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Eastern NY Commercial Horticulture Program

Biofungicide, Biorational Fungicide, and Copper Fungicide Programs to Manage *Alternaria* Leaf Spot and Head Rot in Broccoli

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Background

Brassica crops, like broccoli, are susceptible to a number of plant pathogens. Black Rot (BR), Downy Mildew (DM) and *Alternaria* Leaf Spot/Head Rot (ALS), are among the most common and destructive diseases of brassica crops grown in the Northeast. Production of marketable organic brassica crops in the Hudson Valley is limited by these pervasive diseases despite grower efforts to implement best cultural practices like crop rotation and improving air flow in crops by adjusting planting spacing. A number of low-risk “biorational” products are allowed in organic production and are labeled to manage these diseases. One of the obstacles organic growers face in managing the three diseases is discerning which, if any, of these disease control materials are effective.



Photo 1. - Trial field on September 30, 2021

With support from the Hudson Valley Farm Hub (HVFH) in 2020, Cornell Cooperative Extension Eastern New York Commercial Horticulture (ENYCHP) regional vegetable specialists Ethan Grundberg and Teresa Rusinek evaluated nine biorational fungicides on broccoli produced at HVFH where BR, DM and ALS have all posed persistent production challenges. ALS was overwhelmingly the primary disease affecting the trial broccoli in 2020. Under these high pressure conditions, none of the biorational products alone provided acceptable levels of suppression. The results from the 2020 screening trial support what both private industry and researchers have concluded about managing other diseases with biorational products: biorationals alone are typically insufficient to manage intense disease pressure, especially difficult to control pathogens like those that cause ALS. Instead, more researchers and growers are experiencing greater success managing plant diseases with biorationals by using those products in rotation with more aggressive chemistries and as tank-mix companions to other products. Results from the 2020 trial informed the development of more robust season-long bio-rational programs built by rotating through different chemistries and tank-mixing compatible products that were trialed in 2021 at the Farm Hub.

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Methods

'Emerald Crown' broccoli was seeded on July 14 into 72-cell propagation trays and kept in the greenhouse until moved outdoors to harden off on August 6. Seedlings were planted with a water wheel transplanter on August 17 at 12" in-row spacing and 3 rows per bed approximately 12" apart. Plots were 10 bed feet and separated by a 3 bed foot planted buffer. Plots were arranged in a randomized complete block design with 4 replicates. No supplemental irrigation was necessary and weeds were managed with hand tools. Entrust (spinosad) was applied at 6 fl oz/acre August 11 to suppress flea beetles and Deliver (*Bacillus thuringiensis kurstaki*) was applied at 1 lb/acre September 16 to control lepidopteran pests. Treatments were applied weekly on August 25 and 31, September 8, 15, 22, 30, and October 11. All fungicide applications were made using a CO₂-powered backpack sprayer calibrated to deliver 39 gallons/acre of spray solution at 40 psi with four twin turbojet nozzles (TTJ60-8003VS) spaced 15" apart. The OMRI-listed adjuvant Attach (pinene polymers) was used at a rate of 16 fl oz/100 gal in all of the treatments, including to spray the untreated control.

Treatment Programs	Products and Rates*
A = 1	UTC (sprayed with water and Attach at 0.125% v/v dilution)
B = 2	Badge X2 @ 1.35 lbs/acre
C = 3	Badge X2 @ 1.35 lbs/acre PLUS Regalia @ 2 qt/acre
D = 4	Badge X2 @ 1.35 lbs/acre PLUS LifeGard @ 4.5 oz/100 gal
E = 5	Badge X2 @ 1.35 lbs/acre PLUS Stargus @ 3 qt/acre
F = 6	Badge X2 @ 1.35 lbs/acre PLUS Double Nickel 55 LC @ 2 qt/acre
G = 7	Badge X2 @ 1.35 lbs/acre PLUS OSO @ 6.5 fl oz/acre
H = 8	Badge X2 @ 1.35 lbs/acre PLUS Howler @ 5 lbs/acre
I = 9	Badge X2 @ 1.35 lbs/acre PLUS Theia @ 3 lbs./acre
J = 10	No Bio-Fungicide alternated with Badge X2 @ 1.8 lbs/acre
K = 11	Regalia @ 2 qt/acre alternated with Badge X2 @ 1.8 lbs/acre
L = 12	LifeGard @ 4.5 oz/100 gal alternated with Badge X2 @ 1.8 lbs/acre
M = 13	Stargus @ 96 fl oz/acre alternated with Badge X2 @ 1.8 lbs/acre
N = 14	Double Nickel @ 64 fl oz/acre alternated with Badge X2 @ 1.8 lbs/acre
O = 15	Oso @ 13fl. oz./acre alternated with Badge X2 @ 1.8 lbs/acre
P = 16	Howler @ 5 lbs/acre alternated with Badge X2 @ 1.8 lbs/acre
Q = 17	Theia @ 3 lbs/acre alternated with Badge X2 1.8 lbs/acre
R = 18	PerCarb @ 3 lbs/100 gal alternated with Badge X2 @ 1.8 lbs/acre
S = 19	Regalia @ 2 qt/acre alternated with Badge X2 @ 1.8 lbs/acre PLUS Stargus @ 3 qt/acre
T = 20	Regalia @ 2 qt/acre alternated with Badge X2 @ 1.8 lbs/acre PLUS Double Nickel 55 LC @ 2qt/acre
U = 21	Badge X2 @ 1.35 lbs/acre PLUS Double Nickel 55 LC @ 2 qt/acre weeks 1-5, water and Attach weeks 6,7
V = 22	Badge X2 @ 1.35 lbs/acre PLUS Double Nickel 55 LC @ 2 qt/acre weeks 1-5, Double Nickel 55 LC @ 2qt/acre weeks 6,7

* All treatments included Attach at 0.125% v/v dilution

Alternaria leaf spot (ALS) was evaluated by estimating the percentage of symptomatic leaf area on nine individual plants per plot. Ratings were made every other week on August 31, September 15 and 30,

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and October 13. Disease severity data were used to calculate area under the disease progress curve (AUDPC). AUDPC is commonly used to evaluate the rate at which diseases are spreading and/or how well fungicides are slowing the spread of foliar diseases in the field over multiple sampling dates. ALS severity on broccoli heads and harvest weights were measured over four harvest dates on October 13, 18, 20 and 25. 10 crowns per plot were harvested over the 12-day period and weighed on an Ohaus Catapult 1000 compact bench scale with 0.02 lb resolution, measured with a Fowler 54-100-512-BT electronic calipers with 0.0005"/0.01mm resolution, and visually assessed to estimate the percentage of florets with head rot symptoms.



Photo 2. AUDPC Foliar Disease Rating Scale



Photo 3. Broccoli Crown Disease Rating Scale at Harvest

Average monthly air temperatures (°F) were 72.9 in August, 64.9 in September, and 56.8 in October. Rainfall (in.) was 5.94 in August, 6.82 in September, and 7.94 in October. All data were analyzed using a general linear model and means were compared using Tukey's honestly significant difference test ($P = 0.05$) in JMP Pro (JMP Pro v 15.2.1, SAS Institute, Cary, NC).

Natural inoculum of ALS was the only source of inoculum for this trial. Despite higher than average precipitation, ALS pressure was moderate and head rot severity was low in the trial.

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Comprehensive results are presented in the tables below.

Mean Whole Plot Disease Severity (%)

	31-Aug	15-Sep	30-Sep	13-Oct	AUDPC	Marketable Yield (lbs)	Crown Disease Severity (%)
UTC	0.167 C	1.81 D	9.11	13.1 AB	241.29 AB	4.37	2.33
Badge	0.75 ABC	2.78 ABCD	7.83	11 ABC	228.64 AB	4.44	2.93
Badge + Regalia	0.778 ABC	5.72 A	7.42	9.06 ABC	254.36 AB	5.56	1.05
Badge + <u>LifeGard</u>	0.806 ABC	3 ABCD	7.92	7.17 BC	208.46 AB	5.03	2.2
Badge + <u>Stargus</u>	0.861 ABC	4.83 AB	8.67	9.31 ABC	260.78 AB	5.79	1.55
Badge + Double Nickel 55	0.806 ABC	2.69 ABCD	8.44	8.78 ABC	221.74 AB	4.88	3.05
Badge + Oso	0.722 ABC	2.72 ABCD	6.69	6.33 C	181.14 B	5.73	1.33
Badge + Howler	1.694 A	3.56 ABC	7.53	11.8 ABC	247.99 AB	3.9	2.8
Badge + Theia	1.611 AB	5.86 A	9.69	8.78 ABC	292.78 A	4.66	1.83
Badge ALT No Fungicide	0.194 C	2.44 ABCD	7.61	9.86 ABC	208.78 AB	3.7	2.43
Regalia ALT Badge	0.389 C	2.83 ABCD	7.22	12.3 AB	226.69 AB	3.8	3.73
<u>LifeGard</u> ALT Badge	0.5 BC	1.83 BCD	7.39	12.4 AB	215.04 AB	4.98	1.28
<u>Stargus</u> ALT Badge	0.278 C	2 BCD	9.36	10.9 ABC	233.92 AB	4.25	3.93
Double Nickel ALT Badge	0.417 C	2.33 ABCD	7.11	11.1 ABC	210.08 AB	3.65	3.65
Oso ALT Badge	0.306 C	1.81 CD	7.33	8.31 ABC	186.03 B	5.35	1.35
Howler ALT Badge	0.361 C	1.81 CD	6.94	12.2 AB	206.28 AB	4.77	1.93
Theia ALT Badge	0.361 C	2.81 ABCD	9.94	9.61 ABC	246.49 AB	4.41	2.33
PerCarb ALT Badge	0.306 C	2.53 ABCD	8	11.2 ABC	225.15 AB	4.58	3.65
Regalia ALT Badge + <u>Stargus</u>	0.222 C	2 BCD	8.89	9.42 ABC	217.32 AB	4.31	3.08
Regalia ALT Badge + Double Nickel	0.278 C	2.89 ABCD	8.53	15.1 A	262.85 AB	4.39	3.2
Badge + Double Nickel 55 1-5, No fungicide 6-7	0.694 ABC	3.17 ABCD	7.39	10.2 ABC	222.60 AB	4.88	2.03
Badge + Double Nickel 55 1-5, Double Nickel 6-7	0.694 ABC	4.39 AB	7.53	8.5 ABC	231.68 AB	5.43	2.03
p value	0.00006	<0.0001	ns	0.0007	0.016	ns	ns
			0.3425			0.6389	0.3439

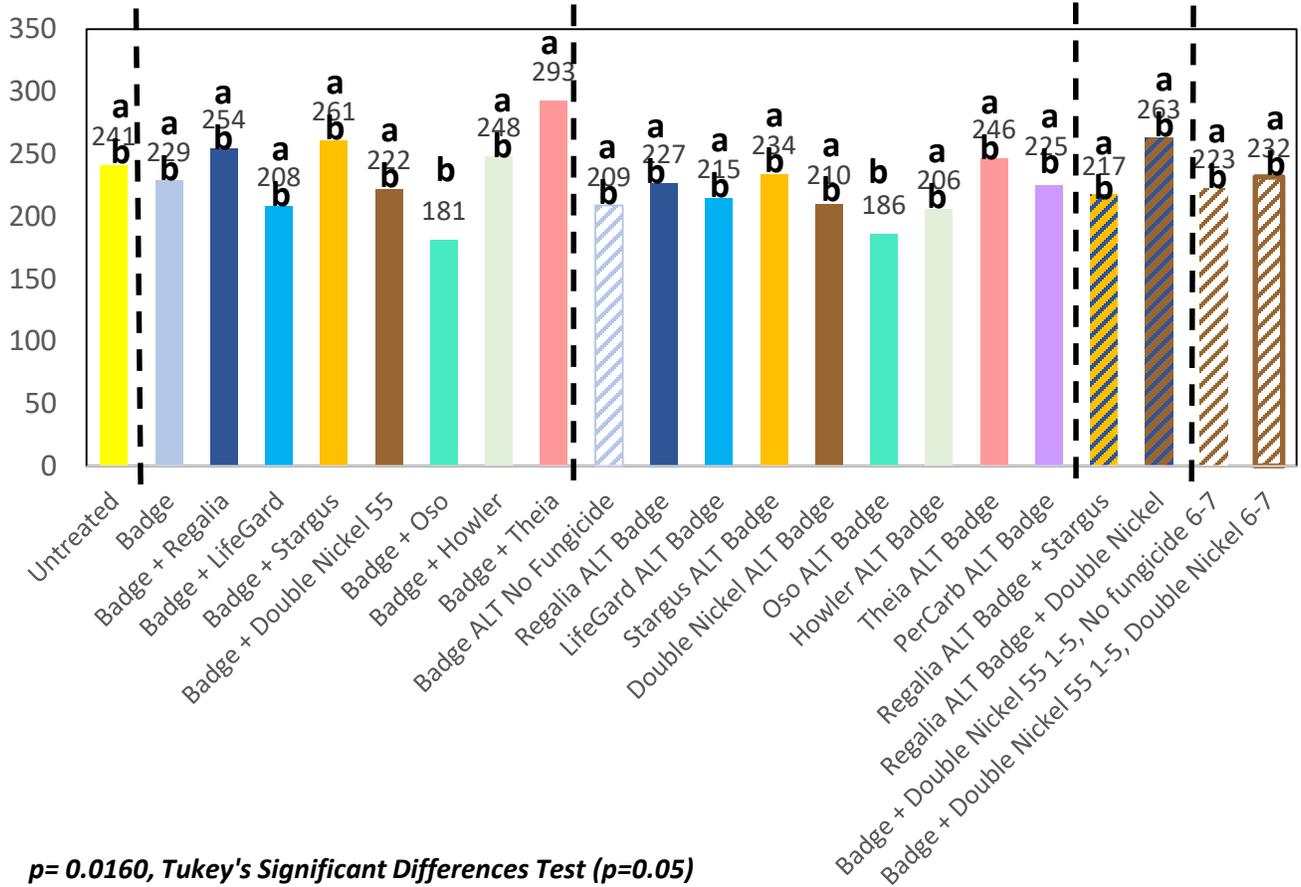
Results

The first disease severity rating took place on August 31. The treatments Badge+ Howler & Badge + Theia were significantly higher in disease severity compared to the untreated control. The remaining treatments were significantly the same as the UTC. The second rating took place on Sept.15. Several treatments had significantly higher disease rating than the UTC, these included: Badge+Regalia; Badge + Stargus; Badge + Howler; and Badge + Double Nickel 55 sprays 1-5 followed by Double Nickel only sprays 6, 7. The remaining treatments were the significantly the same as the UTC. On Sept. 30, there was no statistical difference (NS) between any of the treatments. On Oct. 13, the Badge+Oso treatment was significantly lower in disease severity compared to UTC, the rest of the treatments were significantly the same as UTC. The statistical analysis of the AUDPC showed no statistically significant effect of any treatment on disease severity, however the two treatments that included Oso had the lowest numerical AUDPC rating, Badge + Oso and Oso alternated with Badge. There was no significant effect of treatment on Marketable Yield. The numeric differences in head rot disease severity between treatments were also not statistically significant however, numerically the lowest Crown Disease Severity ratings were: Badge + Regalia, Lifeguard alt with Badge, Badge + Oso, and Oso alternated with badge.

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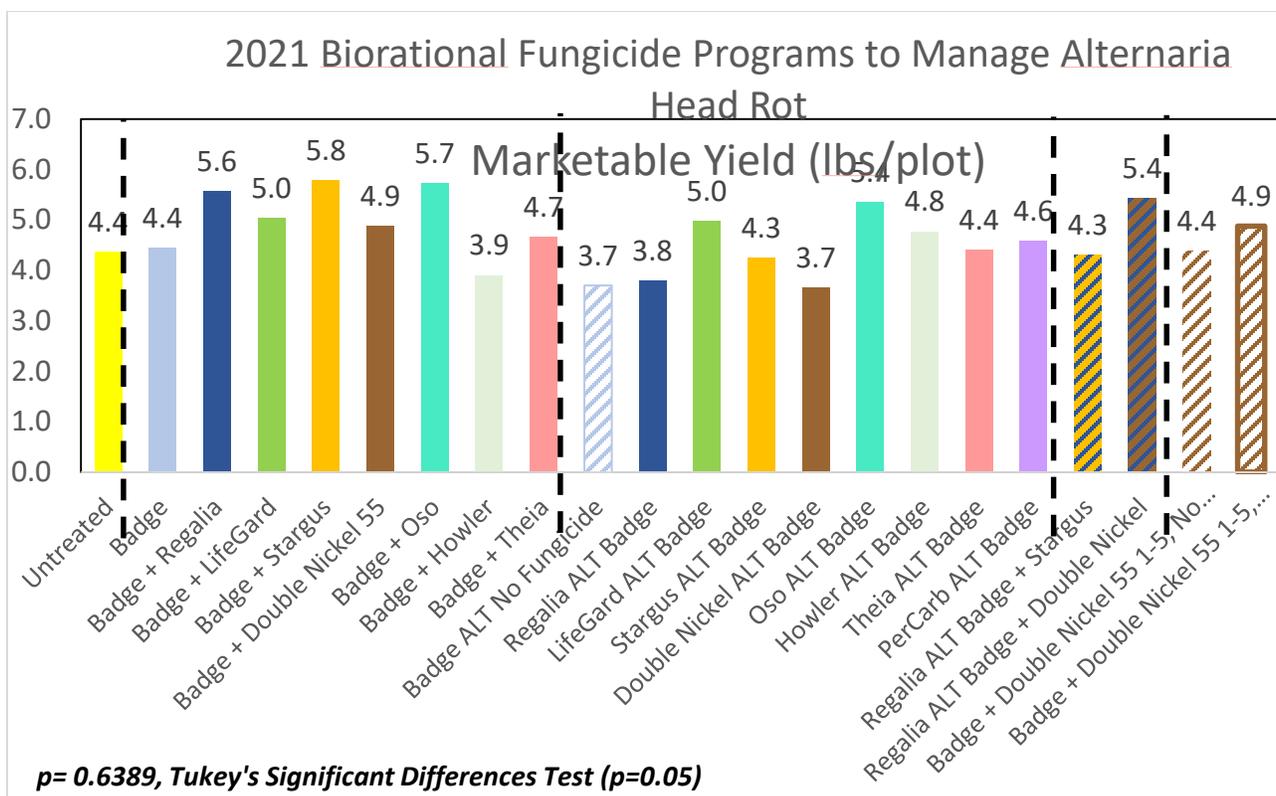
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2021 Biorational Programs to Manage Alternaria Leaf Spot Leaf AUDPC/Disease Intensity Over Time



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Discussion of 2021 Biorational Programs

Analysis of data collected in the 2020 trials at the farm hub revealed trends toward lower disease severity in plots treated with Badge X2, Regalia, Stargus, and Double Nickel. Those products were included in the 2021 Farm Hub trial programs along with several newly released OMRI-listed biorational products, including: Theia (*Bacillus subtilis* strain AFS032321), Howler (*Pseudomonas chlororaphis* strain AFS009), and Oso (polyoxin D zinc salt). A total of 22 biorational programs were evaluated in 2021 with the goal of collecting data to help answer the following research questions:

- 1) Can the addition of a biofungicide or biorational fungicide to a weekly copper application significantly reduce alternaria, black rot, and/or downy mildew severity? If so, does the reduction in disease severity translate to a significant increase in marketable yield compared to the use of copper alone? If so, is the increase in marketable yield large enough to justify the additional expense of adding the biofungicide to the copper applications?

	Program 1	Program 2	Program 3	Program 4	Program 5	Program 6	Program 7	Program 8	Program 9
Week 1	UTC	Badge	Badge + Regalia	Badge + LifeGard	Badge + Stargus	Badge+ Double Nickel	Badge+OSO	Badge + Howler	Badge + Theia
Week 2	UTC	Badge	Badge + Regalia	Badge + LifeGard	Badge + Stargus	Badge+ Double Nickel	Badge+OSO	Badge + Howler	Badge + Theia
Week 3	UTC	Badge	Badge + Regalia	Badge + LifeGard	Badge + Stargus	Badge+ Double Nickel	Badge+OSO	Badge + Howler	Badge + Theia
Week 4	UTC	Badge	Badge + Regalia	Badge + LifeGard	Badge + Stargus	Badge+ Double Nickel	Badge+OSO	Badge + Howler	Badge + Theia
Week 5	UTC	Badge	Badge + Regalia	Badge + LifeGard	Badge + Stargus	Badge+ Double Nickel	Badge+OSO	Badge + Howler	Badge + Theia
Week 6	UTC	Badge	Badge + Regalia	Badge + LifeGard	Badge + Stargus	Badge+ Double Nickel	Badge+OSO	Badge + Howler	Badge + Theia
Week 7	UTC	Badge	Badge + Regalia	Badge + LifeGard	Badge + Stargus	Badge+ Double Nickel	Badge+OSO	Badge + Howler	Badge + Theia

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Conclusion: As stated earlier in the results section, the only program in this group that showed significantly lower disease severity compared to the UTC, was the Badge+Oso treatment on Oct. 13, the rest of the treatments were the significantly the same as the UTC. Numerically this treatment also had one of the lowest AUDPC values. There was no significant effect of treatment on Marketable Yield. The numeric differences in head rot disease severity at harvest between the treatments were also not statistically significant however, numerically the lowest Crown Disease Severity ratings were: Badge + Regalia and Badge + Oso.

- 2) Can alternating applications of copper with a biofungicide or biorational fungicide provide a significant reduction in disease severity compared to a program of every other week copper applications alone? If so, does the reduction in disease severity translate to a significant increase in marketable yield compared to the use of alternate week copper applications alone? If so, is the increase in marketable yield large enough to justify the additional expense of adding the alternate week biofungicide to the program?

	Program 10	Program 11	Program 12	Program 13	Program 14	Program 15	Program 16	Program 17	Program 18
Week 1	None	Regalia	LifeGard	Stargus	Double Nickel	Oso	Howler	Theia	PerCarb
Week 2	Badge	Badge	Badge	Badge	Badge	Badge	Badge	Badge	Badge
Week 3	None	Regalia	LifeGard	Stargus	Double Nickel	Oso	Howler	Theia	PerCarb
Week 4	Badge	Badge	Badge	Badge	Badge	Badge	Badge	Badge	Badge
Week 5	None	Regalia	LifeGard	Stargus	Double Nickel	Oso	Howler	Theia	PerCarb
Week 6	Badge	Badge	Badge	Badge	Badge	Badge	Badge	Badge	Badge
Week 7	None	Regalia	LifeGard	Stargus	Double Nickel	Oso	Howler	Theia	PerCarb

Conclusion: The statistical analysis of the AUDPC showed no statistically significant effect of any treatment on disease severity, however the treatment that included Oso had one of the lowest numerical AUDPC ratings of all the programs in the trial. There was no significant effect of treatment on Marketable Yield. The numeric differences in head rot disease severity at harvest between the treatments were also not statistically significant however, numerically the lowest Crown Disease Severity ratings were: Lifeguard alt with Badge and Oso alt with Badge. The data suggests that there is no significant reduction in disease severity when alternating applications of copper with a biofungicide or biorational fungicide compared to a program of every other week copper applications alone. The data also suggests that copper applications can be reduced without significantly increasing disease severity.

- 3) Can ISR/SAR biofungicides alternated with tank mix applications of copper and a biofungicide/biorational provide a comparable level of disease suppression to weekly applications of the tank mix combinations (blue programs)? If so, is there any measurable difference in disease suppression between Regalia and LifeGard alternated with the copper+bio tank mix programs?

	Program 19	Program 20
Week 1	Regalia	Regalia
Week 2	Badge + Stargus	Badge + Double Nickel
Week 3	Regalia	Regalia
Week 4	Badge + Stargus	Badge + Double Nickel
Week 5	Regalia	Regalia
Week 6	Badge + Stargus	Badge + Double Nickel
Week 7	Stargus	Double Nickel

Conclusion: Neither program was statistically significantly better than the UTC or the tank mix program of Badge + Regalia for disease severity, marketable yield or crown disease. Numerically, the Regalia

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alternated with Badge + Stargus had a lower AUDPC value compared to the UTC and Regalia alternated with Badge+ Double Nickel treatments.

- 4) Can copper be eliminated from late fungicide applications (weeks 6 and 7) in order to reduce the risk of phytotoxicity on broccoli crowns without sacrificing the disease suppressing performance of the fungicide programs when compared to programs including late copper applications (blue programs)? Does spraying a stand-alone biofungicide/biorational late improve disease suppression and marketable yield compared to programs with no fungicide applications in weeks 6 and 7?

	Program 21	Program 22
Week 1	Badge+ Double Nickel	Badge+ Double Nickel
Week 2	Badge+ Double Nickel	Badge+ Double Nickel
Week 3	Badge+ Double Nickel	Badge+ Double Nickel
Week 4	Badge+ Double Nickel	Badge+ Double Nickel
Week 5	Badge+ Double Nickel	Badge+ Double Nickel
Week 6	NONE	Double Nickel
Week 7	NONE	Double Nickel

Conclusion: There was no statistically significant difference between disease severity, Marketable Yield or crown disease severity between programs 21 and 22 or comparing these program 6 Badge+ Double Nickel (weeks1-7). Programs 21 and 22 had numerically lower Crown Disease ratings compared to program 6, but there was no discernable benefit when Double

Nickel was applied in weeks 6 and 7 compared to none in weeks 6 and 7. This data suggests that eliminating copper based fungicide applications after crown initiation does not significantly impact Alternaria crown rot.

2022 Research Questions and Programs

Oso had the lowest numerical AUDPC (disease) ratings and among the highest in marketable yield in the 2021 Farm Hub trial. In other ALS trials in NYS, OSO @ 13 fl.oz rate, has been shown to provide 60% control of ALS on foliage and 96% control of ALS head rot compared to the UTC (Smart, C. 2021) Trails conducted by Hoepting , C. 2021 using Oso at the 6.5 fl. oz rate, resulted in 81% control of ALS on foliage and and 67% control of Alternaria head rot, compared to the UTC. Promising results in field trials using OSO for ALS management will guide this year’s trial at the Farm Hub. Because OSO is a relatively expensive product to apply, we intend to trial several programs using the lower rate of OSO @ 6.5 fl.oz to demonstrate efficacy at a cost that is economically feasible for most growers.

- 1) How well do weekly applications of Oso and Badge perform to manage disease in broccoli? Establish baseline of individual product efficacy to better understand potential impacts of tank mixes and rotation programs incorporating multiple modes of action.

	Program 1*	Program 2	Program 3
Week 1	UTC	Badge	Oso
Week 2	UTC	Badge	Oso
Week 3	UTC	Badge	Oso
Week 4	UTC	Badge	Oso
Week 5	UTC	Badge	Oso
Week 6	UTC	Badge	Oso
Week 7	UTC	Badge	Oso

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- 2) Compared to either Oso or Badge alone, how do weekly tank mix combinations of Oso+Badge, Regalia + Badge, and EcoSwing + Badge perform? Is that added cost of the second product in tank mix cost effective?

	Program 4	Program 5	Program 6
Week 1	Badge+OSO	Regalia+Badge	Badge+EcoSwing
Week 2	Badge+OSO	Regalia+Badge	Badge+EcoSwing
Week 3	Badge+OSO	Regalia+Badge	Badge+EcoSwing
Week 4	Badge+OSO	Regalia+Badge	Badge+EcoSwing
Week 5	Badge+OSO	Regalia+Badge	Badge+EcoSwing
Week 6	Badge+OSO	Regalia+Badge	Badge+EcoSwing
Week 7	Badge+OSO	Regalia+Badge	Badge+EcoSwing

- 3) Data from previous years have suggested that applying Badge alone in alternating weeks controlled alternaria as well as weekly applications of tank mixes of Badge and biorationals. Can programs integrate early Badge applications with later season biorational applications improve disease suppression? How does program performance of a Badge alternated with no spray (None) program change when the Badge is frontloaded and fewer applications are made during crown development? Also, can Carb-O-Nator be used in place of Badge for growers without sacrificing efficacy for growers interested in reducing copper use?

	Program 7	Program 8	Program 9	Program 10
Week 1	Badge	Badge	Carb-O-Nator	Badge
Week 2	Badge	Badge	Carb-O-Nator	Badge
Week 3	Badge	Badge	Carb-O-Nator	Badge
Week 4	None	Oso	Oso	EcoSwing
Week 5	Badge	Badge	Carb-O-Nator	Badge
Week 6	None	Oso	Oso	EcoSwing
Week 7	None	Oso	Oso	EcoSwing

- 4) Compared to the yellow programs, is there any benefit to tank mixing Badge with a bio-fungicide (Regalia) when applications are made on the same schedule as in the yellow programs? Is the co-application of another bio-fungicide product (Stargus) instead of Badge cost effective? Does the biorational selected for alternation impact the performance of the program (Oso vs Stargus)

	Program 11	Program 12	Program 13	Program 14
Week 1	Regalia+Badge	Regalia+Badge	Regalia+Badge	Regalia+Stargus
Week 2	Regalia+Badge	Regalia+Badge	Regalia+Badge	Regalia+Stargus
Week 3	Regalia+Badge	Regalia+Badge	Regalia+Badge	Regalia+Stargus
Week 4	NONE	Stargus	Oso	Oso
Week 5	Regalia+Badge	Regalia+Badge	Regalia+Badge	Regalia+Stargus
Week 6	NONE	Stargus	Oso	Oso
Week 7	NONE	Stargus	Oso	Oso

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- 5) Can delaying the initiation of a fungicide program comprised of the best performers from previous years (Badge and Oso) provide comparable levels of disease control to weekly applications of copper or tank mixes of copper and biorationals?

	Program 15	Program 16
Week 1	None	None
Week 2	None	None
Week 3	Badge	None
Week 4	Badge+Oso	None
Week 5	Badge	Badge
Week 6	Badge+Oso	Badge+Oso
Week 7	Badge+Oso	Badge+Oso