2016

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UNIVERSITY OF VERMONT EXTENSION
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2016 EVALUATING THE EFFICACY OF ORGANIC APPROVED FUNGICIDES FOR THE CONTROL OF POWDERY MILDEW IN SQUASH

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Powdery mildew grows well in environments with high humidity and moderate temperatures and can be problematic on crops in the Northeast. Cucurbit crops face powdery mildew and often downy mildew on a yearly basis and significant yields losses have been reported. The family of cucurbits is an important part of the diversified crop mix of a typical commercial vegetable farm in Vermont and throughout the Northeast. Growers have been using cultural practices, fungicides, and multiple plantings to mitigate crop loss from powdery mildew, however, the impact of the disease is seasonally dependent and still represents a consistent loss.

Image 1. Powdery mildew on squash stem (left) and leaf (right), Alburgh, Vermont, 2016.

Consumers have become more aware and concerned about the potential health risks and environmental impacts of pesticide use and increased their demand for organic products. As a result, there is greater interest in biopesticides as a potential low-impact management tool. Biopesticides contain microorganisms that work as the active ingredient, which produce a toxin, prey on disease, and/or induce plant resistance. Most of the microorganisms occur naturally in soil or on plant surfaces. These products have not been adequately evaluated in the northeast. Exploring the applications of biofungicides on the broad family of cucurbit crops has potential to positively impact these crops as well as other specialty crops that may benefit from these novel biofungicides. The main objective of this project is to determine the efficacy of organically approved biofungicides for control of powdery mildew in cucurbits.

MATERIALS AND METHODS

The trial was conducted at Borderview Research Farm in Alburgh, VT. The experimental design was a randomized complete block with split plots and four replications. Main plots were five spray treatments (all approved by the Organic Materials Review Institute (OMRI)) and one control, with no fungicide applied (Table 1). Spray treatments consisted of four biofungicides: Regalia (plant extract), Cease *(Bacillus subtilus),* Sonata *(Bacillus pumilus),* Actinovate *(Streptomyces lydicus),* and a copper-based fungicide, Champ.

Table 1. Spray treatment information, 2016.

Spray	Active ingredient
Actinovate	*Streptomyces lydicus*
Cease + Milstop adjuvant	*Bacillus subtilus*(Cease)
Champ	Copper based
Regalia	Plant extract
Sonata	*Bacillus pumilus*

The split plots consisted of two varieties of acorn squash: 'Reba,' which is resistant to powdery mildew and 'Jet,' which is susceptible to powdery mildew. Plots were 12' x 23' with 5' buffers to prevent cross-contamination from biofungicide spray. Squash was spaced 5' between rows and 2' within the row. The previous crop was dry beans. The field was rototilled prior to planting. General plot management is listed in Table 2.

Table 2. General plot management, biofungicide efficacy in squash trial, Alburgh, VT, 2016.

Trial Information	Borderview Research Farm Alburgh, VT
Soil Type	Benson rocky silt loam 8-15% slope
Previous crop	Dry beans
Tillage methods	Rototiller
Varieties	'Jet' acorn squash, powdery mildew susceptible, 85 DTM 'Reba' acorn squash, powdery mildew resistant, 90 DTM
Fertilizer date	30-Apr, 0.91 tons ac^{-1} Pro-gro (5-3-4)
Greenhouse seeding date	16-May
Planting date	3-Jun
Plant spacing	2' x 5'
Plot size	12' x 23'
Flowering date	23-Jun
Powdery mildew arrival date	14-Jul
Harvest date	15-Sep

The squash was transplanted on 3-Jun. Spray treatments were applied on 17-Jun and sprayed seven times, approximately every 7-14 days, until 11-Aug, using a CO_2 pressurized backpack sprayer. Powdery mildew was first sighted on 14-Jul. Plots were scouted weekly, beginning on 5-Aug and continued till 1-Sep. On 1-Sep a final assessment of powdery mildew severity was made by visually assessing the percentage of the plant biomass in each plot infected with powdery mildew. Plots were harvested on 15-Sep. Data was collected on the number of plants harvested, the number of marketable fruit, the number of unmarketable fruit, and the marketable fruit weight which was used to calculate overall yields. A subsample of 10 squash from each variety per plot was stored to evaluate storage life. The stored squash was examined once every three weeks for three months, spoiled squash was removed, and the number of removed squash was noted to determine an overall storage score.

Results were analyzed with an analysis of variance in SAS (Cary, NC). The Least Significant Difference (LSD) procedure was used to separate cultivar means when the F-test was significant ($p< 0.10$).

Variations in yield and quality can occur because of variations in genetics, soil, weather and other growing conditions. Statistical analysis makes it possible to determine whether a difference among varieties is real, or whether it might have occurred due to other variations in the field. At the bottom of each table, a LSD value is presented for each variable (i.e. yield). Least Significant differences (LSD's) at the 10% level of probability are shown. Where the difference between two treatments within a column is equal to or greater than the LSD value at the bottom of the column, you can be sure in 9 out of 10 chances that there is a real difference between the two varieties. Treatments that were not significantly lower in performance than the highest value in a particular column are indicated with an asterisk. In the following example, A is significantly different from C but not from B. The difference between A and B is equal to 1.5, which is less than the LSD value of 2.0. This means that these varieties did not differ in yield. The difference between A and C is equal to 3.0, which is greater than the LSD value of 2.0. This means that the yields of these varieties were significantly different from one another. The asterisk indicates that B was not significantly lower than the top yielding variety.

Variety	Yield
A	6.0
B	7.5*
C	9.0*
LSD	**2.0**

RESULTS AND DISCUSSION

Seasonal precipitation and temperature were recorded with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT. The growing season was dryer than normal with May-September getting 7.27 fewer inches of precipitation as compared to historical averages (Table 3). Temperatures in June-July were comparable to normal averages, while May and August-September were at least 1.8 degrees warmer than normal, per month. Overall, there were an accumulated 2562 Growing Degree Days (GDDs) this season, approximately 268 more than the historical average.

Table 3. Seasonal weather data collected in Alburgh, VT, 2016.

Alburgh, VT	May	June	July	August	September
Average temperature (°F)	58.1	65.8	70.7	71.6	63.4
Departure from normal	1.80	0.00	0.10	2.90	2.90
Precipitation (inches)	1.50	2.80	1.80	3.00	2.50
Departure from normal	-1.92	-0.88	-2.37	-0.93	-1.17
Growing Degree Days (base 50°F)	340	481	640	663	438
Departure from normal	74	7	1	82	104

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger. Alburgh precipitation data from August-October was provided by the NOAA data for Highgate, VT. Historical averages are for 30 years of NOAA data (1981-2010) from Burlington, VT.

When comparing spray treatments across both varieties of squash, no significant difference was seen between treatments in the number of marketable or unmarketable fruit (Table 4). A significant difference was seen for the proportion of plants that produced fruit and were harvested, with Regalia being the best performer as 100.0% of its plants produced fruit. However, all other treatments except for Sonata performed comparably to Regalia. Overall, the marketable fruit from each treatment averaged 93.5%.

Table 4. The effect of spray treatment on plot characteristics across acorn squash varieties Jet and Reba, Alburgh, VT, 2016.

Treatment	Marketable fruit	Unmarketable fruit	Marketable fruit	Harvested plants
	fruit ac^{-1}	fruit ac^{-1}	% of total	% of total plants from plot
Actinovate	15000	1300	92.4	99.0*
Cease	14000	868	94.2	99.0*
Champ	14600	1100	93.2	99.0*
Regalia	13800	1260	92.4	**100.0***
Sonata	14700	552	96.6	93.8
Control	14400	1340	92.0	97.9*
LSD (0.10)	NS	NS	NS	3.32
Trial mean	14400	1070	93.5	98.1

*Treatments marked with an asterisk were not statistically different top performing treatment shown in **bold** (p=0.10).
NS – There was no statistical difference between treatments in a particular column (p=0.10).

Powdery mildew severity rates, across both varieties of squash, was lowest for Champ with 11.3% of the plant biomass infected and Regalia was statistically comparable (Table 5). No significant difference was seen between treatments for storage life or yield.

Table 5. The effect of spray treatment on disease, storage, and yield across acorn squash varieties Jet and Reba, Alburgh, VT, 2016.

Treatment	Powdery mildew	Storage^	Yield
	% of total biomass infected	% shelf-stable	tons ac^{-1}
Actinovate	50.0	95.6	13.3
Cease	58.8	100.0	13.1
Champ	**11.3***	93.8	13.9
Regalia	18.8*	95.8	12.8
Sonata	61.3	100.0	13.5
Control	61.3	97.4	13.2
LSD (0.10)	18.0	NS	NS
Trial mean	43.5	97.1	13.3

^Percent of squash shelf-stable from a subsample of 10 squash, 3 months after harvest.
*Treatments marked with an asterisk were not statistically different top performing treatment shown in **bold** (p=0.10).
NS – There was no statistical difference between treatments in a particular column (p=0.10).

When comparing each squash variety across all of the spray treatments, several statistical differences were seen. Reba had significantly more marketable fruit ac^{-1} while Jet had significantly less unmarketable fruit ac^{-1} (Table 6). Also, Jet had 95.3% marketable fruit out of all fruit produced, which was greater than Reba. No significant difference was seen for the proportion plants that were harvested.

Table 6. The effect of squash variety, Jet and Reba, on plot characteristics across all spray treatments, Alburgh, VT, 2016.

Treatment	Marketable fruit	Unmarketable fruit	Marketable fruit	Harvested plants
	fruit ac^{-1}	fruit ac^{-1}	% of total	% of total plants from plot
Jet	13500	**710**	**95.3**	98.6
Reba	**15400**	1430	91.6	97.6
LSD (0.10)	1290	372	2.14	NS
Trial mean	14400	1070	93.5	98.1

Treatments in **bold** were top performers for the given variable.
NS – There was no statistical difference between treatments in a particular column (p=0.10).

Powdery mildew infection severity rates were significantly lower for Reba, with 29.2% of the plant biomass infected with powdery mildew, while Jet had 57.9% of its biomass infected (Table 7, Figure 1). The difference in infection severity may be due to genetic differences. Reba has been bred to be resistant to powdery mildew, while the Jet variety is considered susceptible. Jet yielded 14.6 tons ac^{-1}, which was significantly higher than Reba, which yielded 12.0 tons ac^{-1} (Table 7, Figure 1). It is interesting to note that Reba tended to produce smaller fruit, which can account for a lower yield in spite of producing a greater number of marketable fruits, compared to Jet.

Table 7. The effect of acorn squash variety, Jet and Reba, on disease, storage, and yield across all spray treatments, Alburgh, VT, 2016.

Treatment	Powdery mildew	Storage^	Yield
	% of total biomass infected	% shelf-stable	tons ac^{-1}
Jet	57.9	99.1	**14.6**
Reba	**29.2**	95.1	12.0
LSD (0.10)	10.4	NS	1.37
Trial mean	43.5	97.1	13.3

^Percent of squash shelf-stable 3 months after harvest.
Treatments in **bold** were top performers for the given variable.
NS – There was no statistical difference between treatments in a particular column (p=0.10).

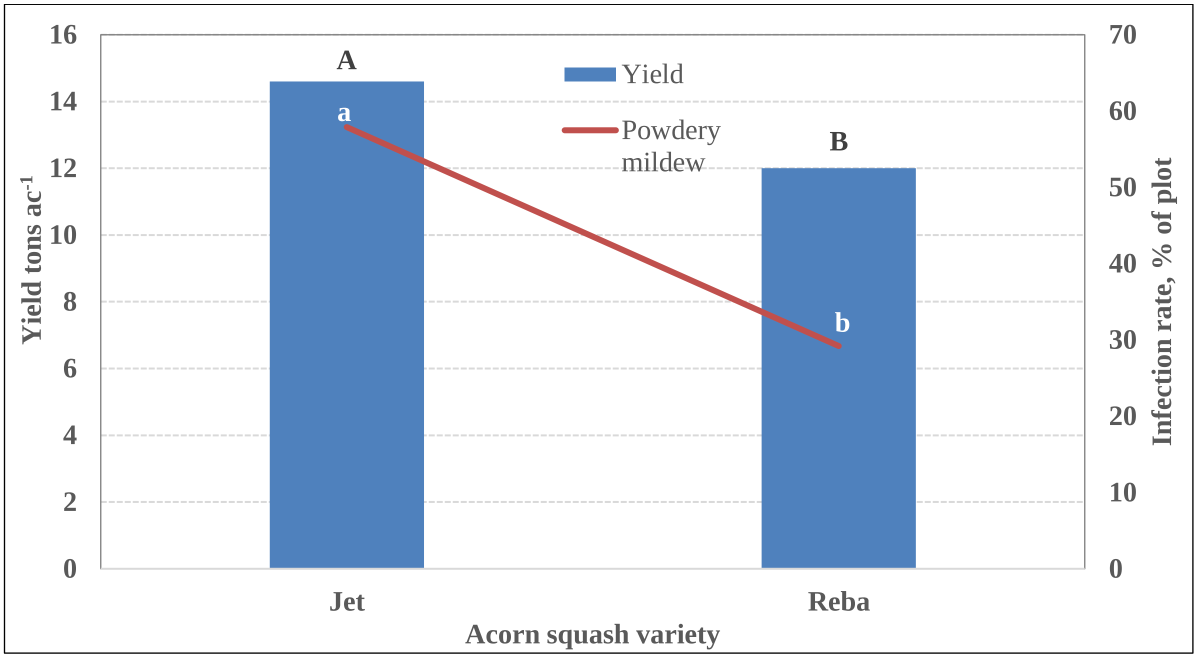

Figure 1. The effect of Jet and Reba varieties on yield across all spray treatments. Treatments with the same letter did not differ significantly from each other (p=0.10). Alburgh, Vermont, 2016.

Interaction of Variety x Biofungicide Treatment

Interactions were observed between squash variety and biofungicide treatment. This indicates that the varieties responded differently to the treatments. This is partially expected since the varieties differed in their susceptibility to powdery mildew.

When comparing all spray treatments on plot characteristics for the acorn squash variety Reba, no significant differences were seen for marketable fruit, unmarketable fruit, or the percentage of plants that produced fruit and were harvested (Table 8).

Table 8. The effect of spray treatments on plot characteristics for the acorn squash variety Reba, Alburgh, VT, 2016.

Treatment	Marketable fruit	Unmarketable fruit	Marketable fruit	Harvested plants
	fruit ac^{-1}	fruit ac^{-1}	% of total	% of total plants from plot
Actinovate	15800	1740	50.0	98.0
Cease	14900	947	94.1	100.0
Champ	14500	1580	90.1	98.0
Regalia	14800	1820	89.3	100.0
Sonata	16200	789	95.2	91.7
Control	16000	1740	90.6	98.0
LSD (0.10)	NS	NS	NS	NS
Trial mean	15400	1430	91.6	97.6

NS – There was no statistical difference between treatments in a particular column (p=0.10).

The acorn squash variety Reba, showed no significant difference for storage life or yield between spray treatments (Table 9). A significant difference was seen for the severity of powdery mildew infection, where Champ was the best performer at 8.75% of the plant biomass showing symptoms. Regalia and Actinovate showed statistically similar results for powdery mildew infection severity (Table 9, Figure 3).

Table 9. The effect of spray treatments on disease, storage, and yield for the acorn squash variety Reba, Alburgh, VT, 2016.

Treatment	Powdery mildew	Storage^	Yield
	% of total biomass infected	% shelf-stable	tons ac^{-1}
Actinovate	25.0*	93.8	12.2
Cease	40.0	100.0	12.1
Champ	**8.75***	87.5	11.6
Regalia	16.25*	91.7	11.0
Sonata	50.0	100.0	12.5
Control	35.0	97.5	12.6
LSD (0.10)	18.8	NS	NS
Trial mean	29.2	95.1	12.0

^Percent of squash shelf-stable 3 months after harvest.
*Treatments marked with an asterisk were not statistically different top performing treatment shown in **bold** (p=0.10).).
NS – There was no statistical difference between treatments in a particular column (p=0.10).

When comparing all spray treatments on plot characteristics for the acorn squash variety Jet, no significant differences were seen for marketable fruit, unmarketable fruit, or proportion of plants that produced fruit and were harvested (Table 10).

Table 10. The effect of spray treatments on plot characteristics for the acorn squash variety Jet, Alburgh, VT, 2016.

Treatment	Marketable fruit	Unmarketable fruit	Marketable fruit	Harvested plants
	fruit ac^{-1}	fruit ac^{-1}	% of total	% of total plants from plot
Actinovate	14100	868	94.3	100.0
Cease	13200	789	94.2	97.9
Champ	14800	631	96.4	100.0
Regalia	12900	710	95.6	100.0
Sonata	13200	316	98.0	95.9
Control	12800	947	93.3	97.9
LSD (0.10)	NS	NS	NS	NS
Trial mean	13500	1070	95.3	98.6

NS – There was no statistical difference between treatments in a particular column (p=0.10).

No significant difference was seen for storage life or yield across all treatments for the squash variety, Jet (Table 11). A significant difference was seen for severity of powdery mildew symptoms on plant biomass, where Champ was the best performer at 13.8% of the plot diseased and Regalia showed statistically similar results (Table 11, Figure 2).

Table 11. The effect of spray treatments on disease, storage, and yield for the acorn squash variety Jet, Alburgh, VT, 2016.

Treatment	Powdery mildew	Storage^	Yield
	% of total biomass infected	% shelf-stable	tons ac^{-1}
Actinovate	75.0	97.5	14.4
Cease	77.5	100.0	14.1
Champ	**13.8***	100.0	16.2
Regalia	21.3*	100.0	14.5
Sonata	72.5	100.0	14.5
Control	87.5	97.2	13.7
LSD (0.10)	32.3	NS	NS
Trial mean	57.9	99.1	14.6

^Percent of squash shelf-stable 3 months after harvest.
*Treatments marked with an asterisk were not statistically different top performing treatment shown in **bold** (p=0.10).
NS – There was no statistical difference between treatments in a particular column (p=0.10).

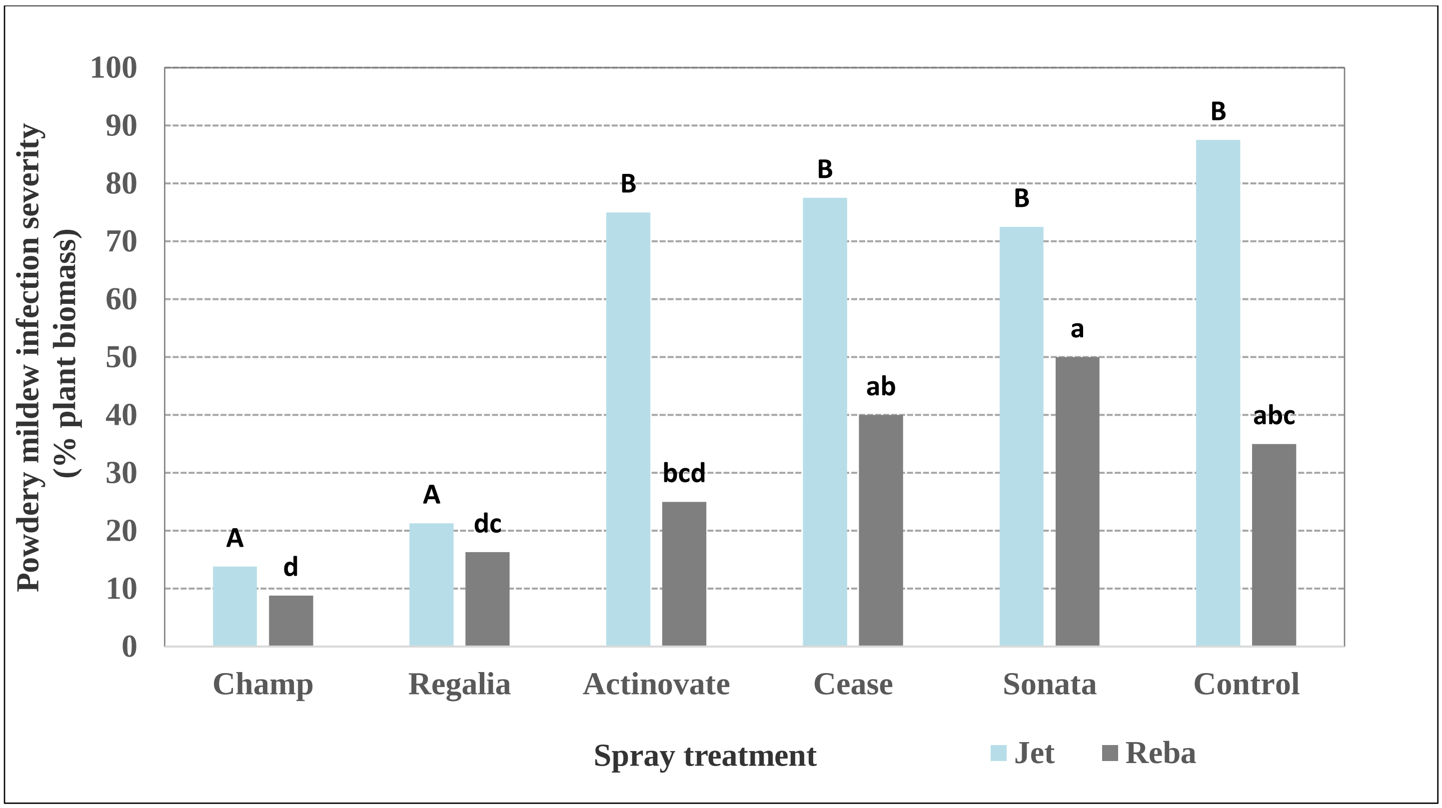

Figure 2. The effect of spray treatments on powdery mildew infection rates for Jet and Reba acorn squash varieties. Treatments with the same letter did not differ significantly from each other (p=0.10). Alburgh, Vermont, 2016.

Overall, powdery mildew pressure during 2016 was relatively low due to dry weather. When comparing acorn squash varieties, Reba, which is resistant to powdery mildew, had significantly lower powdery mildew severity, however yielded significantly lower than Jet, which is susceptible to powdery mildew. In future years, with potentially worse outbreaks of powdery mildew, the benefits of a disease resistant variety may transfer to a yield benefit as well. Also, Champ and Regalia consistently performed better for reducing powdery mildew when compared to the other biofungicides.

Table 12. Costs of spray treatments in the biofungicide trial, Alburgh, VT, 2016.

Spray	Cost per unit	Quantity used, 0.25 acres acorn squash	Cost for quantity used, 0.25 acres acorn squash
Actinovate	$135/18 oz	1.23 oz	$9.23
Cease + Milstop adjuvant	$65/gal (Cease) $80/5 lbs (Milstop)	0.15 gal (Cease) 0.31 lbs (Milstop)	$14.71
Champ	$130/20 lbs	0.24 lbs	$1.56
Regalia	$95/gal	0.15 gal	$14.25
Sonata	$80/2.5 gal	0.12 gal	$3.84

Champ cost $1.56 and Regalia cost $14.25 to spray the approximately 0.25 acres of squash in this trial (Table 12). Champ was the cheapest spray treatment in this trial, and Regalia was one of the most expensive treatments.

It is important to remember that the results presented here only represent one year of research at one location and has been limited to the spray treatments and cucurbits varieties selected above.

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