Quantifying Benefits of Biofungicides in Vegetable Disease Management using Novel Disease Detection Methods - 2019

Project Leaders

Amara Dunn[1], Elizabeth Buck[2], Meg McGrath[3], Crystal Stewart[4]

Cooperator

Sarah Pethybridge[3]

[1]NYS Integrated Pest Management Program; [2]Cornell Vegetable Program; [3]Cornell University, School of Integrative Plant Science, Plant Pathology & Plant-Microbe Biology; [4]Eastern NY Commercial Horticulture Program

Abstract

The primary goal of this project was to generate data on the efficacy and economic impacts of incorporating biofungicides into management of two important vegetable diseases: cucurbit powdery mildew and white mold. Another goal was to evaluate the utility of NDVI (normalized difference vegetation index) sensors for plant health assessment and early disease detection in vegetable crops. In the second year of the project, we conducted replicated trials on research and commercial vegetable farms. Results did not give a clear answer to the question “Can biofungicides effectively replace some conventional fungicides for control of cucurbit powdery mildew?” Replacing alternate conventional fungicide applications with biofungicides often resulted in nearly as good control of powdery mildew and yield as the full conventional fungicide program. However, at two of three trial locations the full conventional fungicide program and a conventional fungicide program where alternate sprays were skipped did not result in statistically different disease control or yield. There were few statistically significant differences in plant health (as measured by NDVI) among treatments, and NDVI readings were most frequently correlated with yield and disease in the trial that had the greatest differences in NDVI values among treatments (Long Island). There were almost no significant differences in fruit quality (Brix) among treatments. In the Western and Eastern NY trials, the organic treatment resulted in powdery mildew control, yield, plant health and fruit quality that was no better than the non-fungicide-treated control that was also planted to a resistant variety. In the Long Island trial, the organic treatment resulted in significantly better powdery mildew control than using no fungicides at all, but not as good as the conventional or conventional/biofungicide treatments. Disease pressure from cucurbit powdery mildew was moderate in the Eastern NY trial, and moderate to high in the LI and Western NY trials. Results for the efficacy of biofungicides against white mold were similarly inconclusive. In the Western NY white mold trials, there was very little white mold even in the non-treated controls, so no differences were detected in plant health (NDVI), disease, or yield among any of the treatments. In the Eastern NY white mold trial treatments that included Contans had (marginally) significantly higher yields, but there was so little disease in the non-treated control that this difference may not have been due to efficacy of Contans.

Background and Justification

Biofungicides are increasingly available for the control of vegetable diseases in NY and are starting to be incorporated into disease management programs in order to reduce use of conventional fungicides, limit fungicide resistance, protect the environment, or improve plant health. Our goal is to quantify the benefits and costs of biofungicides for vegetable disease management. This will enable growers to make informed decisions - whether they already use biofungicides, or are hesitant to try them without unbiased efficacy and economic data. Ultimately, we hope that this project will lead to improved disease control and replacement of some conventional fungicide sprays with biofungicides, reducing the use of products with potentially negative environmental impacts.

Biofungicides can reduce cucurbit powdery mildew infection, but may be less effective than conventional fungicides when used alone. However, if alternated with conventional fungicides, they could reduce environmental and human health impacts of managing cucurbit powdery mildew, while also prolonging the efficacy of conventional fungicides against the powdery mildew pathogen, for which fungicide resistance is a serious concern. Results from the first year of this project did not suggest that adding biofungicides to a full conventional fungicide program for cucurbit powdery mildew significantly improved disease control, yield, or fruit quality. Therefore, in the second year, we evaluated powdery mildew fungicide programs in which biofungicides replaced alternate conventional fungicide programs. We also included a treatment made up of only OMRI-listed fungicides.

Contans contains a fungus that degrades overwintering sclerotia of the white mold pathogen, but a single application is not expected to destroy all sclerotia. Control might be enhanced by using Contans with other biofungicides like Double Nickel (which was effective against white mold on snap beans in another Cornell study). The current project sought to quantify the value of using these products singly or in combination.

Biofungicides should be integrated into a systems approach that considers plant health, environmental management, and chemical/biological controls. In addition to traditional indicators of efficacy, we used NDVI sensors to measure the impact of biofungicides on crop stress and plant health. The ability to remotely sense NDVI has enhanced precision management in other crops, and could be a valuable tool for vegetable farms. We wanted to know whether NDVI assessments were correlated with disease, yield, or fruit quality (Brix). Because many of these farms are highly diversified, a relatively inexpensive handheld NDVI sensor may be a better option for early detection of plant disease or stress.

Objectives

1. Determine whether replacing alternate conventional fungicide applications for cucurbit powdery mildew in winter squash with one of three OMRI-listed biofungicides (LifeGard, Regalia, or Serifel) resulted in at least as good disease control, plant health (NDVI), yield, or fruit quality (Brix) as the full conventional fungicide program. These treatments were also compared to a conventional fungicide program in which every other spray was skipped and a spray program composed of OMRI-listed (organic) products.
2. Determine whether using Double Nickel in combination with Contans improves control of white mold, plant health (NDVI), or yield.
3. Quantify the economic impact of including biofungicides in disease management programs for cucurbit powdery mildew and white mold.
4. Collect preliminary data on the utility of NDVI sensors in early detection of disease or differences in plant health that could be caused by the use of biofungicides.
5. Assess the intention of growers to change their use of biofungicides or chemical fungicides for control of cucurbit powdery mildew and white mold.

Procedures

The fungicides and rates used the trials are summarized in Table 1.

Table 1. Rates for pesticides (conventional fungicides, biofungicides, and other OMRI-listed products) used at each of the three trial sites.

	Rate		
Fungicide	**WNY**	**ENY**	**LI**
White mold			
Contans[a]	2 lb/A	2 lb/A	-
Double Nickel LC[a]	2 qt/A	2 qt/A	-
Powdery mildew			
LifeGard WG[b]	4 oz/100 gal	4 oz/100 gal	4.5 oz/100 gal
Luna Experience[c]	10 fl oz/A	10 fl oz/A	10 fl oz/A
MilStop	3 lb/A	3 lb/A	3 lbs/A
Quintec	6 fl oz/A	6 fl oz/A	6 fl oz/A
Regalia	2 qt/A	2 qt/A	2 qts/A
Serifel	9 oz/A	8 oz/A	8 oz/A
SuffOil-X	1 % v/v	1 % v/v	1% v/v
Vivando	12 fl oz	15 fl oz/A	15 fl oz/A

[a] The white mold trial was only run in Eastern and Western NY in 2019.

[b] The rate on the LifeGard label is in oz/100 gal. Therefore, the per acre rate varies, depending on the volume of the spray application. Volumes for Western NY, Eastern NY, and Long Island were 30 gal/A, 40 gal/A, and 72 gal/A, respectively.

[c] Luna Experience is not allowed for use on Long Island.

White mold

In Eastern NY (ENY), small replicated plots of snap beans (single 20 ft long row) on a vegetable farm were treated with only Contans prior to planting; Contans prior to planting and two applications of Double Nickel at bloom; only Double Nickel at bloom; or no fungicide for white mold. Contans was applied on 22 May and Double Nickel applications were made at about 10% bloom (late June or early July), and approximately one week later. NDVI, disease incidence, and yield data were collected.

In Western NY (WNY), small replicated plots (6 ft x 9 ft) of snap, flat Italian, and yellow wax beans received the same treatments. Contans was applied on 21 May. In the same field, tomatoes were later planted across replicated plots that either did or did not receive Contans.

Cucurbit powdery mildew

Small (10 or 12 plants per plot) trials were conducted at three locations: a research farm in Western NY (WNY), a commercial vegetable farm in Eastern NY (ENY), and the Cornell University research farm on Long Island (LI). All trials used a bush acorn squash variety (‘Honey Bear’) with intermediate powdery mildew resistance.

The biofungicides LifeGard, Regalia, and Serifel were applied twice before the conventional fungicide program was initiated. The first biofungicide was applied 4-5 weeks after direct-seeding the squash, with the goal of making two biofungicide applications before disease was detected. Once disease was detected, applications of conventional fungicides or the other organic products began. Applications were made every 7-10 days. Spray programs varied among trial locations due to factors like weather and crop development. The planned spray program is shown as an example (Table 2). Costs for each spray program were calculated from estimated average costs per acre for each product (Table 3). Disease was assessed by rating 10 leaves per plot for the percent of the leaf surface covered by powdery mildew or by assessing percent disease on the plant canopy in the entire plot. Disease was rated multiple times during the season, and used to calculate the area under the disease progress curve (AUDPC) for each plot. In the Western NY trial, Vivando was accidentally applied to all treatments (except the Organic treatment) at first disease detection, including the non-treated control.

Table 2. Powdery mildew spray program. There was some variation in spray schedules among sites due to factors like weather and plant development.

Date	Non-treated	Conventional	Conventional + skip	Conventional + LifeGard[a]	Conventional + Regalia[a]	Conventional + Serifel[b]	Organic[ab]
~14 days before disease	-	-	-	LifeGard (4 oz/100 gal)	Regalia (2 qt/A)	Serifel (8 oz/A)	LifeGard (4 oz/100 gal)
~7 days before disease	-	-	-	LifeGard (4 oz/100 gal)	Regalia (2 qt/A)	Serifel (8 oz/A)	LifeGard (4 oz/100 gal)
First disease detection	-	Vivando (15 fl oz/A)	Vivando (15 fl oz/A)	Vivando (15 fl oz/A)	Vivando (15 fl oz/A)	Vivando (15 fl oz/A)	MilStop (3 lb/A)
+7-10 days	-	Luna (10 fl oz/A)	-	LifeGard (4 oz/100 gal)	Regalia (2 qt/A)	Serifel (8 oz/A)	Serifel (8 oz/A)
+14-17 days	-	Quintec (6 fl oz/A)	Quintec (6 fl oz/A)	Quintec (6 fl oz/A)	Quintec (6 fl oz/A)	Quintec (6 fl oz/A)	SuffoilX (1% v/v)
+21-24 days	-	Vivando (15 fl oz/A)	-	LifeGard (4 oz/100 gal)	Regalia (2 qt/A)	Serifel (8 oz/A)	MilStop # (3 lb/A)
+28-31 days	-	Luna (10 fl oz/A)	Luna (10 fl oz/A)	Luna (10 fl oz/A)	Luna (10 fl oz/A)	Luna (10 fl oz/A)	Serifel (8 oz/A)
+35-38 days	-	Quintec (6 fl oz/A)	-	LifeGard (4 oz/100 gal)	Regalia (2 qt/A)	Serifel (8 oz/A)	SuffoilX (1% v/v)

[a] LifeGard and Regalia were tank mixed with Nu Film P (1 qt/100 gal)

[b] Serifel was tank mixed with EcoSpreader (4 fl oz/100 gal), but only at spray volumes of 30 or 40 gal/A.

Table 3. Approximate costs per acre of products included in this trial, as provided by a NY distributor or estimated from available prices found online. Prices may vary.

Fungicide	Rate/A		Cost/A/ application
Contans	2	lb	$55.00
Double Nickel LC	2	qt	$35.93
LifeGard[a]	2	oz	$14.38
Luna Experience	10	fl oz	$57.00
MilStop	3	lb	$42.00
Quintec	6	fl oz	$24.90
Regalia	2	qt	$38.50
Serifel	8	oz	$58.50
SuffOil-X[b]	1%	v/v	$14.00
Vivando	15	fl oz	$32.34

[a] LifeGard rate is 4 oz/100 gal. Rate and cost shown here assume a 50 gal/A spray volume.

[b] Suffoil-X cost assumes a 50 gal/A spray volume.

Results and Discussion

White mold

There was very little disease in the white mold trials in 2019. In the Western NY bean trial no significant differences in disease or yield were detected among treatments (Table 4). No plant health (NDVI) results were collected in the bean trial because of severe weed pressure. NDVI measurements would only have assessed the health of weeds in the trial. The tomato trial was abandoned due to a combination of herbicide failure and illness of the collaborator.

Table 4. Disease and yield from white mold trials on beans in Western NY. No differences among treatments were statistically significant at $P = 0.05$. SE = standard error

		AUDPC		Yield (lb)[a]	
Treatment	**Bean type**	**Mean**	**SE**	**Mean**	**SE**
Non-treated	Flat Italian	2.1	2.1	45.6	11.2
Contans	Flat Italian	7.9	7.9	38.8	5.7
Contans & Double Nickel	Flat Italian	0	0	45.5	4.8
Double Nickel	Flat Italian	0	0	33.3	5.3

		AUDPC		Yield (lb)[a]	
Treatment	**Bean type**	**Mean**	**SE**	**Mean**	**SE**
Non-treated	Snap	2.3	2.3	48.2	12.8
Contans	Snap	0	0	49.2	7.0
Contans & Double Nickel	Snap	5.7	5.7	41.6	1.4
Double Nickel	Snap	0	0	69.9	8.9
Non-treated	Yellow Wax	9.7	6.6	58.9	9.1
Contans	Yellow Wax	0	0	51.9	10.3
Contans & Double Nickel	Yellow Wax	0	0	42.1	9.6
Double Nickel	Yellow Wax	1.4	1.4	53.6	10.3

[a] Weight of healthy bean pods per 100 ft of row were estimated based on harvesting 5 ft of row from each plot, then summed over multiple harvest dates.

In the Eastern NY bean trial too little disease occurred to be assessed. Differences in NDVI among treatments were not statistically significant. Differences in yield among treatments were marginally significant (*P* = 0.06), with higher yields in plots to which Contans had been applied during the spring. However, the fact that so little disease was observed in any plots (including the non-treated plots that received neither Contans nor Double Nickel) calls into question whether this difference is really due to degradation of sclerotia by the active ingredient in Contans. The NDVI readings were not significantly correlated with yield.

Table 5. NDVI and yield from white mold trial on snap beans in Eastern NY. Both measurements were made on 19 July. SE = standard error

	NDVI		Yield (lbs)[a]		
Treatment	Mean	SE	Mean		SE
Non-treated	0.73	0.01	5.5	b[b]	0.2
Contans	0.71	0.01	9.1	a	0.8
Contans & Double Nickel	0.69	0.03	8.9	a	0.9
Double Nickel	0.68	0.01	5.2	b	0.4

[a] Weight of pods per plot

[b] Means followed by the same letter are not significantly different according to a Friedman's test (*P* = 0.06) followed by a Fisher's LSD (*P* = 0.05).

Cucurbit powdery mildew – disease severity

The fact that the full conventional fungicide program and the conventional fungicide program that skipped every other spray did not result in statistically significant differences in disease in two of the three trial sites complicates the interpretation of the results. In Western and Eastern NY, alternating conventional fungicides with either LifeGard or Serifel resulted in statistically similar disease control (as measured by AUDPC) compared to the full conventional program (and to the conventional/skip fungicide program). Alternating conventional fungicides with Regalia resulted in significantly higher disease at these two sites. The organic treatment resulted in statistically similar (Eastern NY) and significantly more severe (Western NY) disease compared to the nontreated control. However, in the Long Island trial, all three biofungicides resulted in similar disease control; significantly worse than the conventional fungicide program, but much better than the non-treated control (and similar to the conventional/skip treatment). In other disease assessments (e.g., on individual dates, the lower leaf surface), the conventional/skip treatment was not as good at the full conventional program. The organic program did not provide as good control as the conventional, conventional/skip or conventional/biofungicide programs, but was better than the non-treated control. On the following graphs, the cost (per acre) of each treatment as it was applied in the trial is shown. Disease ratings taken on the upper and lower leaf surfaces over the entire season are summarized in Tables 6 and 7.

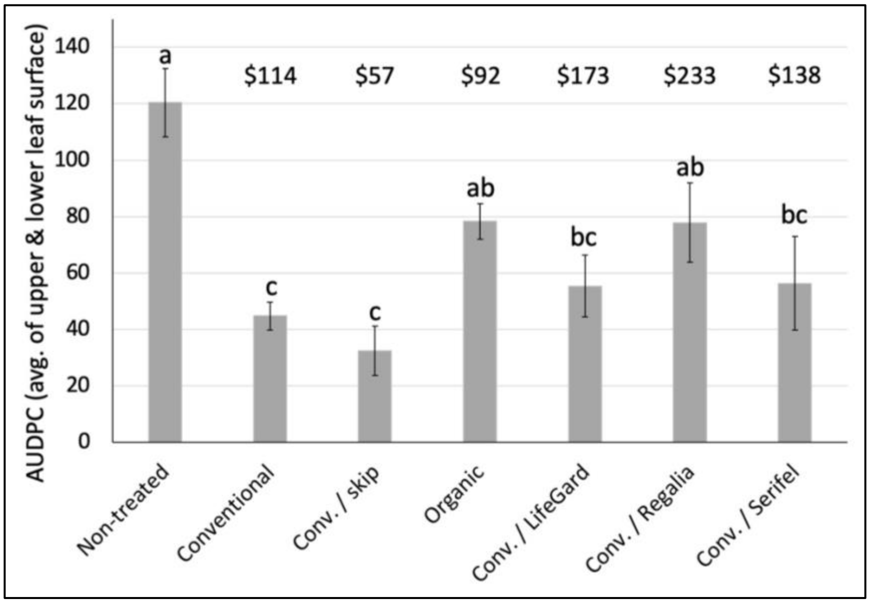

Figure 1. Severity of cucurbit powdery mildew in the Eastern NY trial. Disease ratings on lower and upper leaf surfaces were averaged for each date, and these averaged ratings were used to calculate AUDPC (area under the disease progress curve). Error bars show one standard error above and below the mean value for each treatment. Bars labeled with the same letter are not significantly different based on a Friedman's test (*P* = 0.01). The cost (per acre) of fungicides for each treatment as applied in the trial is shown above each bar.

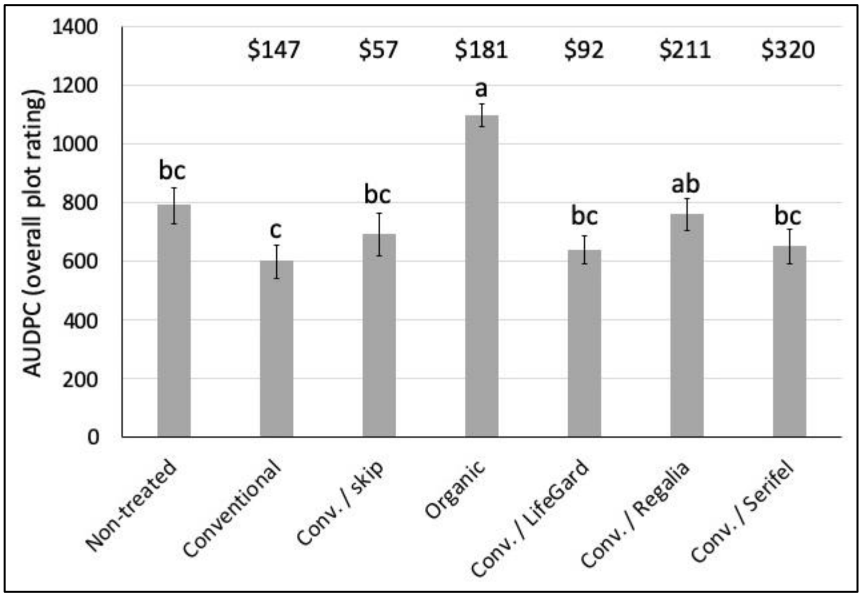

Figure 2. Severity of cucurbit powdery mildew in the Western NY trial. Whole plots were visually rated for the percent of the canopy with powdery mildew, and these ratings were used to calculate AUDPC (area under the disease progress curve). Error bars show one standard error above and below the mean value for each treatment. Bars labeled with the same letter are not significantly different based on a Friedman's test (*P* = 0.03). The cost (per acre) of fungicides for each treatment as applied in the trial is shown above each bar.

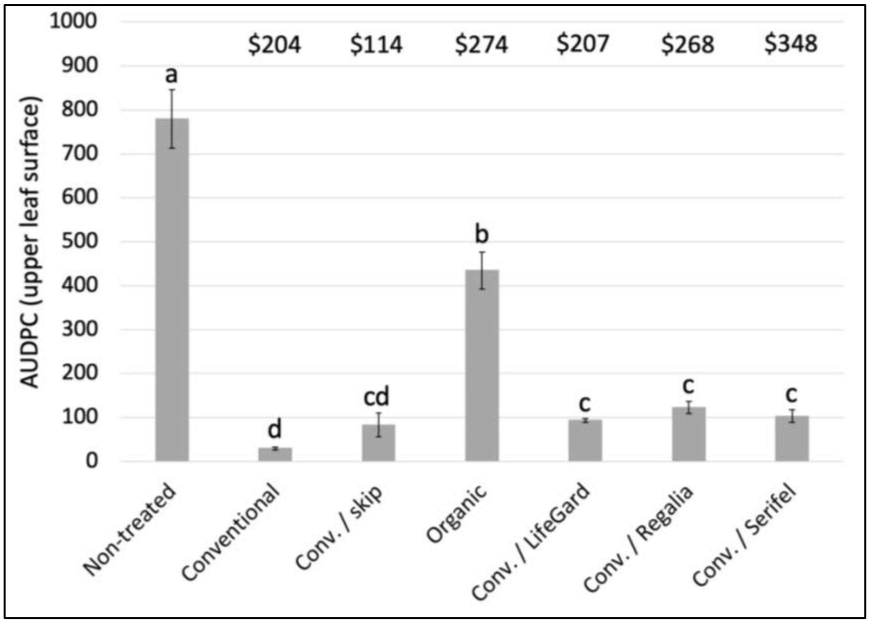

Figure 3. Severity of cucurbit powdery mildew in the Long Island trial. Results shown are from AUDPC (area under the disease progress curve) calculated from rating the upper surfaces of leaves, only. Error bars show one standard error above and below the mean value for each treatment. Bars labeled with the same letter are not significantly different based on an ANOVA (*P* <0.0001) followed by a Tukey's HSD (*P* = 0.05). The cost (per acre) of fungicides for each treatment as applied in the trial is shown above each bar.

Table 6. Severity of powdery mildew on the upper surface of winter squash leaves in the Western NY, Eastern NY, and Long Island trials, quantified as the percent of the leaf surface covered with powdery mildew on the final rating date.

	WNY (9/5/19)		ENY (9/3/19)		LI (9/17)	
Treatment	**Mean**	**SE[a]**	**Mean**	**SE**	**Mean**	**SE**
Non-treated	59.8 a[b]	6.2	21.6 a	2.2	63.0 a	10.4
Conventional	14.1 c	1.8	2.3 d	1.2	3.0 c	0.9
Conventional / skip	36.3 bc	4.8	2.0 d	1.2	13.0 b	4.1
Organic	54.6 a	6.1	11.1 ab	1.6	67.0 a	5.0
Conventional / LifeGard	30.4 bc	5.6	5.2 cd	2.0	13.8 b	0.1
Conventional / Regalia	42.1 ab	5.0	9.8 bc	3.0	23.0 b	3.8
Conventional / Serifel	34.3 b	5.9	4.5 d	1.9	18.0 b	1.0
P-values	0.012		0.006		<0.0001	

[a] SE = Standard error; [b] Means followed by the same letter within a column are not significantly different based on either a Friedman's test (WNY and ENY) or an ANOVA followed by a Tukey's HSD (P = 0.05). P-values for each test are shown at the bottom of the table.

Table 7. Severity of powdery mildew on the lower surface of winter squash leaves in Western NY, Eastern NY, and Long Island trials, quantified as the percent of the leaf surface covered with powdery mildew on the final rating date.

	WNY (9/5/19)		ENY (9/3/19)		LI (9/17)	
Treatment	**Mean**	**SE[a]**	**Mean**	**SE**	**Mean**	**SE**
Non-treated	68.0 b[b]	2.8	22.4 a	2.6	86.0 a	2.8
Conventional	42.1 c	3.7	7.4 cd	1.4	19.4 c	5.0
Conventional / skip	61.0 bc	1.6	5.5 d	2.2	53.1 b	5.6
Organic	82.5 a	1.6	13.9 abc	1.7	87.0 a	3.1
Conventional / LifeGard	62.8 b	10.2	9.0 bcd	3.1	59.9 b	5.0
Conventional / Regalia	66.3 b	5.5	15.2 ab	2.9	52.0 b	5.4
Conventional / Serifel	64.8 b	2.9	9.1 cd	2.2	54.5 b	1.0
P-values	0.017		0.006		<0.0001	

[a] SE = Standard error; [b] Means followed by the same letter within a column are not significantly different based on either a Friedman's test (WNY and ENY) or an ANOVA followed by a Tukey's HSD (*P* = 0.05). *P*-values for each test are shown at the bottom of the table.

Cucurbit powdery mildew - yield

There were no statistically significant differences in yield in the Eastern NY trial. In the Western NY trial, the number of marketable fruit harvested per 10 plants when either LifeGard or Serifel was alternated within a conventional fungicide program was not statistically different from either the full conventional spray program or the conventional program with skips. When Regalia was alternated within a conventional fungicide program, yield was significantly lower. In the Long Island trial, all three biofungicides (alternated with conventional fungicides) resulted in statistically similar yields to both the conventional and the conventional/skip spray programs. Local estimates of prices that could be obtained by selling acorn squash (at auction, wholesale, or in a grocery store) were obtained and used to compare the value of fruit harvested from each plot, extrapolated to a per acre value.

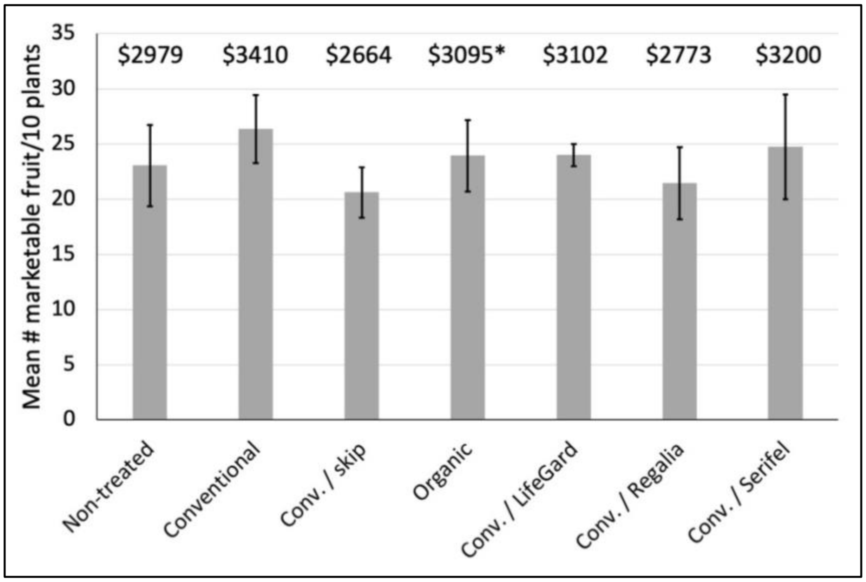

Figure 4. Yield in Eastern NY cucurbit powdery mildew trial. The average number of marketable fruit per plot of 10 plants is shown. Error bars show one standard error above and below the mean value for each treatment. There were no statistically significant differences in yield among treatments (Friedman's test P = 0.352). The yield per plot of 10 plants was extrapolated to yield per acre (assuming 6 ft between rows and 2 ft between plants within rows, resulting in 3,620 plants/A) and used to estimate the average local wholesale value (per acre) of each treatment, shown above each bar. The value of the organic treatment (*) was not adjusted to account for expected higher prices for certified organic produce.

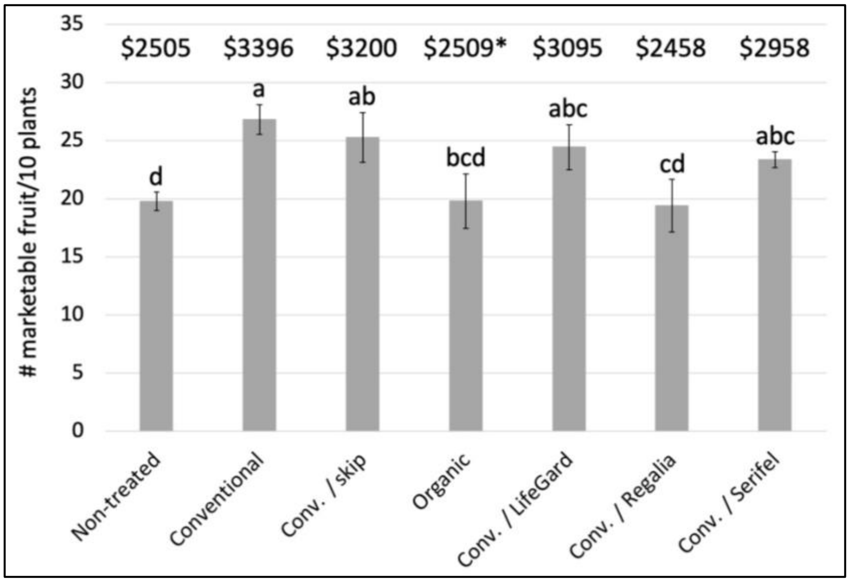

Figure 5. Yield in Western NY cucurbit powdery mildew trial. The average number of marketable fruit per 10 plants is shown. Error bars show one standard error above and below the mean value for each treatment. Bars labeled with the same letter are not significantly different based on a Friedman's test (*P* = 0.05). The yield per plot of 10 plants was extrapolated to yield per acre (assuming 6 ft between rows and 2 ft between plants within rows, resulting in 3,620 plants/A) and used to estimate the average local auction value (per acre) of each treatment, shown above each bar. The value of the organic treatment (*) was not adjusted to account for expected higher prices for certified organic produce.

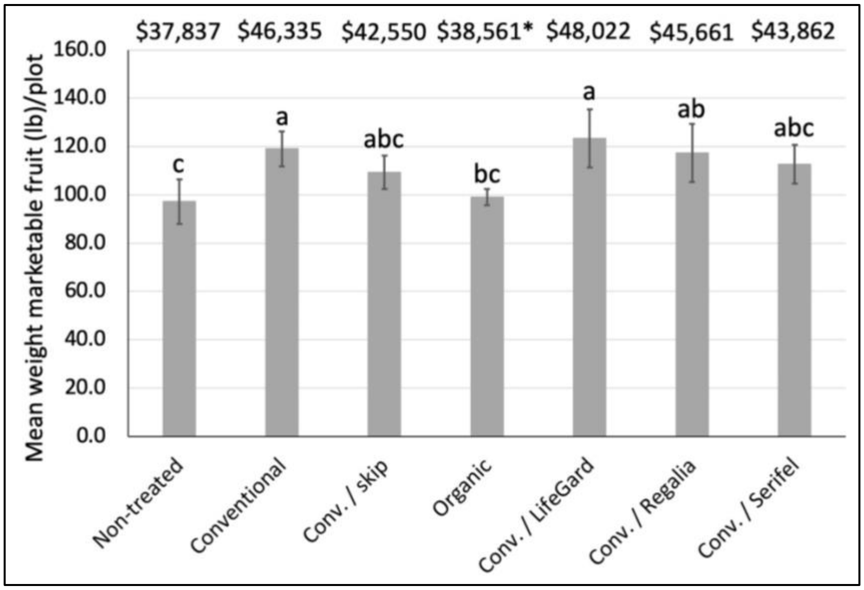

Figure 6. Yield in Long Island NY cucurbit powdery mildew trial. Mean weight of marketable fruit harvested per plot of 12 plants is shown. Error bars show one standard error above and below the mean value for each treatment. Bars labeled with the same letter are not significantly different based on an ANOVA (*P* <0.0001) followed by a Tuikey's HSD (*P* = 0.05). The yield per plot of 12 plants was extrapolated to yield per acre (assuming 6 ft between rows and 2 ft between plants within rows, resulting in 3,620 plants/A) and used to estimate the average value based on the price at local grocery stores (per acre) of each treatment, shown above each bar. The value of the organic treatment (*) was not adjusted to account for presumably higher prices for certified organic produce.

Cucurbit powdery mildew - fruit quality and plant health

The most substantial differences in NDVI values among treatments were in the Long Island trial, where both the non-treated control and the organic treatment had much lower average NDVI values over the season (Table 8). In the Western NY trial, alternating LifeGard with conventional fungicides resulted in a slightly but significantly higher average NDVI than Regalia or Serifel. In the Long Island trial, LifeGard and Regalia had slightly but significantly higher average NDVI readings compared to Serifel.

In the Long Island trial, most NDVI ratings were significantly correlated with visual assessments of disease severity on either the same date or future dates. In the Western NY trial, only later season NDVI measurements were significantly correlated with disease ratings either on the same date or on future dates. In Eastern NY, only NDVI readings taken very late in the season were significantly correlated with disease ratings. In the Long Island and eastern NY trials NDVI readings on most dates were significantly correlated with yield, while only later NDVI readings were significantly correlated with yield in Western NY. There were almost no significant correlations between NDVI readings and Brix in either the Western NY or the Long Island trials, and correlations with Brix in the Eastern NY trial could not be calculated.

Table 8. Normalized difference vegetation index (NDVI) measured over the top of the canopy with a GreenSeeker on multiple dates and averaged over the season at all three trial sites (Western NY, Eastern NY, and Long Island).

	WNY			**ENY**		**LI**		
Treatment	**Mean**		**SE**[a]	**Mean**	**SE**	**Mean**		**SE**
Non-treated	0.78	bc[b]	0.01	0.80	0.01	0.65	c	0.01
Conventional	0.82	a	0.00	0.79	0.00	0.80	a	0.01
Conventional / skip	0.81	a	0.00	0.76	0.02	0.78	b	0.01
Organic	0.75	c	0.01	0.78	0.02	0.65	c	0.01
Conventional / LifeGard	0.81	a	0.01	0.80	0.01	0.79	a	0.01
Conventional / Regalia	0.79	b	0.01	0.74	0.02	0.80	a	0.00
Conventional / Serifel	0.79	b	0.01	0.79	0.03	0.77	b	0.00
P-values	0.003			0.117		0.003		

[a] SE = standard error

[b] Means followed by the same letter within a column are not significantly different (Friedman's test) at the P-values shown.

There were very few statistically significant differences in Brix values among treatments (Table 9). The only exception was that the Brix value for the Conventional/LifeGard treatment in Eastern NY was significantly lower than for the Conventional/Serifel treatment.

Table 9. Brix was measured on 5 marketable fruit per plot (Western NY and Long Island) or on 5 marketable fruit per treatment (Eastern NY).

	WNY		**ENY**			**LI**	
Treatment	**Mean**	**SE**[a]	**Mean**		**SE**	**Mean**	**SE**
Non-treated	10.6	0.5	10.0	ab[b]	1.2	14.5	0.1
Conventional	10.0	0.6	10.2	ab	1.4	14.3	0.2
Conventional / skip	9.9	0.3	9.0	ab	1.4	13.4	0.5
Organic	10.0	0.4	12.2	ab	1.0	13.9	1.1
Conventional / LifeGard	10.4	0.3	7.2	b	0.9	13.0	0.4
Conventional / Regalia	10.5	0.2	8.7	ab	0.8	14.5	0.4
Conventional / Serifel	9.8	0.5	13.4	a	1.2	13.6	0.3
P-value	0.393		0.03			0.306	

[a] SE = standard error

[b] Means followed by the same letter within a column are not significantly different at the P-values shown when Friedman's, Kruskal-Wallis (followed by Dunn's P = 0.05), and ANOVA tests were run on data from Western NY, Eastern NY, and Long Island, respectively.

Summary of Findings

Overall, results suggest that biofungicides may be able to effectively replace some conventional fungicide sprays for cucurbit powdery mildew, but more work is needed before making specific recommendations to growers. Of the three biofungicides we studied, none was consistently better or worse across all trials. Future studies might investigate how many or which conventional sprays should be replaced with biofungicides. Studies conducted in larger plots might also help elucidate minor differences that were obscured in this small plot trial. While NDVI values were somewhat correlated with future disease ratings, this project does not suggest that this technology could be used to replace visual scouting for cucurbit powdery mildew. Because disease pressure was very low, no conclusions can be drawn about the effectiveness of combining Contans with Double Nickel to control white mold on beans.

Cucurbit powdery mildew - cost of treatments

Depending on the trial location (and accompanying variations in spray schedules and rates), alternating conventional fungicides with biofungicides ranged from slightly less expensive than the conventional fungicide program to more than twice the cost. Although in most cases there were no statistically significant differences in the value of the crop between the conventional/biofungicide programs and the full conventional program, the numerical value of the crop ranged from being slightly higher (LifeGard alternated with conventional fungicides on Long Island) to lower (all other biofungicide treatments). Again, the lack of statistically significant differences between the full conventional spray program and the conventional spray program with skips makes any conclusions about the economics of replacing some conventional fungicides with biofungicides, tentative, at best. Furthermore, these were very small plot trials, where it can sometimes be difficult to detect yield differences. More studies would be needed to clarify these results.

Outreach and Evaluation

In Summer 2019, twilight meetings in Western and Eastern NY and on Long Island were attended by 90 growers and industry professionals. We shared information about how the biofungicides compared in these trials, and best practices for using them effectively. While 16% of responding meeting participants reported that they had used biofungicides to manage cucurbit powdery mildew in 2019, at the end of the meeting 53% planned to use biofungicides in 2020, and the remaining respondents said they might use them. All attendees reported increased knowledge about biofungicides and how to use them as part of IPM.

Results from the second year of the trial were shared with growers (83 attendees) at the 2020 Empire State Producers Expo. Out of those who responded to a survey at this meeting, 32% reported that they were not currently using biofungicides, but planned to start using them, and 79% reported increased knowledge about biofungicides and using them as part of IPM.

More general information about what biopesticides are, how they work, and how they should be used was also shared through presentations reaching growers and industry professionals representing various commodities (334 total).

Project locations

Trials were conducted at Cornell Lake Erie Research and Extension Laboratory in Portland, NY (Chautauqua County), on vegetable farms in Eastern NY (Columbia, Fulton, and Montgomery Counties), on a vegetable farm in Western NY (Niagara County) and at Long Island Horticultural Research and Extension Center (LIHREC) Cornell University (Suffolk County).

Resources developed

Dunn, A.R., Buck, E., McGrath, M.T., Pethybridge, S.J., Stewart, C., and Telenko, D. "And the results are in…from Year 1. What do biofungicides add to vegetable disease management Part 3" *Biocontrol Bytes*. New York State Integrated Pest Management Program, Cornell University, 6 April 2019. Web, accessed 6 April 2019.

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Dunn, A.R., Buck, E., McGrath, M.T., Pethybridge, S.J., Steward, C., and Telenko, D. "And the results are in...from Year 1. What do biofungicides add to vegetable disease management Part 3" VegEdge (April 17, 2019) vol. 15(5):4-6. Web, accessed 19 April 2019.

Two summaries of the biofungicides used in these trials continue to be shared with growers:

Dunn, A.R. "Quantifying benefits of biofungicides in white mold management using novel disease detection methods –Year 1 Summary." New York State Integrated Pest Management Program, Cornell University. Web, accessed 1 April 2019.

Dunn, A.R. "Quantifying benefits of biofungicides in cucurbit powdery mildew management using novel disease detection methods – Year 1 Summary." New York State Integrated Pest Management Program, Cornell University. Web, accessed 1 April 2019.

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