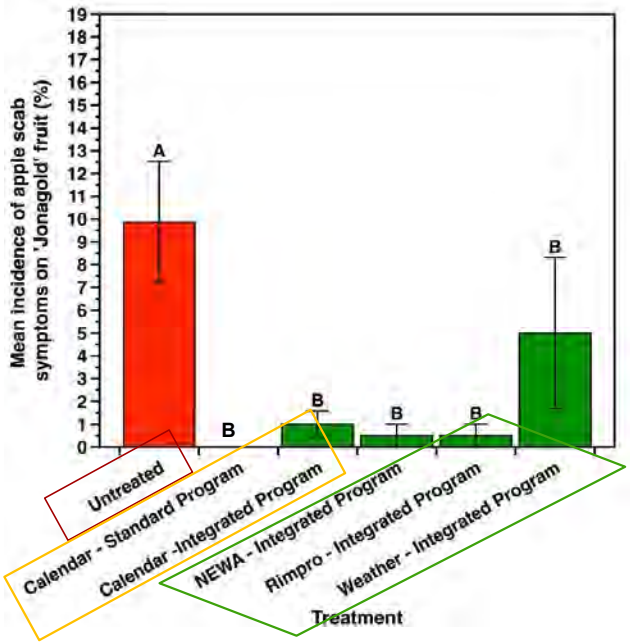
‘Gala’



‘Empire’

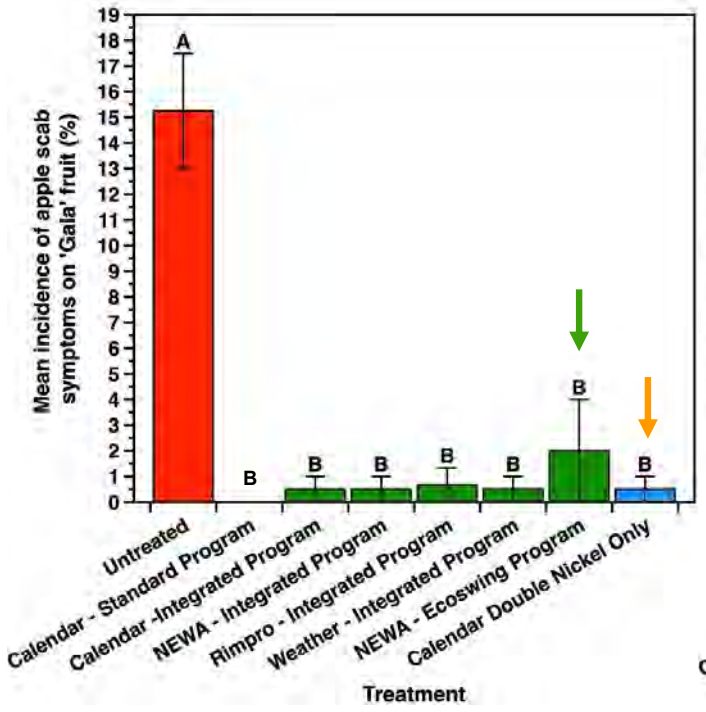


‘Jonagold’

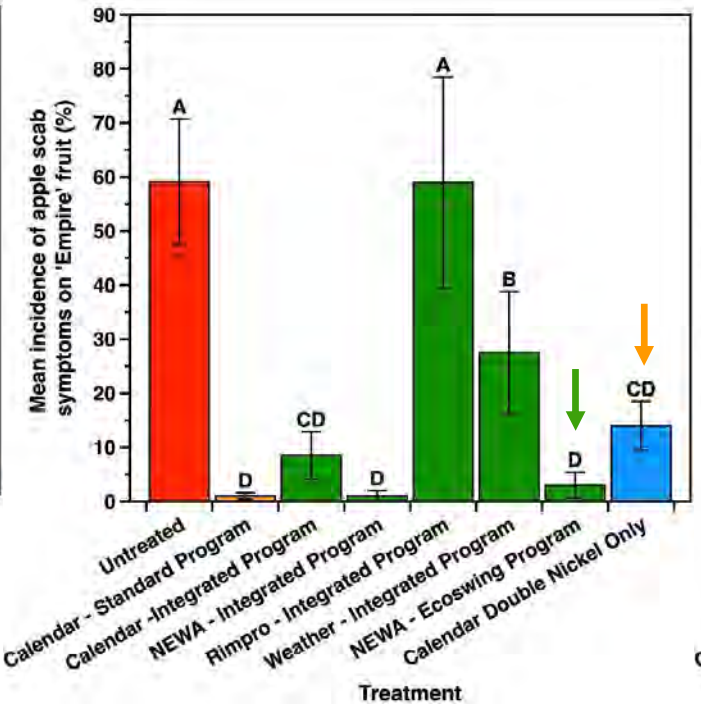


Apple Scab Incidence for Standard Season Management 2023

‘Gala’



‘Empire’



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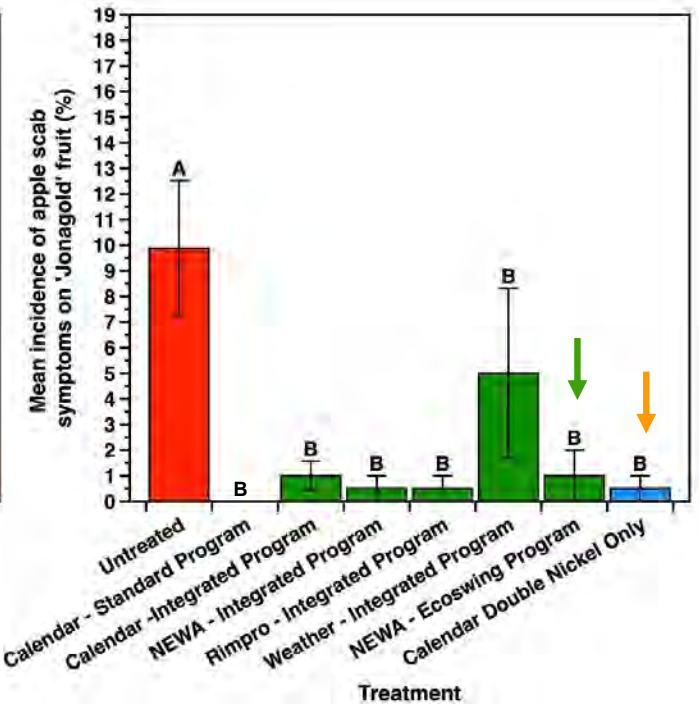
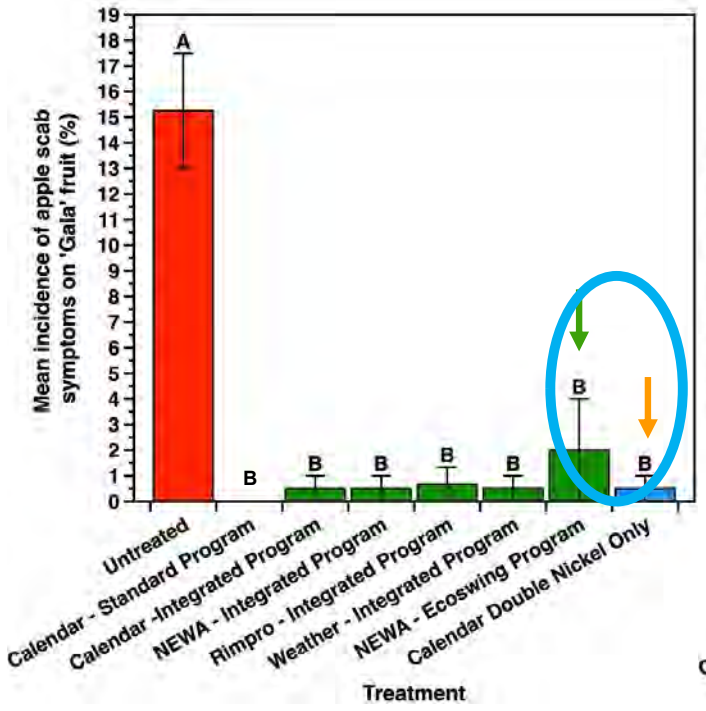


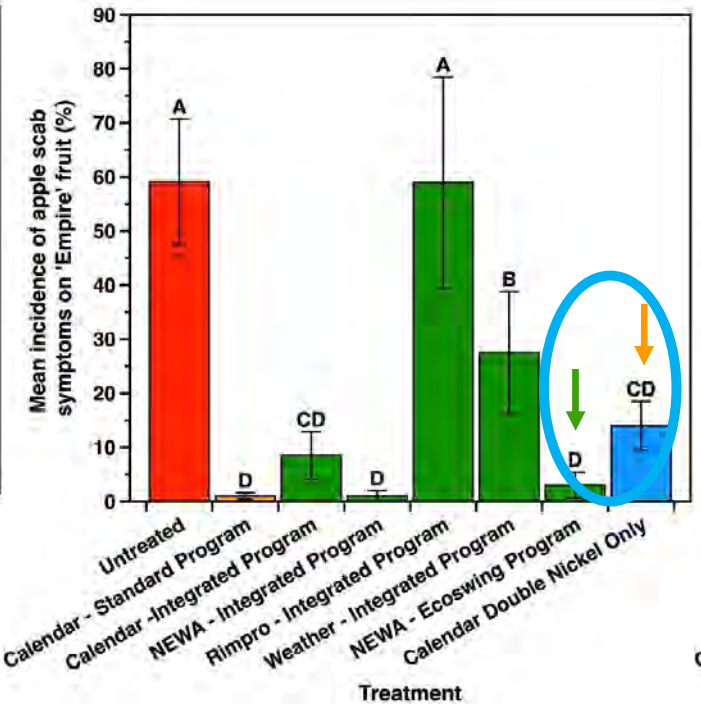
Using only biopesticides just more variable among plots/fields

2023 Mean Incidence on Fruit

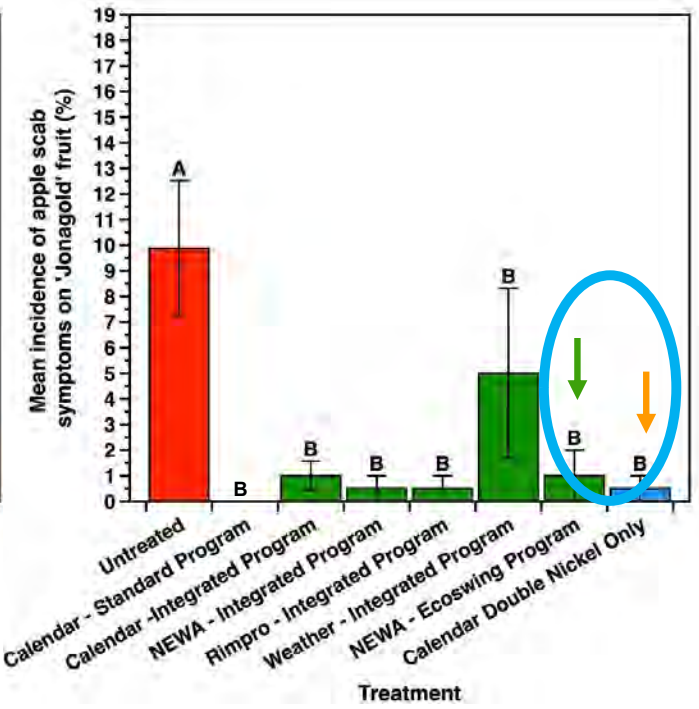
‘Gala’



‘Empire’



‘Jonagold’



2023 Forecast predictions & applications

Stage	Date	Treatment	RIM Risk (value)	NEWA ejection	Weather (rain inches)	Material
GT	4/12/23	All	-	-	-	Biopesticide or Protectant
HIG	4/16/23	All	Slight (2)	<1%	0.01	Single Site
TC	4/21/23	All	Extreme (1591)	43%	1.20	Biopesticide or Protectant
Pink	4/28/23	All	Extreme (1695)	29%	3.90	Single Site
Bloom	5/5/23	All	Slight (5)	8%	0.20	Biopesticide or Protectant
Petal Fall	5/12/23	All	None	0%	0.00	Biopesticide or Protectant
1C	5/19/23	NEWA	-	19%	-	Single Site
1C	5/19/23	RIMpro+ Weather	low (0)	-	0.68	Biopesticide or Protectant
1C	5/21/23	Calendar	-	-	-	Biopesticide or Protectant
2C	5/31/23	All	None (0)	0%	0.00	Biopesticide or Protectant
3C	6/11/23	NEWA	-	(100%) / 2 to 3-day infection	-	Single Site
3C	6/11/23	RIMpro	None (0)	0	-	Biopesticide or Protectant
3C	6/11/23	Weather	-	-	0.80	Biopesticide or Protectant
3C	6/13/23	RIMpro	High (613)	0	-	Single Site
3C	6/13/23	Weather	-	-	2.00	Single Site
3C	6/13/23	NEWA	-	(100%) 4-day infection	-	Single Site
3C	6/18/23	Calendar	-	-	2.85	Single Site
4C	6/30/23	Calendar	-	-	-	Biopesticide or Protectant
4C	6/30/23	NEWA, RIMpro, Weather	High	66 h of leaf wetness / 4-day infection	1.99	Single Site

Forecasting Field Trial at Cornell AgriTech 2022 & 2023

Year	Program	Single-Sites	Protectants	Seasonal Rain Fall (inches)
2022	Calendar	4	4	3.93
	Weather	4	4	
	NEWA	4	4	
	RIMPRO	3	5	
2023	Calendar	4	4	6.79
	Weather	2	6	
	NEWA	3	5	
	RIMPRO	2	6	

- **Protectant are biopesticides or multisites (captan + mancozeb)**
- **In years with moderate rainfall > forecasted predictions = key to success**
- **Extended season management could be beneficial with more erratic weather patterns**
- **Weather and RIMpro reliance on biopesticides detrimental in larger sized plantings**

Extended season management?

Extending the apple scab management season

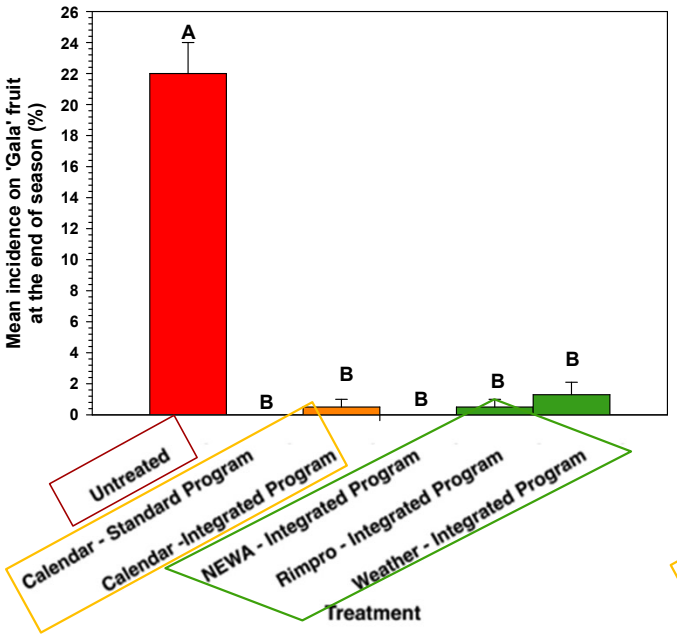
- Erratic weather patterns
- Long periods of dry spells
- Short periods of heavy rain
- Possibly a better control strategy?

2023	Rainfall (inches)	Leaf Wetness (hours)
Standard Season GT – 2C (April to early June)	6.79	201
Extended Season GT – 4C (April to late June/early July)	12.64	537

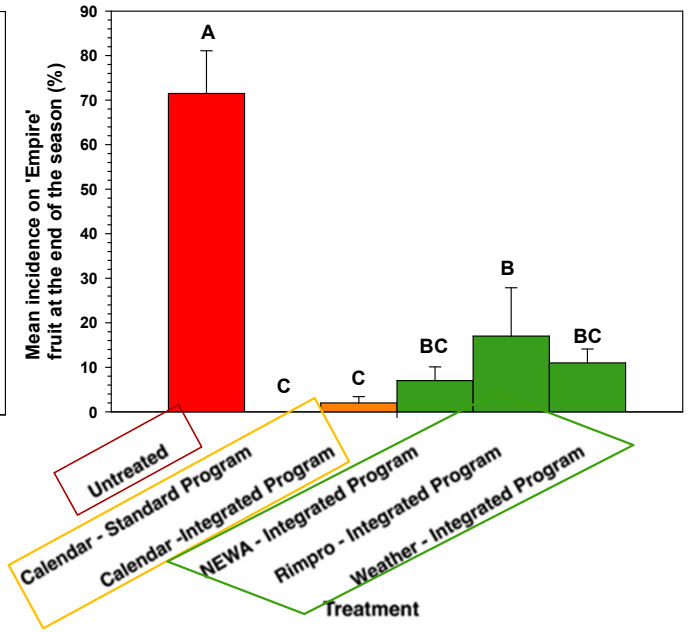
Double amount of rain and leaf wetness hours in June than the whole season

Apple Scab Incidence on Fruit Extended Season Management 2023

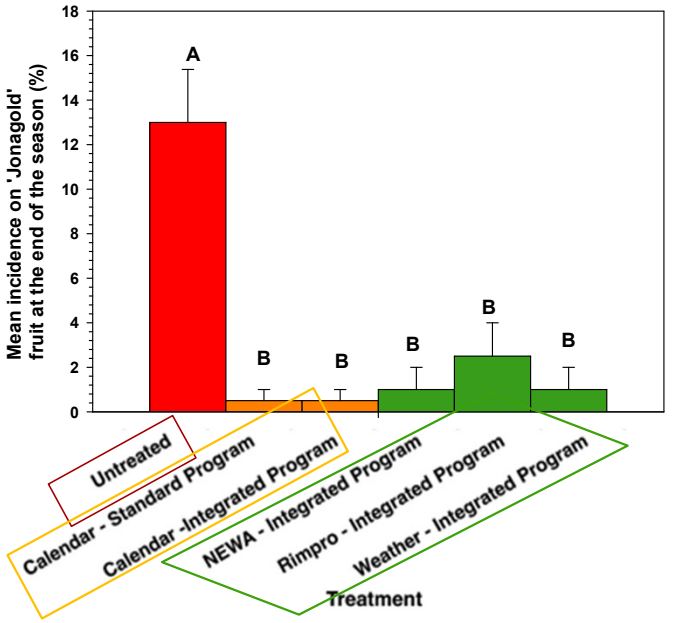
‘Gala’



‘Empire’

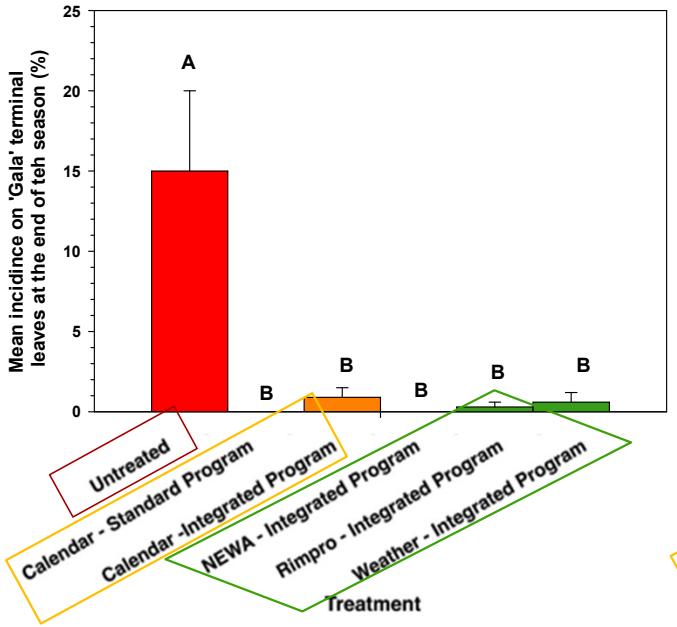


‘Jonagold’

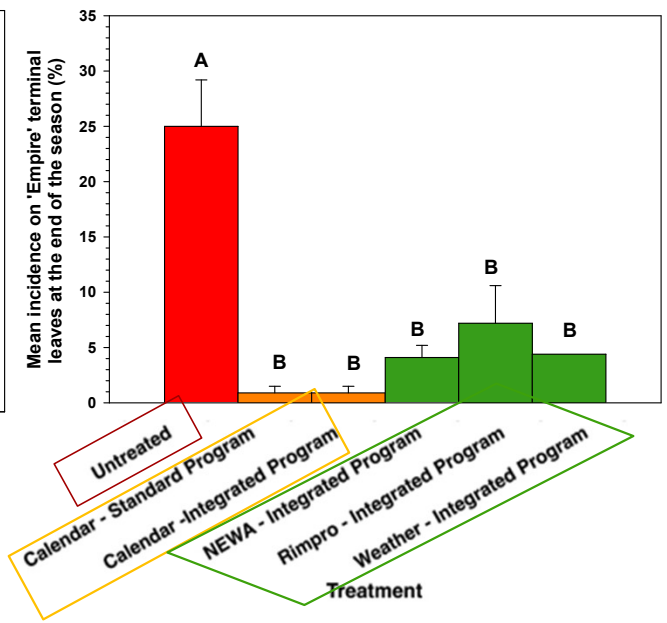


Apple Scab Incidence on Terminal Leaves for Extended Season Management 2023

‘Gala’



‘Empire’



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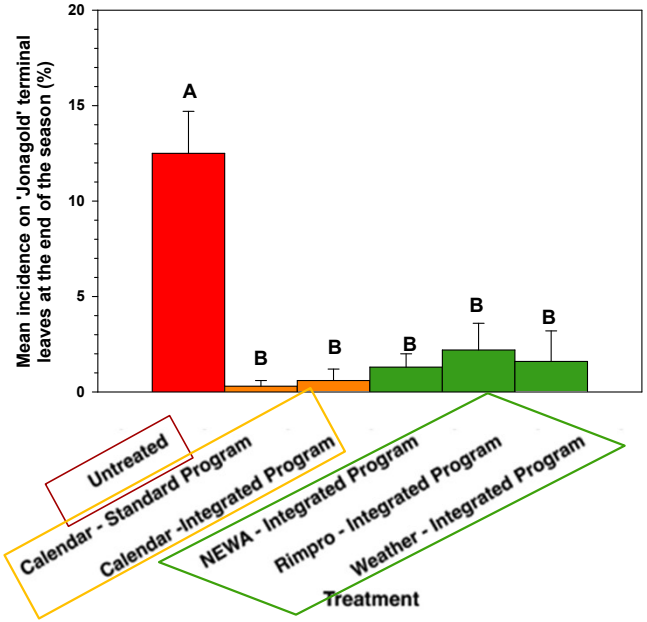
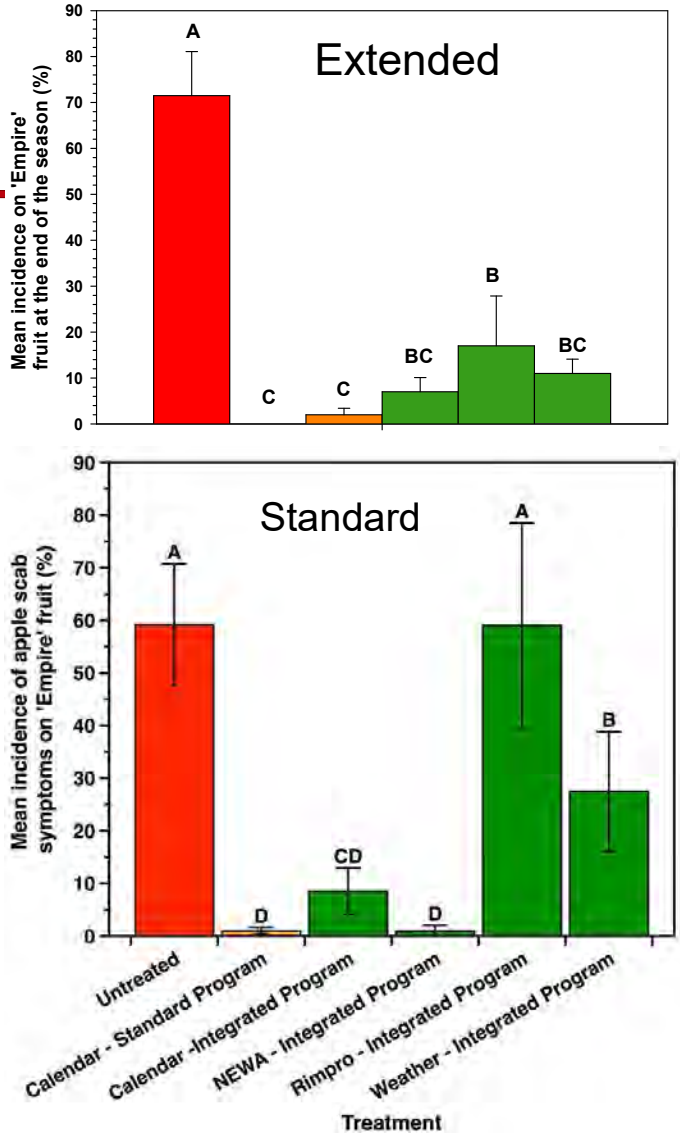


2023 Forecast predictions & applications

Stage	Date	Treatment	RIM Risk (value)	NEWA ejection	Weather (rain inches)	Material
GT	4/12/23	All	-	-	-	Biopesticide or Protectant
HIG	4/16/23	All	Slight (2)	<1%	0.01	Single Site
TC	4/21/23	All	Extreme (1591)	43%	1.20	Biopesticide or Protectant
Pink	4/28/23	All	Extreme (1695)	29%	3.90	Single Site
Bloom	5/5/23	All	Slight (5)	8%	0.20	Biopesticide or Protectant
Petal Fall	5/12/23	All	None	0%	0.00	Biopesticide or Protectant
1C	5/19/23	NEWA	-	19%	-	Single Site
1C	5/19/23	RIMpro+ Weather	low (0)	-	0.68	Biopesticide or Protectant
1C	5/21/23	Calendar	-	-	-	Biopesticide or Protectant
2C	5/31/23	All	None (0)	0%	0.00	Biopesticide or Protectant
3C	6/11/23	NEWA	-	(100%) / 2 to 3-day infection	-	Single Site
3C	6/11/23	RIMpro	None (0)	0	-	Biopesticide or Protectant
3C	6/11/23	Weather	-	-	0.80	Biopesticide or Protectant
3C	6/13/23	RIMpro	High (613)	0	-	Single Site
3C	6/13/23	Weather	-	-	2.00	Single Site
3C	6/13/23	NEWA	-	(100%) 4-day infection	-	Single Site
3C	6/18/23	Calendar	-	-	2.85	Single Site
4C	6/30/23	Calendar	-	-	-	Biopesticide or Protectant
4C	6/30/23	NEWA, RIMpro, Weather	High	66 h of leaf wetness / 4-day infection	1.99	Single Site

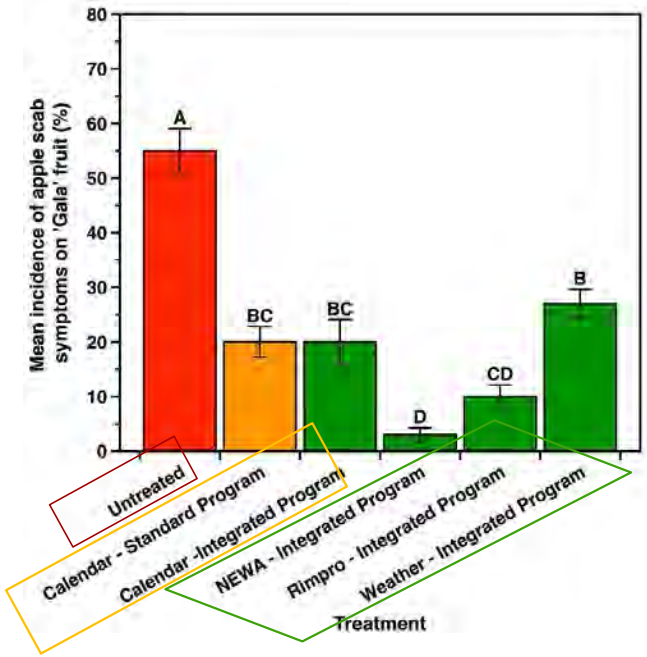
Forecast predictions vs outcomes – ‘Empire’ in 2023 as example

Stage	Date	Treatment	RIM Risk (value)	NEWA ejection	Weather (rain inches)	Material
3C	6/11/23	NEWA	-	(100%) / 2 to 3-day infection	-	Single Site
3C	6/11/23	RIMpro	None (0)	0	-	Biopesticide or Protectant
3C	6/11/23	Weather	-	-	0.80	Biopesticide or Protectant
3C	6/13/23	RIMpro	High (613)	0	-	Single Site
3C	6/13/23	Weather	-	-	2.00	Single Site
3C	6/13/23	NEWA	-	(100%) 4-day infection	-	Single Site
3C	6/18/23	Calendar	-	-	2.85	Single Site

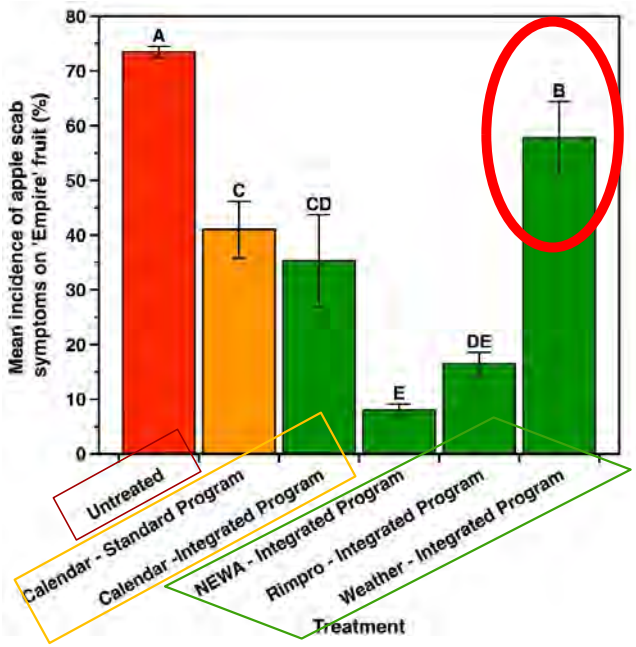


Apple Scab Incidence on Fruit
Extended Season Management 2024

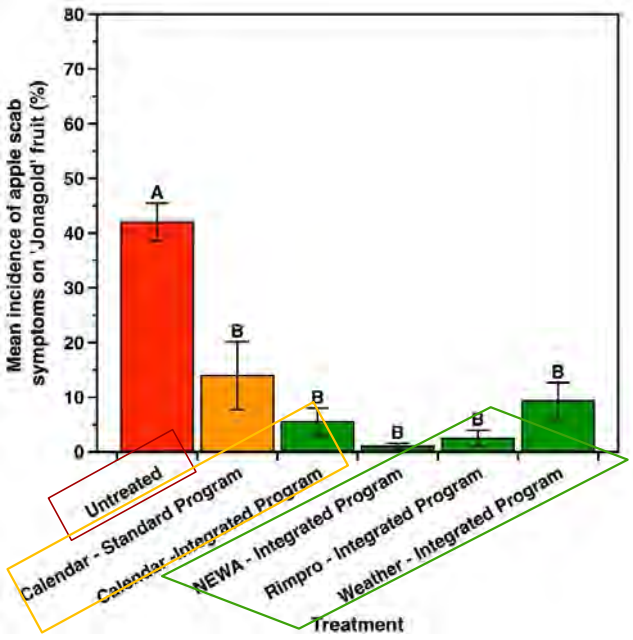
‘Gala’



‘Empire’

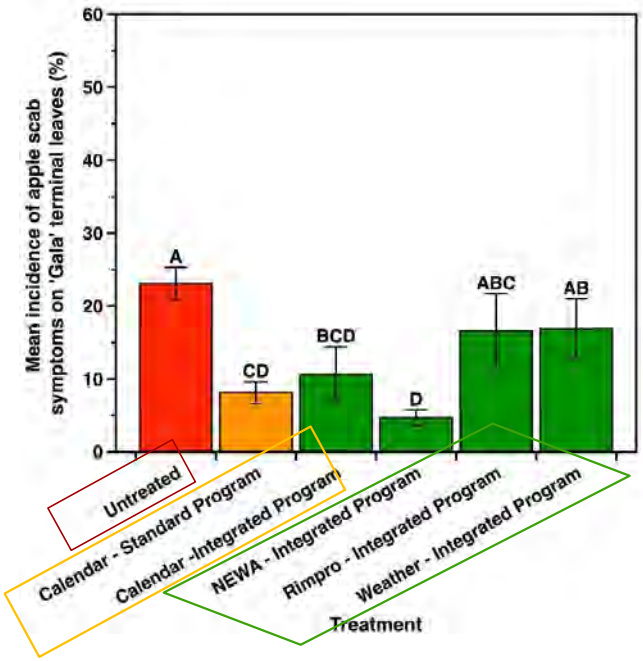


‘Jonagold’

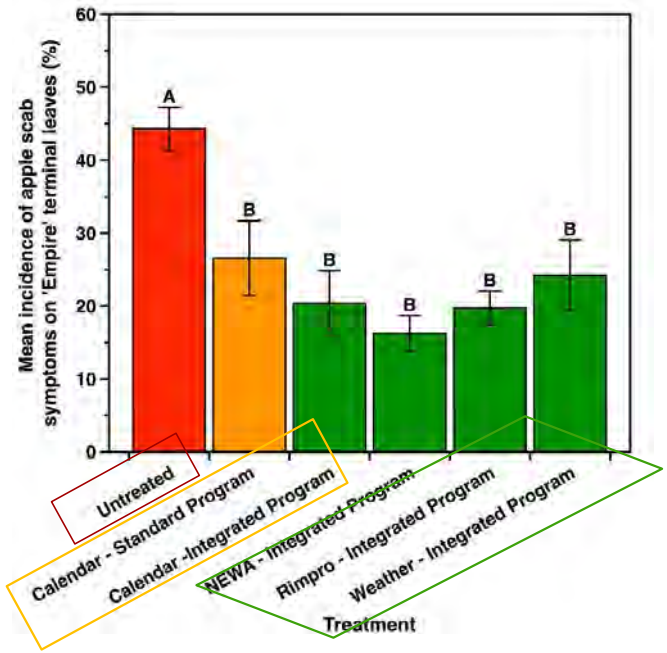


Apple Scab Incidence on Terminal Leaves for Extended Season Management 2024

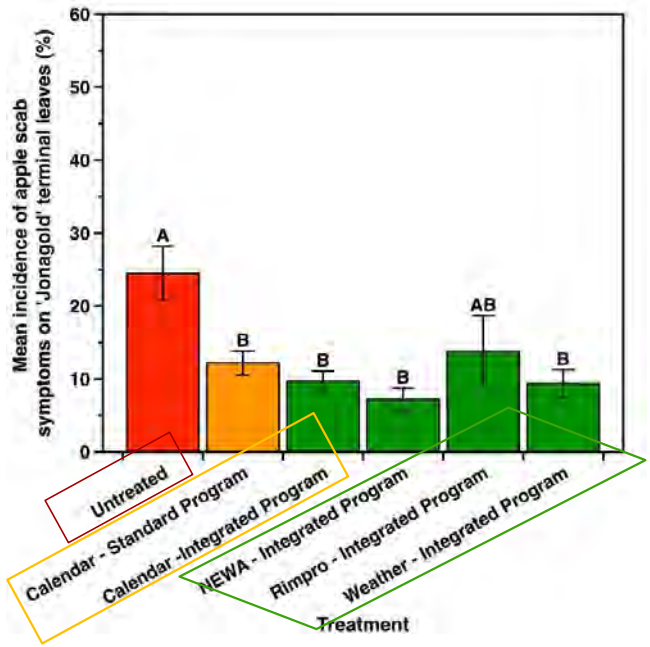
‘Gala’



‘Empire’



‘Jonagold’



2024 Forecast predictions & applications

Stage	Date	Treatment	RIM Risk (value)	NEWA ejection or hrs. leaf wetness	Weather (rain inches)	Material
GT	4/9/24	All	-	-	-	Biopesticide or Protectant
HIG	4/15/24	Calendar	-	-	-	Single Site
HIG	4/15/24	NEWA + rimpro	High (300)	21%	-	Single Site
HIG	4/16/24	Weather	-	-	0.6	Biopesticide
TC	4/23/24	All	Slight (30)	7%	0.02	Biopesticide or Protectant
Pink	4/29/24	Calendar + NEWA + rimpro	Extreme (999)	20%	-	Single Site
Pink	4/29/24	Weather			0.9	Biopesticide
Bloom	5/6/24	NEWA + rimpro	High (550)	19%	-	Single Site
Bloom	5/7/24	Weather	-	-	1.5	Single Site
Bloom	5/7/24	Calendar	-	-	-	Biopesticide or Protectant
Petal Fall	5/14/24	NEWA + rimpro + Weather	Medium (155)	4%	0.07	Biopesticide
Petal Fall	5/14/24	Calendar	-	-	-	Single Site
1C	5/25/24	All	None (0)	19 h LW	0.25	Biopesticide or Protectant
2C	6/4/24	All	High (550)	41 h LW	1.5	Single Site
3C	6/14/24	All	Low (150)	0 h LW	0.0	Biopesticide
4C	6/24/24	Calendar	-	-	-	Single Site
4C	6/24/24	NEWA + rimpro + Weather	None (0)	0 h LW	0.0	Biopesticide

Forecasting Field Trial at Cornell AgriTech 2023 & 2024

Year	Program	Single-Sites	Protectants	Seasonal Rain Fall (inches)
2023 Extended	Calendar	5	5	12.64
	Weather	4	6	
	NEWA	5	5	
	RIMPRO	4	6	
2024 Extended	Calendar	5	5	6.79
	Weather	2	8	
	NEWA	4	6	
	RIMPRO	4	6	

- **Protectant are biopesticides or multisites (captan + mancozeb)**
- **In years with moderate rainfall > forecasted predictions = key to success**
- **Extended season management could be beneficial with more erratic weather patterns**
- **Weather and RIMpro reliance on biopesticides detrimental in larger sized plantings**

Summary: Forecasting Field Trials

- Low apple scab pressure (< 5 infection periods) > Excellent control
- Variety is going to make huge difference in whether this works: our perceptions of biopesticide performance based on trials on large susceptible trees
- All Decision Support Systems (DSS) are effective: The integration of forecast data and how it's handled especially at the end of primary season is most important with our erratic climates
  - Some may work better and might be more reliable than others
- Extending the management season may be beneficial with erratic climate patterns

Disease Forecasting and Apple Scab. Take home message

- Climate change impacting the potential impact & losses from apple scab
- Decision support systems (DSS) and modern planting systems of on non-'McIntosh' relatives will continue to dimmish impact of apple scab
- In low pressure years and low risks systems: No appreciable difference between calendar and forecast timing
- NY industry: rely on biopesticides integrated with single-site fungicides once restrictions occur (e.g. Mancozeb)

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