The Efficacy of Spraying Fungicides to Control Fusarium Head Blight Infection in Spring Malting Barley

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There is high demand in the Northeast for sourcing local foods and beverages. One market that has generated interest from both farmers and end-users is malted barley. The Northeast is home to over 180 microbreweries and 37 craft distillers. Until recently, local malt was not readily available to brewers or distillers. The expanding malting industry provides farmers with new markets for grain crops. Regional maltsters continue to find it challenging to source enough local grain to match demand for their product. Local barley does not always meet the strict quality standards for malting. One major obstacle for Northeast growers is that our climate is conducive to the development of *Fusarium* head blight (FHB) infection of grain. This fungal disease is currently the most significant 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 (commonly abbreviated as DON) is the primary mycotoxin associated with FHB. The fungus can overwinter in soils and spores can be transported by air currents. *Fusarium* can infect plants at spike emergence through grain fill. Products with DON values greater than 1 ppm pose health risks and are considered unsuitable for human consumption by the FDA.

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. There are limited studies evaluating organic approved biofungicides, biochemicals, or biostimulants for management of this disease. In April 2022, the UVM Extension Northwest Crops and Soils Program initiated year seven of a spring barley fungicide trial to determine the efficacy and optimal timing of fungicide application to reduce FHB infection in malting barley in Vermont.

MATERIALS AND METHODS

A field experiment was established at the Borderview Research Farm located in Alburgh, Vermont in the spring of 2022 to investigate the effects of cultivar resistance, fungicide efficacy, and 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 two cultivars evaluated were Robust, a 6-row malting barley that is a FHB susceptible variety, and ND Genesis, a 2-row malting barley with some resistance to FHB infection. The fungicide+timing treatments are listed in Table 2.

All plots were managed with practices similar to those used by barley producers in the region. The previous crop planted at the site was oats and the soil type was Benson rocky silt loam (Table 1). Prior to planting, the trial area was prepared with a Pottinger TerraDisc. The plots were seeded with a Great Plains Cone Seeder on 23-Apr at a seeding rate of 350 live seeds m^2. The plot size was 5’x 20’.

Table 1. Trial agronomic information, 2022.

Location	Borderview Research Farm Alburgh, VT
Soil type	Benson rocky silt loam
Previous crop	Oats
Row spacing (inch)	7
Seeding rate (live seed m^{-2})	350
Replicates	4
Varieties	ND Genesis and Robust
Planting date	23-Apr
Harvest date	1-Aug
Harvest area (ft)	5 x 20
Tillage operations	Pottinger TerraDisc

Fungicides evaluated in the 2022 spring barley fungicide trial included Caramba, ChampION, Miravis Ace, Prosaro, Prosaro Pro, and Sphaerex (Table 3). Fungicides were applied at heading (Feekes stage 10.5). Three treatments consisted of a combination of applications of two fungicides. For one dual treatment, Miravis Ace was applied at heading, followed by Prosaro Pro five to seven days after heading. In another dual treatment, Miravis Ace was applied at heading followed by Sphaerex five to seven days after heading. In the final dual treatment, ChampION was applied both at heading and five to seven days after heading. Each variety was treated with fungicide when it reached the appropriate state of maturity (Table 2).

Heading date applications were applied when the barley reached 50% spike emergence (Table 3). The adjuvant 'Induce' was added to all treatments at a rate of 0.125%. All but one plot (control) in each replicate was inoculated within 24 hours of the heading treatment with a spore suspension (100,000 spores/ml) consisting of a mixture of isolates of *Fusarium graminearum* endemic to the area. The control plots were sprayed with water with no *Fusarium* spores. One plot per replicate was inoculated with *Fusarium*, but was not treated with a fungicide (*Fusarium* only). Five days after the heading application for the Robust barley, and seven days after heading application for Genesis barley, the second fungicide application was applied for the dual treatment plots. The applications were 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.

Table 2. Treatment Application Dates.

Variety and treatment	Application date
Genesis Heading Applications	21-Jun
Genesis Inoculated with *Fusarium*	22-Jun
Genesis Post-heading Applications	28-Jun
Robust Heading Applications	17-Jun
Robust Inoculated with *Fusarium*	16-Jun
Robust Post-Heading Applications	22-Jun

When the barley reached the soft dough growth stage, FHB infection rates were assessed by clipping 60-100 randomly selected spikes from each plot, counting spikes, and visually assessing each head for FHB infection. The head assessment occurred on 13-Jul for the Robust plots and 15-Jul for the Genesis plots. The infection rate was assessed by using 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 with an Almaco SPC50 plot combine on 1-Aug. Grain moisture, test weight, and yield were measured at harvest. Harvest moisture and test weight were determined for each plot using a DICKEY-john Mini GAC moisture and test weight meter. Higher test weight in barley is associated with better malting quality. The optimal test weight for barley is 48 lbs bu^{-1} or higher.

Following harvest, barley was cleaned with a small Clipper cleaner (A.T. Ferrell, Bluffton, IN). A one-pound subsample was collected to determine quality. Approximately 300 g of each sample was ground into flour using the Perten LM3100 Laboratory Mill. Deoxynivalenol (DON) concentrations were analyzed at the McMaster lab at Virginia Tech on an Agilent 6890N / 5975 GC/MS. This method has a detection range of from 0.025ppm – 15ppm.

Following is a list of the fungicides and application rates evaluated in this trial (Table 3). Descriptions have been provided from manufacturer information.

Table 3. Plot treatments-fungicide application rates.

Treatments	Application rate
Control	Water
Caramba	14 fl oz ac^{-1} +.125% Induce ac^{-1}
ChampION	1.5 lbs ac^{-1}
Miravis Ace	13.7 fl oz ac^{-1} + .125% Induce ac^{-1}
Prosaro	6.5 fl oz ac^{-1} +.125% Induce ac^{-1}
Prosaro Pro	10.3 fl oz ac-1 +.125% Induce ac^{-1}
Sphaerex	7.3 fl oz ac^{-1} +.125% Induce ac^{-1}
Fusarium graminearum	100,000 spores/ml

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.

Miravis® Ace (EPA# 100-1601) is a combination of propiconazole and Adepidyn®fungicide – the first SDHI mode of action available for *Fusarium* head blight control. It distributes evenly within the leaf and creates a reservoir within the wax layer of the leaf that withstands rain and degradation. It also provides protection against Septoria leaf spot and other foliar disease.

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.

Prosaro Pro® (EPA# 0000264-01209-AA-0000000) With the addition of fluopyram, Prosaro® PRO 400 SC fungicide offers better disease control and greater DON reduction relative to Prosaro® fungicide, leading to healthier plants and higher yield potential.

Sphaerex® (EPA# 7969-473) Sphaerex contains two proven active ingredients — metconazole and prothioconazole. Sphaerex fungicide is currently registered for use on wheat but not for use on barley or oats and not available for sale for those additional uses. This information regarding the use of Sphaerex fungicide on barley is provided for educational purposes only and is not intended to promote the sale of this product for this purpose.

Data were analyzed using a general linear model procedure of SAS (SAS Institute, 2008). Replications were treated as random effects, and treatments were treated as fixed. Mean comparisons were made using the Least Significant Difference (LSD) procedure where the F-test was considered significant, at $p<0.10$. Variations in project results can occur because of variations in genetics, soil, weather, and other growing conditions. Statistical analysis makes it possible to determine whether a difference among treatments 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 (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 values. Treatments that were not significantly lower in performance than the highest value in a particular column are indicated with an asterisk. In the accompanying example, treatment A is significantly different from treatment C but not from treatment B. The difference between A and B is equal to 200, which is less than the LSD value of 300. This means that these treatments did not differ in yield. The difference between A and C is equal to 400, which is greater than the LSD value of 300. This means that the yields of these treatments were significantly different from one another.

Treatment	Yield
A	**2100***
B	1900*
C	1700
LSD	300

RESULTS

Seasonal precipitation and temperature recorded at a weather station at Borderview Research Farm are displayed below in Table 4. The growing season was cooler than normal overall, although the month of May was warmer than average. There were 3510 Growing Degree Days (GDDs) in the season, 36 growing degree days less than normal. There were 20.1 inches of precipitation, 4.97 inches more than normal.

Table 4. Temperature and precipitation summary for Alburgh, VT, 2022.

Alburgh, VT	April	May	June	July
Average temperature (°F)	44.8	60.5	65.3	71.9
Departure from normal	-0.81	2.09	-2.18	-0.54
Precipitation (inches)	5.57	3.36	8.19	3.00
Departure from normal	2.50	-0.40	3.93	-1.06
Growing Degree Days (32-95°F)	391	883	1000	1236
Departure from normal	-20.0	65.0	-64.0	-17.0

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

Barley Variety x Fungicide+Timing Interactions:

There were no statistical interactions between treatments and varieties, indicating that both varieties trialed responded similarly to treatments.

Impact of Fungicide and Timing

Harvest metrics are shown in Table 5. The DON concentrations and FHB incidence and severity are shown in Table 6. There were statistically significant differences between treatments for all parameters measured (Tables 5 and 6).

Harvest moisture was statistically different between treatments, but all treatments were under 14% and did not require further drying for storage. Test weights across the trial were lower than the industry standard of 48 lbs bu^{-1} for malting barley. The Miravis Ace and Prosaro Pro treatment had the highest test weight at 46.7 lb bu^{-1}. Yields were good across the trial, ranging from 3364 lbs ac^{-1} to 4492 lbs ac^{-1}. The highest yield was the ChampION treatment, and the lowest yielding treatment was the *Fusarium* only treatment.

Most treatments and timings, including the control and the *Fusarium* inoculated plots, had average DON concentrations below the 1 ppm threshold recommended by the FDA. The highest DON concentrations in the trial were in the Prosaro treatment (applied at heading) at 1.04 ppm. The dual ChampION treatment (applied both at heading and also 5-7 days post-heading) was also just over the 1 ppm threshold (1.03 ppm). The lowest DON concentration was in the Miravis Ace applied with Sphaerex at 0.34 ppm. This was statistically similar to Miravis Ace applied with Prosaro Pro with DON concentration of 0.45 ppm and the Sphaerex treatment with DON concentration of 0.54 ppm.

Table 5. Harvest quality by fungicide treatment and timing, Alburgh, VT, 2022.

Treatment	Timing	Test weight	Harvest moisture	Yield at 13.5% moisture
		lbs bu^{-1}	%	lbs ac^{-1}
Control	Heading	44.1^{bc}	12.8^{a-c}	3370^{d}
Fusarium	Heading	43.5^{bc}	13.2^{a-d}	3364^{d}
Caramba	Heading	43.4^{c}	12.7^{ab}	3841^{b-d}
ChampION	Heading	44.9^{bc}	13.2^{b-d}	**4492^{a}**
ChampION	Heading & Post-heading	44.1^{bc}	**12.5^{a}**	3949^{a-d}
Miravis Ace	Heading	44.5^{bc}	13.5^{cd}	4344^{ab}
Miravis Ace, Prosaro Pro	Heading, Post-heading	**46.7^{a}**	13.4^{cd}	4155^{a-c}
Miravis Ace, Sphaerex	Heading, Post-heading	45.1^{ab}	13.0^{a-c}	4173^{ab}
Prosaro	Heading	43.3^{c}	13.0^{a-c}	3828^{b-d}
Prosaro Pro	Heading	44.7^{bc}	12.7^{ab}	3994^{a-d}
Sphaerex	Heading	43.3^{c}	13.8^{d}	3526^{cd}
LSD (p=0.10) ‡		1.62	0.72	644
Trial mean		44.3	13.1	3913

† Within a column, treatments with the same letter are statistically similar to the top performer in **bold**.

‡ LSD- Least significant difference at p=0.10.

The incidence and severity of Fusarium head blight infection was calculated for each plot. Incidence refers to the percentage of plants evaluated that were infected with FHB. Severity refers to the average degree of infection of each head examined. The fusarium only plots had the lowest severity and incidence of FHB by visual assessment. This was statistically similar to the untreated control and the Prosaro Pro treatment. The relatively low severity and incidence of FHB in the inoculated vs. uninoculated plots indicates that fusarium spores are ubiquitous and abundant in the environment.

Table 6. DON concentrations and FHB severity and incidence by fungicide treatment and timing, Alburgh, VT, 2022.

Treatment	Timing	DON	Average FHB severity	Incidence of FHB infected heads
		ppm	%	%
Control	Heading	0.66[bc]	12.8[a-c]	20.5[a-c]
Fusarium	Heading	0.85[c-e]	**7.70[a]**	**12.2[a]**
Caramba	Heading	0.70[b-d]	16.2[c-e]	28.4[cd]
ChampION	Heading	0.98[de]	21.3[e]	37.4[d]
ChampION	Heading & Post-heading	1.03[e]	17.2[c-e]	28.1[cd]
Miravis Ace	Heading	0.64[bc]	20.6[de]	34.3[d]
Miravis Ace, Prosaro Pro	Heading, Post-heading	0.45[ab]	16.1[c-e]	28.9[cd]
Miravis Ace, Sphaerex	Heading, Post-heading	**0.34[a]**	15.8[b-e]	29.8[cd]
Prosaro	Heading	0.92[cd]	14.7[b-d]	25.4[b-d]
Prosaro Pro	Heading	1.04[e]	9.20[ab]	14.0[ab]
Sphaerex	Heading	0.54[ab]	14.4[b-d]	26.3[b-d]
LSD (p=0.10) ‡		0.28	6.62	13.1
Trial Mean		0.74	15.1	25.9

†Treatments within a column with the same letter are statistically similar to the top performer in **bold**.

‡ LSD- Least significant difference.

Impact of Variety

Table 7. Harvest quality and FHB assessment by variety, Alburgh, VT, 2022.

Variety	Harvest moisture	Test weight	Yield @13.5% moisture	DON	Average FHB severity	Incidence of FHB infected heads
	%	lbs bu^{-1}	lbs ac^{-1}	ppm	%	%
ND Genesis	13.7	43.9	**4216**	0.96	21.7	37.5
Robust	**12.5**	**44.8**	3609	**0.52**	**8.50**	**14.3**
LSD (0.10) ‡	0.31	0.69	274	0.12	2.82	5.60
Trial Mean	13.1	44.3	3913	0.74	15.1	25.9

The top performing treatment in each column is indicated in **bold.**
‡LSD - Least significant difference at p=0.10.

There were significant differences between varieties across all parameters evaluated. Both varieties were below 14% moisture at harvest (Table 7). Robust had higher test weight at 44.8 lbs bu^{-1} although both were below the industry standard of 48 lbs bu^{-1}. ND Genesis had higher yields by 607 lbs ac^{-1}. Interestingly, Robust had lower DON concentrations, FHB severity and incidence, although it is purported to be the more susceptible variety of the two (Table 7, Figure 1).

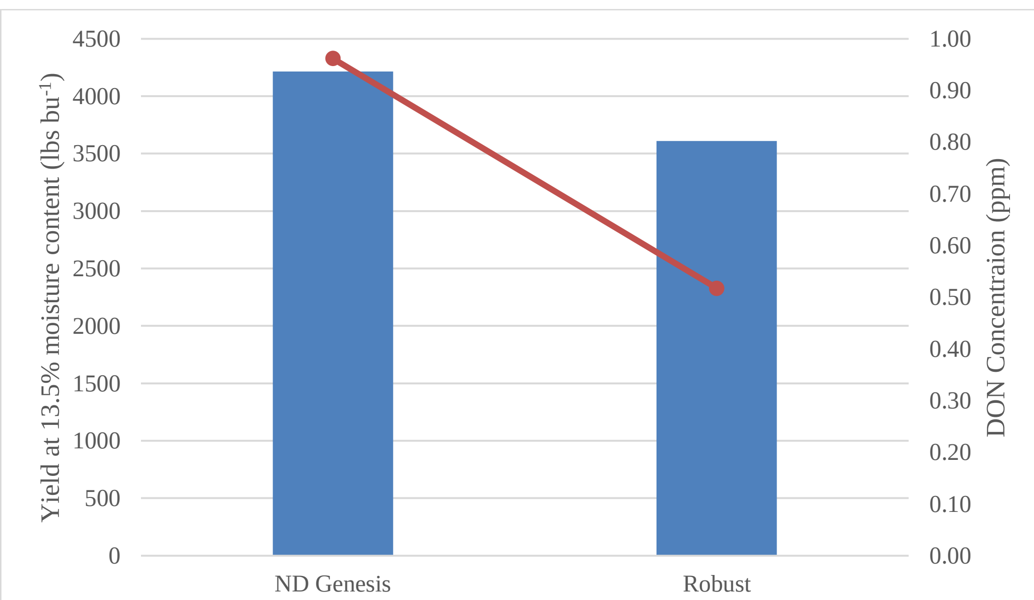

Figure 1. The impact of variety on barley yield and DON concentration.

DISCUSSION

Higher levels of *Fusarium* infection and resulting DON vomitoxin concentrations in grain are associated with cool and damp weather conditions at the time of grain fill and heading. Although average temperatures were below normal with above normal precipitation through the growing season, most of this precipitation arrived before or after the barley was heading which is the critical period for *Fusarium* infection, resulting in fairly low DON levels across the trial. Four treatments produced results of DON concentrations lower than those in the untreated control: Miravis Ace applied with Sphaerex (0.34 ppm), Miravis Ace applied with Prosaro Pro (0.45 ppm), Sphaerex (0.54 ppm), and Miravis Ace (0.64 ppm).

This trial is expected to continue for additional years. It is important to remember that the results only represent one year of data.

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