What do biopesticides add to your cucurbit powdery mildew program?

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Here we report the results from the first year of a two-year project. The goal of this project is to quantify the benefits of adding biofungicides to a cucurbit powdery mildew management program. In this first year, we wanted to determine whether adding three biofungicides (LifeGard, Regalia, or Serifel) to a conventional chemical fungicide program would improve disease control, plant health, yield, or fruit quality. These treatments were compared to a conventional chemical spray program and a spray program composed of OMRI-listed (organic) products. We started with an intensive spray program (i.e., short spray interval, frequent use of biofungicides), to ensure that an inability to detect effects of adding biofungicides was not due to insufficient applications.

Small plot (10 or 12 plants each) trials were conducted at three locations: a research farm in Western NY (WNY), a commercial vegetable farm in Eastern NY (ENY), and a 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 every 7-10 days, starting when plants had at least two true leaves. Once disease was detected, applications of conventional chemicals or organic products began. Product rates varied somewhat among the three trials, including an accidental application of LifeGard in WNY at more than twice the labeled rate (Table 1). Spray programs also varied due to factors like weather and crop development. The spray program for the LI trial is provided as an example (Table 2). Costs for the spray program were calculated from estimated average costs per acre for each product (Table 3).

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

	Rate		
Fungicide	WNY	ENY	LI
LifeGard	11.3 oz/100 gal	2.8 oz/100 gal	4.5 oz/100 gal
Luna Experience[a]	10 fl oz/A	10 fl oz/A	6 fl oz/A
MilStop	3 lb/A	3 lbs/A	3 lbs/A
Quintec	6 fl oz/A	6 fl oz/A	4 fl oz/A
Regalia	2 qt/A	2 qts/A	2 qts/A
Serifel	8 oz/A	8 oz/A	8 oz/A
Vivando	15 fl oz/A	15 fl oz/A	15.4 fl oz/A
Oil[b]	1% vol/vol	1% vol/vol	1% vol/vol

[a] Luna Experience is not allowed for use on Long Island.
[b] JMS Stylet oil was used in Western NY. Suffoil-X was used in Eastern NY and Long Island trials.

Table 2. Sprays applied to the Long Island trial in 2018. This schedule is representative of the schedules planned for all three sites, but there was some variation among sites due to factors like weather and plant development. Costs per acre of each spray program were calculated from average costs shown in Table 3.

	Treatment					
Date	Non-treated	Conventional	Conventional + LifeGard	Conventional + Regalia	Conventional + Serifel	Organic
7/19/18	-		LifeGard	Regalia	Serifel	LifeGard
7/27/18	-		LifeGard	Regalia	Serifel	LifeGard
8/3/18	-	Vivando	LifeGard + Vivando	Regalia + Vivando	Serifel + Vivando	MilStop
8/10/18	-	Quintec	LifeGard + Quintec	Regalia + Quintec	Serifel + Quintec	Serifel
8/17/18	-	Luna	LifeGard + Luna	Regalia + Luna	Serifel + Luna	SuffoilX
8/24/18	-	Vivando	LifeGard + Vivando	Regalia + Vivando	Serifel + Vivando	MilStop
8/31/18	-	Quintec	LifeGard + Quintec	Regalia + Quintec	Serifel + Quintec	Serifel
9/7/18	-	Luna	LifeGard + Luna	Regalia + Luna	Serifel + Luna	SuffoilX
Total cost (per A)	-	$228.28	$343.32	$536.28	$696.28	$257.76
Cost increase compared to conventional (per A)	-	$ -	$115.04	$308.00	$468.00	$29.48

Table 3. Average 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
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.

Short summary of results

We did not detect any statistically significant improvement in disease control, yield, plant health (as measured by NDVI), or fruit quality (Brix) from adding any biofungicide to a conventional cucurbit powdery mildew spray program. All biofungicide + conventional fungicide treatments were statistically the same as using the conventional fungicides alone. Disease pressure was relatively low in the ENY trial, and moderate in LI and WNY. In the WNY and ENY trials, the organic treatment resulted in statistically similar disease control, yield, plant health and fruit quality, when compared to both the conventional treatment and the non-treated control. In the LI trial, statistical analysis of the organic treatment was limited by plant death from Phytophthora blight, but the organic treatment provided similar powdery mildew control to the conventional fungicide program through late August. In many cases, there was no statistically significant difference between the conventional fungicide program and the non-treated control, making it difficult to draw clear conclusions from these data. Other challenges, like pressure from aphids or other diseases, or relatively low pressure from cucurbit powdery mildew may also have influenced the results.

Disease and yield

We saw no evidence that treatment influenced the date on which powdery mildew was first detected in the plots. Disease was detected later in ENY (mid-August) compared to WNY and LI (1 Aug). In addition, a severe aphid outbreak in WNY and plant death due to Phytophthora blight on LI were confounding factors in these trials. In both WNY and LI trials, all treatments that included conventional chemicals (whether or not they included biofungicides) resulted in significantly less disease than the non-treated control. Disease severity in the organic treatment was not statistically different from the control or the conventional spray program over the entire season (AUDPC), at any of the sites (Table 4). However, in the LI trial the organic treatment provided good powdery mildew control through late August. By the last disease rating date (17 Sep), powdery mildew control on the organic treatment was not as good as the other treatments, but this was 10 days after the last fungicide application. There were no statistically significant differences in weight of marketable fruit among the treatments at any of the sites (Table 5). Because two of the four organic plots were wiped out by Phytophthora blight in the LI trial, we were not able to statistically compare this treatment to other treatments.

Table 4. Severity of powdery mildew on winter squash in Western NY, Eastern NY, and on Long Island.

	Powdery mildew on the upper surface of the leaves[a]					
	WNY (AUDPC)		ENY (% of leaf)		LI (AUDPC)	
Treatment	Mean	SE	Mean	SE	Mean	SE
Non-treated control	810.1 a[b]	99.70	16.8 a	0.05	348.2 a	84.47
Organic	702.2 ab	52.82	22.5 a	0.03	324.8[c]	
Conventional	437.3 bc	48.94	17.5 a	0.05	9.4 b	5.78
LifeGard + Conventional	418.6[d] bc	87.98	13.0 a	0.06	7.5 b	3.88
Regalia + Conventional	285.4 c	6.63	11.0 a	0.03	8.7 b	15.13
Serifel + Conventional	449.6 bc	91.52	12.5 a	0.01	6.2 b	3.76

[a] Severity was quantified either as the area under the disease progress curve (AUDPC) measured over the whole season, or as the percent of the leaf surface covered with powdery mildew.
[b] Means followed by the same letter are not significantly different at $P = 0.05$. SE = standard error.
[c] Plants in two of the four organic plots were killed by Phytophthora blight in the LI trial, so this treatment could not be included in the statistical analysis.
[d] In WNY, LifeGard was accidentally applied at a much higher rate (11.3 oz/100 gal).

Table 5. Yield at all three sites was assessed by comparing the weight of marketable fruit harvested per 10 healthy plants to account for some plant death due to causes other than powdery mildew.

	Weight (lbs) of marketable fruit per 10 healthy plants					
	WNY		ENY		LI	
Treatment	Mean	SE	Mean	SE	Mean	SE
Non-treated control	28.7 a[a]	7.9	27.2 a	4.5	43.5 a	2.4
Organic	17.4 a	5.6	24.0 a	2.3	32.4[b] a	
Conventional	22.4 a	2.0	28.6 a	2.6	28.6 a	6.7
LifeGard + Conventional	28.9[c] a	2.3	22.3 a	3.1	52.0 a	9.9
Regalia + Conventional	29.0 a	2.0	22.2[d] a	1.9	44.2 a	6.1
Serifel + Conventional	19.9 a	4.0	25.7 a	1.7	33.1 a	5.0

[a] Means followed by the same letter are not significantly different at $P = 0.05$. SE = standard error.
[b] Plants in two of the four organic plots were killed by Phytophthora blight in the LI trial, so this treatment could not be included in the statistical analysis.
[c] In WNY, LifeGard was accidentally applied at a much higher rate (11.3 oz/100 gal).
[d] Only 3 replicate plots could be included in the analysis of the Regalia + Conventional treatment in the ENY trial.

Fruit quality and plant health

In WNY, there were no statistically significant differences in Brix among any of the treatments. In the LI trial, adding any of the biofungicides did not result in a statistically significant increase in Brix compared to the conventional fungicide program, alone. Adding LifeGard to the conventional fungicide program significantly increased Brix compared to the non-treated control. When other biofungicides were added to the conventional spray program, Brix values were numerically but not statistically different from the non-treated control (Table 6).

Table 6. Brix was measured on 5 marketable fruit per plot and the average Brix per plot was compared among treatments in WNY and LI trials.

	Brix - WNY		Brix - LI	
Treatment	Mean	SE	Mean	SE
Non-treated control	9.0 a[a]	0.45	8.3 b	0.7
Organic	9.8 a	0.79	10.0[b]	
Conventional	9.8 a	0.51	10.5 ab	0.6
LifeGard + Conventional	8.9[c] a	0.45	10.9 a	0.1
Regalia + Conventional	9.5[d] a	0.57	10.6 ab	0.2
Serifel + Conventional	10.1 a	0.48	10.2 ab	0.9

[a] Means followed by the same letter are not significantly different at $P = 0.05$. SE = standard error.
[b] Plants in two of the four organic plots were killed by Phytophthora blight in the LI trial, so this treatment could not be included in the statistical analysis.
[c] In WNY, LifeGard was accidentally applied at a much higher rate (11.3 oz/100 gal).
[d] Only 3 replicate plots could be included in the analysis of the Regalia + Conventional treatment in the WNY trial.

The handheld GreenSeeker was used to collect NDVI data at all three sites. In addition, a Crop Circle mounted to a gator was used to collect NDVI data in WNY. In the WNY and ENY trials, there were not statistically significant differences in average NDVI readings or NDVI readings on individual dates among any of the treatments. In the LI trial, the conventional and all the conventional + biofungicide treatments resulted in statistically higher average NDVI values compared to the non-treated control (Table 7). From late July through 24 Aug, there were no statistically significant differences in NDVI values among treatments in the LI trial. However, on 31 Aug and 17 Sep NDVI values were significantly higher in the conventional fungicide treatment and in all of the conventional + biofungicide treatments compared to the non-treated control. Because two of the four organic plots were wiped out by Phytophthora blight in the LI trial, we were not able to statistically compare this treatment to other treatments.

Overall, we did not see strong evidence that NDVI readings (as assessed by the GreenSeeker or the gator-mounted Crop Circle) enabled early disease detection at any of the three trial sites. At some sites and on some dates the NDVI readings were significantly correlated with yield, Brix, or disease (but usually disease on the same date, rather than a future date). Neither device (the GreenSeeker or the Crop Circle) was more likely to produce readings that were significantly correlated with disease, yield, or Brix.

Table 7. 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 sites. Data from the final three rating dates on LI are also shown.

	NDVI									
	WNY - Avg		ENY - Avg		LI - 31 Aug		LI – 17 Sep		LI - Avg	
Treatment	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Non-treated control	0.73 a[a]	0.02	0.81 a	0.02	0.66 b	0.01	0.47 b	0.01	0.79 b	0.002
Organic	0.72 a	0.01	0.81 a	0.01	0.73	0.02	0.46		0.80[b]	
Conventional	0.73 a	0.01	0.79 a	0.02	0.78 a	0.02	0.62 a	0.01	0.83 a	0.004
LifeGard[c] + Conventional	0.75 a	0.01	0.81 a	0.01	0.82 a	0.02	0.64 a	0.04	0.84 a	0.007
Regalia + Conventional	0.76 a	0.01	0.80 a	0.01	0.83 a	0.01	0.62 a	0.02	0.84 a	0.002
Serifel + Conventional	0.74 a	0.01	0.79 a	0.02	0.79 a	0.01	0.59 a	0.02	0.82 a	0.004

[a] Means followed by the same letter are not significantly different at $P = 0.05$, SE = standard error.
[b] Plants in two of the four organic plots were killed by Phytophthora blight in the LI trial, so this treatment could not be included in the statistical analysis.
[c] In WNY, LifeGard was accidentally applied at a much higher rate (11.3 oz/100 gal).

Overall, we did not see strong evidence that NDVI readings (as assessed by the GreenSeeker or the gator-mounted Crop Circle) enabled early disease detection at any of the three trial sites. In the LI trial, NDVI was only sometimes weakly correlated with disease ratings on the same date. At some later rating dates NDVI was significantly correlated with yield or Brix. In the ENY trial, some but not all early NDVI readings (6 and 16 Aug) were significantly correlated with marketable yield, but there were minimal correlations with disease. In the WNY trial, NDVI readings on individual dates were more often correlated with disease ratings on the same date, and only seldom significantly correlated with disease ratings on a future date. At some (but not all) dates)throughout the season, NDVI was significantly correlated with marketable yield. Neither device (the GreenSeeker or the Crop Circle) was more likely to produce readings that were significantly correlated with disease, yield, or Brix.

Costs of treatments

Not surprisingly, all the biofungicide + conventional treatments were substantially more expensive than the conventional fungicide program (Table 2). Because we did not detect a statistically significant increase in yield as a result of adding the biofungicides to the conventional program, we did not see evidence from these small plot trials that the additional costs were justified. However, disease pressure was relatively low, and sometimes it is difficult to detect yield differences in small research plots. The spray programs we followed were also more intensive than most growers are likely to use. In this first year of the project, we wanted to test a very conservative program. Future trials will assess less intensive programs (e.g., replacing some chemical sprays with biofungicides, instead of applying both on a weekly basis).

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