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NORTHWEST CROPS & SOILS PROGRAM

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Public interest in sourcing local foods has extended into beverages, and the current demand for local brewing and distilling ingredients is quickly increasing. One new market that has generated interest of both farmers and end-users is malted barley. This only stands to reason since the Northeast alone is home to over 175 microbreweries and 35 craft distillers. Until recently, local malt was not readily available to brewers or distillers. However, a rapid expansion of the fledgling malting industry will hopefully give farmers new markets and end-users hope of readily available malt. To date, the operating maltsters struggle to source enough local grain to match demand for their product. In addition to short supplies, the local malt barley that is available often does not meet the rigid quality standards for malting. One major obstacle for growers is *Fusarium* head blight (FHB) infection of grain. This disease is currently the most important disease facing organic and conventional grain growers in the Northeast, resulting in loss of yield, shriveled grain, and most importantly, mycotoxin contamination. A vomitoxin called Deoxynivalenol (DON) is considered the primary mycotoxin associated with FHB. The spores are usually transported by air currents and can infect plants at flowering through grain fill. Eating contaminated grain greater than 1ppm poses a health risk to both humans and livestock.

Fungicide applications have proven to be relatively effective at controlling FHB in other barley growing regions. Limited work has been done in this region on the optimum timing for a fungicide application to barley specifically to minimize DON. In addition, there are limited studies evaluating organic approved biofungicides, biochemicals, or biostimulants for management of this disease. In April of 2016, the UVM Extension Northwest Crops and Soils Program initiated year three of a spring barley fungicide trial to determine the efficacy and timing of fungicide application to reduce FHB infection on cultivars with varying degrees of disease susceptibility.

MATERIALS AND METHODS

A field experiment was established at the Borderview Research Farm located in Alburgh, VT on 21-Apr to investigate the effects of cultivar resistance, fungicide efficacy, application timing on FHB and DON infection in spring malting barley. The experimental design was a randomized complete block, with a split-plot arrangement of cultivar as the whole-plot and fungicide+timing treatments as the sub-plots. The main plot of cultivar included Robust, a 6-row malting barley which is a FHB susceptible variety, and Conlon, a 2-row malting barley with moderate FHB resistance. The fungicide+timing treatments are listed in Table 2.

The seedbed at the Alburgh location was prepared by conventional tillage methods. All plots were managed with practices similar to those used by producers in the surrounding areas (Table 1). The previous crop planted at the site was sunflowers. Prior to planting the trial area was disked and spike tooth harrowed to prepare for planting. The plots were seeded with a Great Plains Cone Seeder on 21-Apr at a seeding rate of 325 live seeds per m^2. Plot size was 5’x 20’.

Table 1. General plot management of the trial, 2016.

Location	Borderview Research Farm Alburgh, VT
Soil type	Benson rocky silt loam
Previous crop	Sunflowers
Row spacing (inch)	7
Seeding rate (live seed m^2)	325
Replicates	4
Varieties	Conlon and Robust
Planting date	21-Apr
Harvest date	4-Aug
Harvest area (ft)	5 x 20
Tillage operations	Spring plow, disk & spike tooth harrow

When the barley reached 50% spike emergence (16-Jun), plots were sprayed with the fungicide treatments (Table 2). The application was made using a Bellspray Inc. Model T4 backpack sprayer. This model had a carbon dioxide pressurized tank and a four-nozzle boom attachment. It sprayed at a rate of 10 gallons per acre. The adjuvant 'Induce' was added to the Prosaro and Caramba applications at a rate of 0.125%. All but one plot (Control) of each cultivar was inoculated 24 hours (17-Jun), after the heading treatment was applied, with a spore suspension (40,000 spores/ml) consisting of a mixture of isolates of *Fusarium graminearum* endemic to the area.

The *Fusarium graminearum* spores were multiplied and harvested using the 'Gz conidial suspension inoculum protocol'. Four days after the heading application (20-Jun) plots not previously treated with a fungicide were sprayed with the fungicides treatments except for the control and *Fusarium graminearum* only plots (Table 2). Water was applied at the same rate as the fungicides to the control plots and to those that were only inoculated with *Fusarium graminearum.* Below is a list of the treatment materials evaluated in this trial. Descriptions have been provided from manufacturer information.

Actinovate® (EPA# 73314-1) is a biological fungicide (0.0371% Streptomyces lydicus WYEC 108) that suppresses and controls root rot, damping-off fungi and foliar fungal pathogens. Its active ingredient is a patented bacterium that grows around the root system (when soil drenched) and foliage of the plant (when sprayed on) while using several novel modes of antifungal action to protect plants.

Caramba® (EPA# 7969-246) fungicide is a highly effective fungicide containing the active ingredient metconazole, resulting in significant yield protection and reductions of deoxynivalenol (DON) levels in grain. It is not only effective on head scab, but provides control of late-season foliar diseases as well.

ChampION® (EPA# 55146-1) is a 77% copper hydroxide-based, broad-spectrum fungicide for disease control. When copper hydroxide is mixed with water, it releases copper ions, which disrupt the cellular proteins of the fungus. This product is approved for use in organic production systems.

Prosaro® (EPA# 264-862) fungicide provides broad-spectrum disease control, stops the penetration of the fungus into the plant and the spread of infection within the plant and inhibits the reproduction and further growth of the fungus.

SONATA® (EPA# 69592-13) fungicide provides excellent control of powdery mildews and rusts. Based on a patented strain of Bacillus pumilus (QST 2808), SONATA is an excellent fit for integrated disease management programs. SONATA contains a unique, patented strain of Bacillus pumilus (QST 2808) that produces an antifungal amino sugar compound that inhibits cell metabolism. SONATA also creates a zone of inhibition on plant surfaces, preventing pathogens from establishing on the plant.

Table 2. Plot treatments-fungicide application dates and rates.

Treatments	Heading application	4 days after heading application	Application rate
	date	date	
Control	16-Jun	20-Jun	Water
Fusarium graminearum	17-Jun		40,000 spores/ml
Actinovate	16-Jun	20-Jun	6 fl oz ac^{-1}
Caramba	16-Jun	20-Jun	14 fl oz ac^{-1} +.125% Induce ac^{-1}
ChampION	16-Jun	20-Jun	1.5 lbs ac^{-1}
Prosaro	16-Jun	20-Jun	6.5 fl oz ac^{-1} +.125% Induce ac^{-1}
SONATA	16-Jun	20-Jun	2 qt ac^{-1}

When the barley reached the soft dough growth stage (17-Jul), FHB intensity was assessed by randomly clipping 60-100 heads throughout each plot, spikes were counted and a visual assessment of each head was rated for FHB infection. To assess the infection rate we use the North Dakota State University Extension Service's "A Visual Scale to Estimate Severity of Fusarium Head Blight in Wheat" online publication.

Grain plots were harvested in Alburgh with an Almaco SPC50 plot combine on 4-Aug, the harvest area was 5' x 20'. At the time of harvest grain moisture, test weight and yield were calculated.

Following harvest, seed was cleaned with a small Clipper cleaner (A.T. Ferrell, Bluffton, IN). An approximate one pound subsample was collected to determine quality. Quality measurements included standard testing parameters used by commercial mills. Test weight was measured by the weighing of a known volume of grain. Generally the heavier the wheat is per bushel, the higher baking quality. The acceptable test weight for bread wheat is 56-60 lbs per bushel. Once test weight was determined, the samples were then ground into flour using the Perten LM3100 Laboratory Mill. At this time flour was evaluated for mycotoxin levels. Deoxynivalenol (DON) analysis was analyzed using Veratox DON 5/5 Quantitative test from the NEOGEN Corp. This test has a detection range of 0.5 to 5 ppm. Samples with DON values greater than 1 ppm are considered unsuitable for human consumption.

All data was analyzed using a mixed model analysis where replicates were considered random effects. The LSD procedure was used to separate cultivar means when the F-test was significant ($P < 0.10$). There were significant differences among the two locations for most parameters and therefore data from each location is reported independently.

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 (e.g. yield). Least Significant Differences at the 10% level of probability are shown. Where the difference between two varieties 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. In the following example, variety A is significantly different from variety C, but not from variety B. The difference between A and B is equal to 725, which is less than the LSD value of 889. This means that these varieties did not differ in yield. The difference between A and C is equal to 1454, which is greater than the LSD value of 889. This means that the yields of these varieties were significantly different from one another. The asterisk indicates that variety B was not significantly lower than the top yielding variety.

Variety	Yield
A	3161
B	3886*
C	**4615***
LSD	**889**

RESULTS

Seasonal precipitation and temperature recorded at weather stations in close proximity to the 2016 site are shown in Table 3. The growing season this year was marked by lower than normal temperatures in April, and higher than average temperatures in May and August. Rainfall amounts were below average throughout the growing season resulting in 5.52 inches of precipitation less than normal. From April to August, there was an accumulation of 4536 Growing Degree Days (GDDs) which was 43.7 GDDs above the 30 year average.

Table 3. Temperature and precipitation summary for Alburgh, VT, 2016.

Alburgh, VT	April	May	June	July	August
Average temperature (°F)	39.8	58.1	65.8	70.7	71.6
Departure from normal	-4.92	1.84	0.01	0.13	2.85
Precipitation (inches)	2.56	1.53	2.81	1.79	2.98
Departure from normal	-0.26	-1.92	-0.88	-2.37	-0.93
Growing Degree Days (32-95°F)	291	803	1017	1201	1224
Departure from normal	-97.9	49.5	3.20	4.45	84.4

Historical averages are for 30 years of data provided by the NOAA (1981-2010) for Burlington, VT. Alburgh precipitation data from 8/17/16-10/31/16 was missing and was replaced by data provided by the NOAA for Highgate, VT.

Barley Variety x Fungicide+Timing Interactions:

There was a variety by fungicide treatment interaction for average FHB infected head severity. This interaction indicates that malting barley varieties respond differently to the fungicide treatments. The average FHB infected head severity of the Conlon plots spikes at the 4-days after application of Actin ovate (31.6%), and then varies little between the other fungicide + timing treatments (Figure 1). The infected head severity of the Robust plots spike at the heading applied Acintovate (24.3%), and then similarly, varies little between the other fungicide+timing treatments. Interestingly, the average FHB infected head severity between varieties were opposite of each other across all of the fungicide +timing treatments.

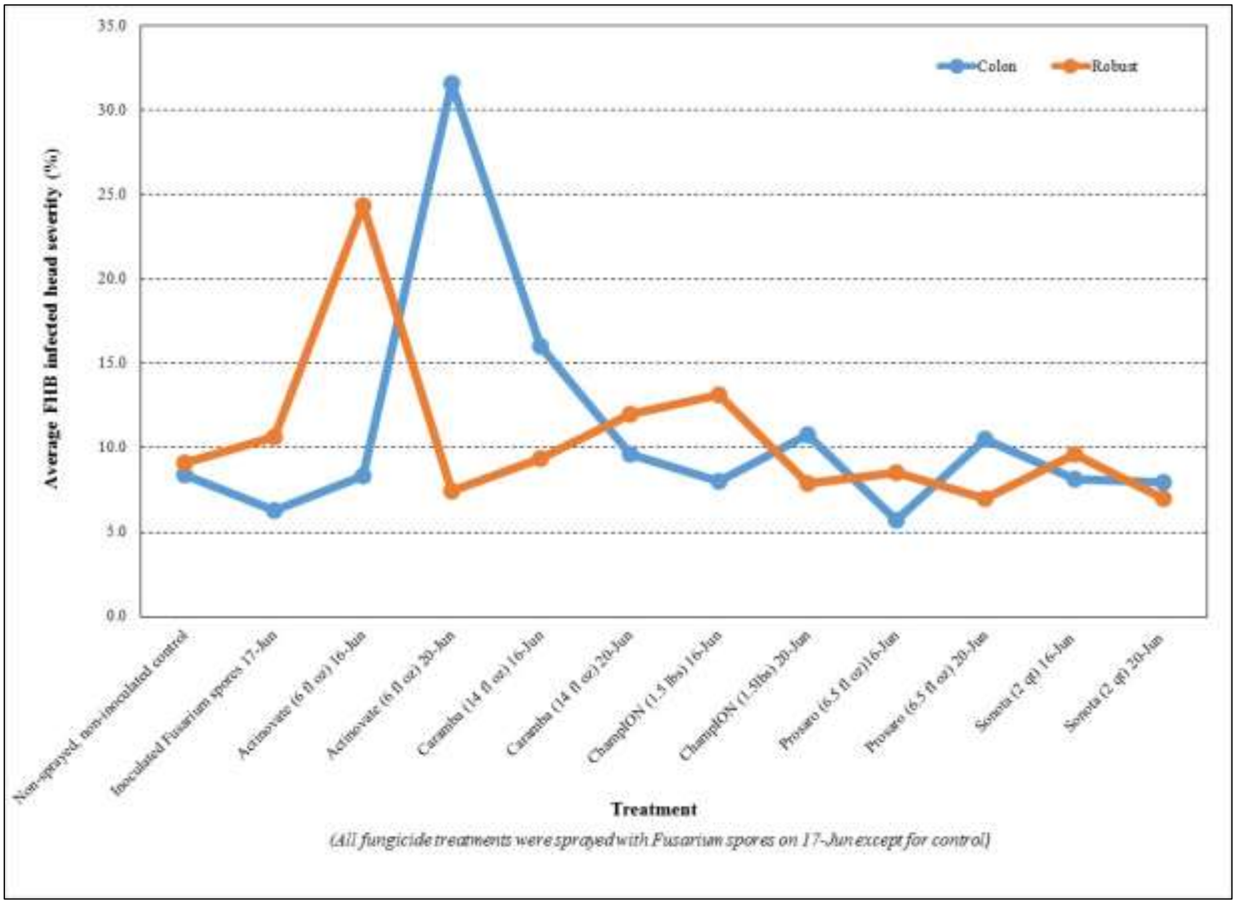

Figure 1. The interaction between barley variety x fungicide+timing on the average FHB infected head severity.

Impact of Fungicide and Timing

There were no significant differences in the average FHB plot severity, average FHB infected head severity and the incidence of infected heads between fungicide+timing treatments (Table 4). Prosaro applied four days after the heading treatment had the lowest average FHB plot severity (0.44%), and the highest was ChampION applied four days after the heading treatment at 1.25%. The lowest FHB infected head severity was Prosaro applied at heading (7.14%). Actinovate applied at heading had the lowest incidence of FHB infected heads (3.47%) and the highest incidence was Caramba applied at heading (10.2%)

Table 4. The FHB incidence and severity following fungicide treatments at heading and four days after heading, Alburgh, VT, 2016.

Treatment	Average FHB severity	Average FHB infected head severity	Incidence FHB of infected heads
	%	%	%
Non-sprayed, non-inoculated control	0.73	8.75	7.72
Inoculated Fusarium spores 17-Jun	0.78	8.46	8.01
Actinovate – heading	0.64	16.3	**3.47**
Actinovate – 4 days after heading	0.70	19.5	5.53
Caramba - heading	1.09	12.7	10.2
Caramba – 4 days after heading	0.72	10.8	6.91
ChampION - heading	1.09	12.7	8.59
ChampION – 4 days after heading	1.25	9.32	8.53
Prosaro - heading	0.60	**7.14**	6.88
Prosaro – 4 days after heading	**0.44**	8.75	5.03
Sonota - heading	0.71	8.89	6.71
Sonota – 4 days after heading	0.46	7.48	5.34
LSD (0.10)	NS	NS	NS
Trial Mean	0.77	10.7	6.91

Values shown in **bold** are of the highest value or top performing.
NS - None of the treatments were significantly different from one another.

There were significant differences in yield and harvest moisture between fungicide+timing treatments (Table 5). All of the treatments, except for the ChampION applied at heading, yielded higher than the untreated control (Figure 2). The heading application of Prosaro yielded the highest with 3958 lbs ac^{-1}. Other high yielding fungicide+timing treatments were the 4-days after heading applied Prosaro (3743 lbs ac^{-1}), the Fusarium only treatment (3683 lbs ac^{-1}), and the heading application of Caramba (3508 lbs ac^{-1}).

Table 5. The impact application timing and fungicide on barley yield and quality.

Treatment	Harvest moisture	Test weight	Yield @13.5% moisture	DON
	%	lbs bu^{-1}	lbs ac^{-1}	ppm
Non-sprayed, non-inoculated control	16.0*	41.8	3156	0.19
Inoculated Fusarium spores 17-Jun	16.1*	43.6	3683*	0.28
Actinovate – heading	17.2*	41.6	3233	0.23
Actinovate – 4 days after heading	17.6*	43.5	3229	0.29
Caramba - heading	19.4	43.9	3508*	0.20
Caramba – 4 days after heading	20.1	**44.6**	3264	0.35
ChampION - heading	17.0*	42.8	3121	0.28
ChampION – 4 days after heading	17.5*	44.1	3457	0.24
Prosaro - heading	17.3*	44.0	**3958***	**0.19**
Prosaro – 4 days after heading	17.6*	43.6	3743*	**0.19**
Sonota - heading	16.3*	43.3	3441	0.35
Sonota – 4 days after heading	17.5*	42.5	3251	0.31
LSD (0.10)	1.73	NS	453	NS
Trial Mean	17.5	43.3	3420	0.26

Values shown in **bold** are of the highest value or top performing.
* Treatments that are not significantly different than the top performing variety in a column are indicated with an asterisk**.**
NS - None of the treatments were significantly different from one another.

The lowest harvest moisture was the untreated control at 16.0%. The treatments with the highest harvest moisture were both applications of Caramba. All of the fungicide+timing treatments had moistures above 14%, the optimum moisture for grain storage, and therefore had to be dried down. Caramba applied 4-days after heading had the highest test weight of 44.6 lbs bu^{-1}, the lowest test weight was Actinovate (41.6 lbs bu^{-1}) applied at heading. None of the fungicide+timing treatments met industry standards of 48 lbs bu^{-1} for barley. The Prosaro treatments and the untreated control had the lowest DON level (0.19 ppm). All fungicide+timing treatments had DON concentrations below the FDA 1 ppm recommendation.

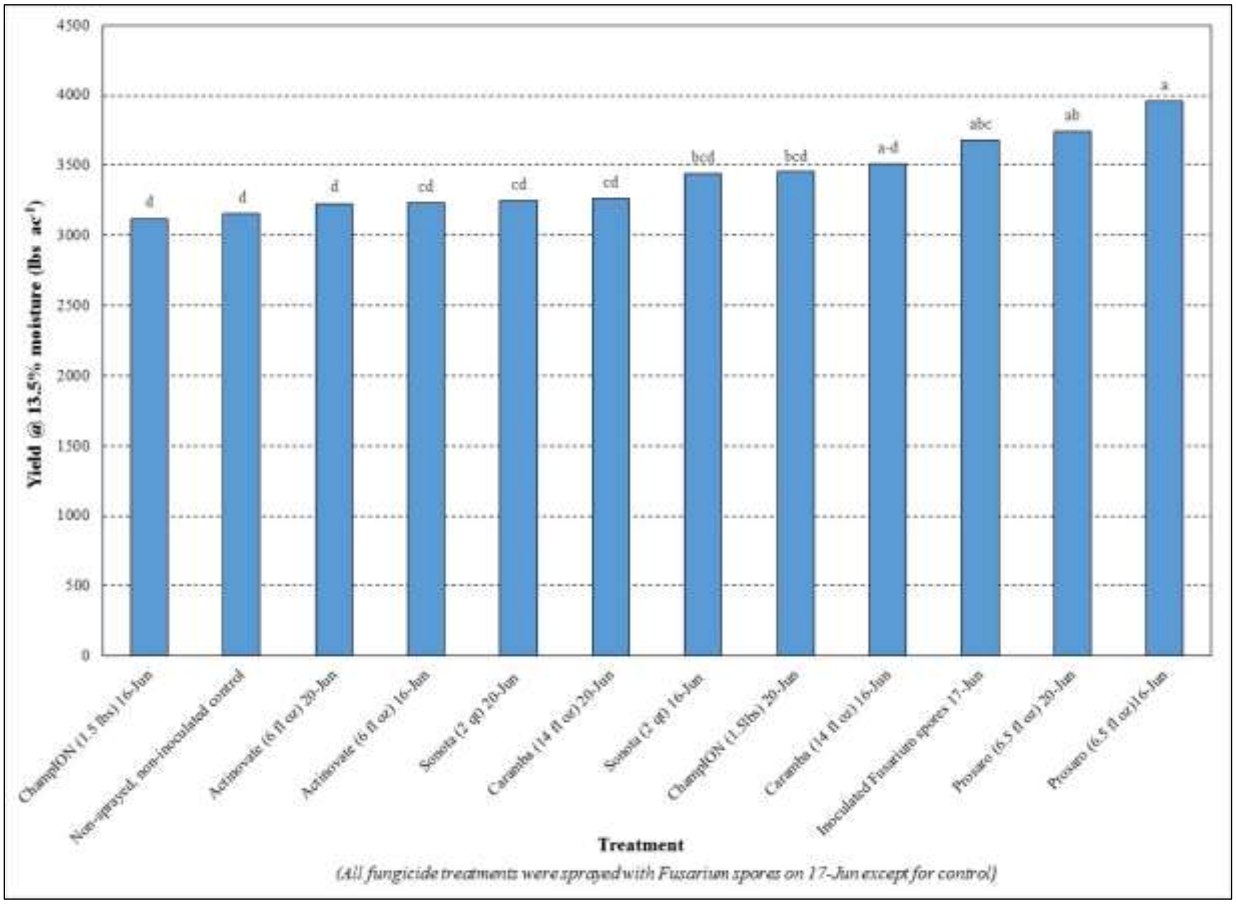

Figure 2. The impact of application timing and fungicide on barley yield.
Treatments with the same letter did not differ significantly.

Impact of Variety

There were no significant differences in the average FHB plot severity, infected head severity, and incidence of FHB infection between malting barley varieties (Table 6).

Table 6. The impact of malting barley variety of FHB incidence and severity.

Variety	Average FHB severity	Average FHB infected head severity	Incidence FHB of infected heads
	%	%	%
Conlon	**0.74**	10.9	**6.80**
Robust	0.81	**10.5**	7.01
LSD (0.10)	NS	NS	NS
Trial Mean	0.77	10.7	6.91

Values shown in **bold** are of the highest value or top performing.
NS - None of the varieties were significantly different from one another.

The malting barley varieties were significantly different in harvest moisture and test weight (Table 7). Conlon had the lowest harvest moisture (16.8%). Both varieties had moistures above 14% and therefore had to be dried down for storage. Robust had the highest test weight of 44.5 lbs bu^{-1}. Neither of the varieties achieved industry standards for test weight of 48 lbs bu^{-1}. Varieties did not differ in yield or DON concentrations.

Table 7. The impact of malting barley variety of quality and yield.

Variety	Harvest moisture	Test weight	Yield @13.5% moisture	DON
	%	lbs bu^{-1}	lbs ac^{-1}	ppm
Conlon	**16.8***	42.0	**3469**	**0.24**
Robust	18.2	**44.5***	3371	0.28
LSD (0.10)	0.70	0.82	NS	NS
Trial Mean	17.5	43.3	3420	0.26

* Varieties that are not significantly different than the top performing variety shown in **bold** in a column are indicated with an asterisk**.**
NS - None of the varieties were significantly different from one another.

DISCUSSION

Overall, the 2016 growing season was ideal for growing spring barley. The warmer than average temperatures along with below normal rainfall throughout much of the growing season resulted in minimal fungal growth. This is evident in the low DON concentrations in both varieties. All of the treatments, including the untreated control and the Fusarium only plots, had DON concentrations below the 1 ppm threshold. The application of a conventional fungicide (Prosaro) at heading and 4-days after heading had the lowest DON concentrations and the highest yields. It is interesting, given the ideal growing conditions, that none of the treatments attained the industry standard for test weight. High harvest moistures might have contributed to overall low test weights.

The average yield in 2016 was 3042 lbs ac^{-1}, 1944 lbs ac^{-1} more than the average yield in 2015. This could be attributed to the cool and wet conditions in 2015 that resulted in high weed and disease pressure.

It is important to remember that the results only represent one year of data. The Northwest Crops and Soils program will be repeating this trial again in 2017.

ACKNOWLEDGEMENTS

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