NORTHWEST CROPS & SOILS PROGRAM

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

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THE UNIVERSITY OF VERMONT EXTENSION

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. Vermont is home to over 74 craft breweries and 22 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 soil or crop debris 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 2023, the UVM Extension Northwest Crops and Soils Program initiated year eight of a spring barley fungicide trial to determine the efficacy and optimal timing of fungicide application to reduce FHB infection in malting barley.

MATERIALS AND METHODS

A field experiment was established at the Borderview Research Farm located in Alburgh, Vermont in the spring of 2023 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 a whole-plot and fungicide+timing treatments as the sub-plots. The two cultivars evaluated were Robust, a 6-row malting barley, and ND Genesis, a 2-row malting barley.

All plots were managed with practices similar to those used by barley producers in the region. The previous crop planted at the site was industrial hemp 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 14-Apr at a seeding rate of 350 live seeds m^{-2}. The plot size was 5'x 20'.

Table 1. Trial agronomic information, 2023.

Location	Borderview Research Farm Alburgh, VT
Soil type	Benson rocky silt loam
Previous crop	Industrial Hemp
Row spacing (inch)	6
Seeding rate (live seed m^{-2})	350
Replicates	4
Varieties	ND Genesis and Robust
Planting date	14-Apr
Harvest date	30-Jul
Harvest area (ft)	5 x 20
Tillage operations	Pottinger TerraDisc

Fungicides evaluated in the 2023 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) or four days post-heading. 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 four days after heading. In another dual treatment, Miravis Ace was applied at heading followed by Sphaerex four days after heading. In the final dual treatment, ChampION was applied both at heading and four 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 2). 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^{-1}) 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). Four days after the heading application for the 'Robust' barley and 'Genesis' barley, the second fungicide application was applied for the dual treatment plots (Table 2). 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	15-Jun
Genesis Inoculated with *Fusarium*	15-Jun
Genesis Post-heading Applications	19-Jun
Robust Heading Applications	15-Jun
Robust Inoculated with *Fusarium*	15-Jun
Robust Post-Heading Applications	19-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 14-Jul for the Robust plots and 16-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 30-Jul. 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 from 0.025 ppm – 15 ppm.

The 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	13.5 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 diseases.

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 April was warmer than average. There were 3591 Growing Degree Days (GDDs) in the season, 44 GDDs more than normal. There was 22.1 inches of precipitation, 6.92 inches more than normal. The wet conditions were conducive to FHB infection and development, providing ideal conditions to assess the efficacy of fungicides.

Table 4. Temperature and precipitation summary for Alburgh, VT, 2023.

Alburgh, VT	April	May	June	July
Average temperature (°F)	48.3	57.1	65.7	72.2
Departure from normal	2.70	-1.28	-1.76	-0.24
Precipitation (inches)	4.94	1.98	4.40	10.8
Departure from normal	1.87	-1.78	0.14	6.69
Growing Degree Days (32-95°F)	524	766	1027	1274
Departure from normal	112	-53.0	-37.0	22.0

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 statistically significant interactions between variety and fungicide+timing treatments in terms of plot severity, FHB incidence and DON concentrations (Figure 1, 2 and 3), meaning that in terms of these variables, the two varieties responded differently to the fungicide treatments.

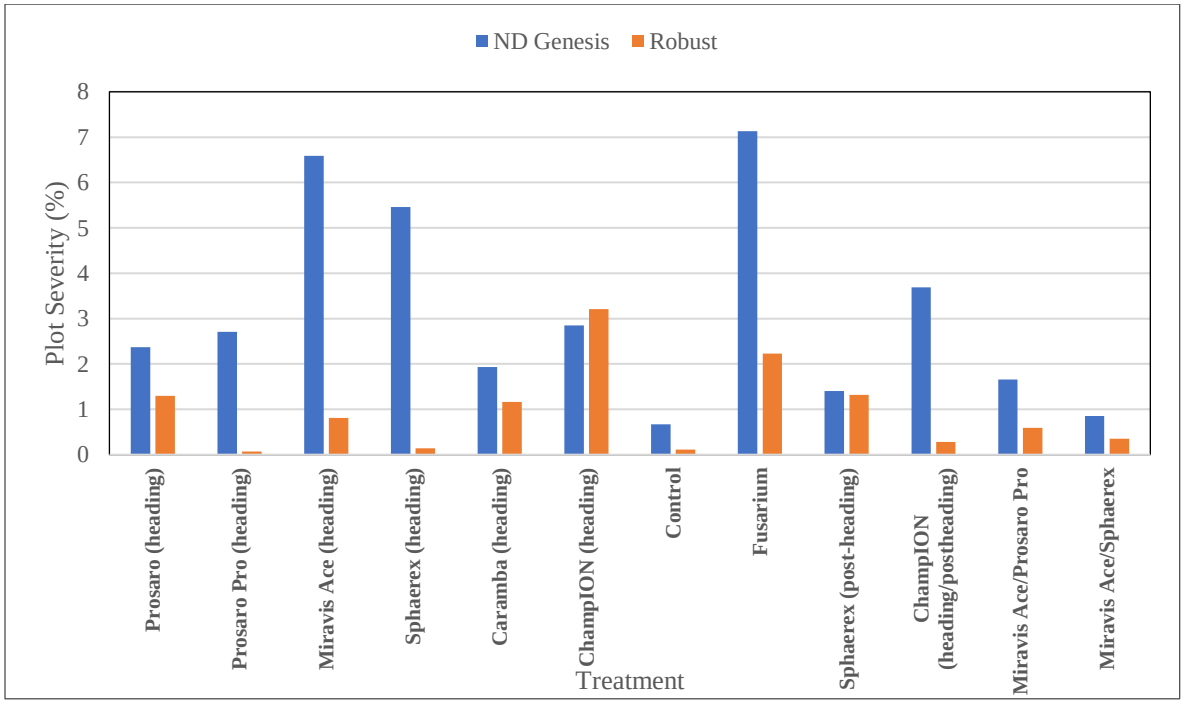

Figure 1. FHB plot severity by barley variety and treatment, Alburgh VT 2023.

For most treatments, Robust responded with decreased average plot severity much more so than ND Genesis (Figure 1). For the ChampION at heading and Sphaerex post-heading treatments, the two varieties had similar levels of severity throughout the plot, indicating that for these treatments the Robust variety did not respond more strongly to these treatments than ND Genesis.

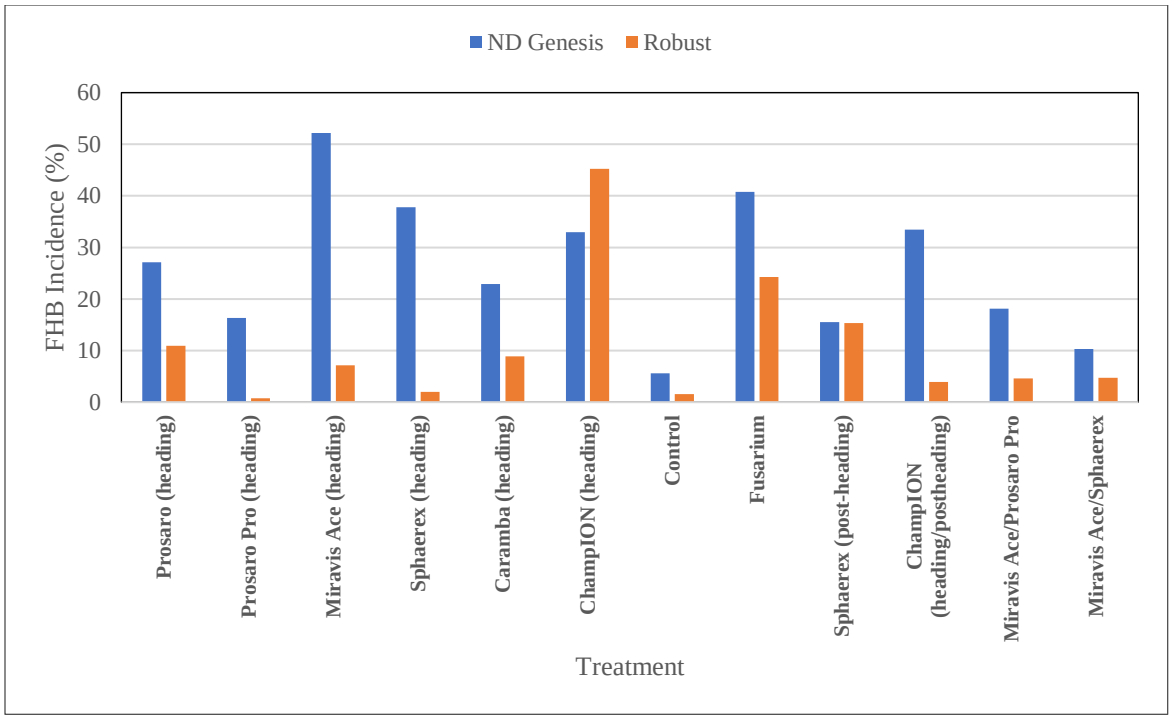

Figure 2. FHB incidence by barley variety and treatment, Alburgh VT 2023.

A similar pattern emerges when considering FHB incidence (Figure 2). While for most treatments Robust showed a noticeably lower incidence of FHB in response to the treatments than ND Genesis, for the ChampION at heading and Sphaerex post-heading treatments, the two varieties had similar levels of FHB incidence. For these treatments the Robust variety did not respond more strongly to these treatments than ND Genesis.

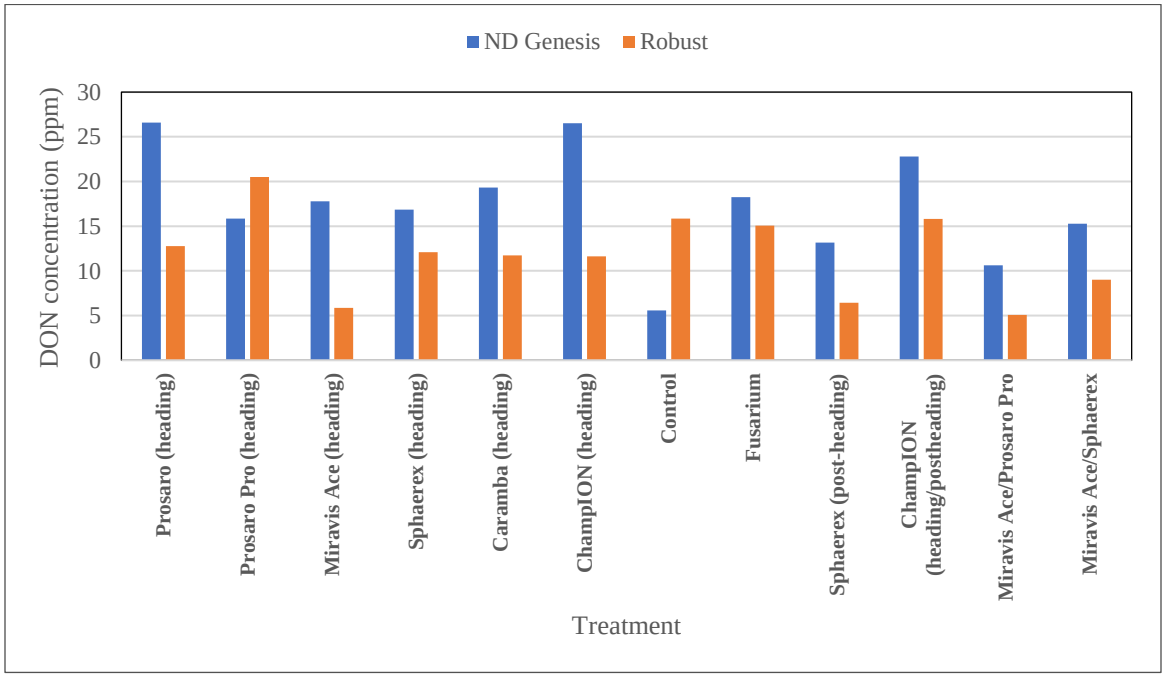

Figure 3. DON concentrations by barley variety and treatment, Alburgh VT 2023.

The final DON concentrations in the harvested barley are by far the most important indicator of the efficacy of fungicide applications. The two varieties responded differently in terms of DON concentrations to the treatments (Figure 3). As with the other two indicators, for most treatments the Robust variety showed a greater reduction in DON concentrations in response to treatments than the ND Genesis variety. Interestingly, the control did show that Robust was more susceptible to the natural levels of fusarium during the growing season compared to ND Gensis. When fusarium was sprayed to inoculate the plots, the ND Gensis showed higher levels of infection compared to Robust. This may be due to spray timing. The fusarium and subsequent fungicide treatments were applied at heading and 4 to 6 days after the heading spray. This data may indicate that the heading treatment applied to ND Gensis was too late to provide much protection. The fungicide treatment of the Robust appeared to be better timed and more effective at controlling disease compared to the timing of application to ND Gensis. Although we try our best to hit optimum timing with persistent rainfall it was difficult to find spray windows for the fungicide 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 only statistically different with the dual Miravis Ace and Sphaerex treatment which had the highest harvest moisture at 18.9% compared to the rest of the treatments, which were not statistically different from each other. All the treatments were over 14.0% and did 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 control treatment had the highest test weight at 44.0 lb bu^{-1}. The highest yielding treatment was the dual ChampION application at 3319 lbs ac^{-1}. Although, it was only statistically different from the *Fusarium* only treatment which had the lowest yield at 2737 lbs ac^{-1}.

All the treatments and timings, including the control and the *Fusarium* inoculated plots, had DON concentrations above the 1 ppm threshold recommended by the FDA. The highest DON concentrations in the trial was the Prosaro treatment applied at heading at 19.7 ppm. The lowest DON concentration was the dual application of Miravis Ace and Prosaro Pro at 7.86 ppm. This was statistically similar to Sphaerex at post-heading (9.81 ppm), the control (10.7 ppm), Miravis Ave at heading (11.8 ppm), and the dual treatment of Miravis Ace and Sphaerex (12.2 ppm).

Table 5. Harvest quality by fungicide treatment and timing, Alburgh, VT, 2023.

Treatment	Timing	Test weight	Harvest moisture	Yield at 13.5% moisture
		lbs bu^{-1}	%	lbs ac^{-1}
Control	Heading	**44.0**	**17.8**	3301*
Fusarium	Heading	42.5*†	18.0*	2737
Caramba	Heading	43.6*	18.2*	3194*
ChampION	Heading	42.7*	17.9*	3123*

ChampION	Heading & post-heading	41.7	18.2*	**3319**
Miravis Ace	Heading	42.6*	18.1*	2980*
Miravis Ace, Prosaro Pro	Heading & post-heading	44.0*	17.9*	3187*
Miravis Ace, Sphaerex	Heading & post-heading	43.0*	18.9	3038*
Prosaro	Heading	41.9*	18.2*	3059*
Prosaro Pro	Heading	42.2*	18.1*	3073*
Sphaerex	Heading	42.5*	17.9*	2890*
Sphaerex	Post-heading	42.7*	18.4*	2993*
LSD (p=0.10) ‡		2.10	0.86	537
Trial mean		42.8	18.1	3075

† Within a column, treatments with an asterik (*) 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. The average infected head refers to the average degree of infection in infected heads only. The FHB plot severity is a weighted average for each plot of the severity of the infected heads multiplied by the number of heads at that degree of infection. The control treatment had the lowest incidence of FHB by visual assessment (3.59%) and the lowest plot disease severity (0.39%). The dual treatment of Miravis Ace and Sphaerex had the lowest FHB severity average at 4.63%. This was statistically similar to the control and the Prosaro Pro treatment. While the ChampION applied at heading had the highest incidence of FHB infected heads (39.1 %) and the Fusarium only treatment had the highest plot disease severity and highest infected head severity, 4.68% and 14.4% respectfully (Table 6).

Table 6. DON concentrations and FHB severity and incidence by fungicide treatment and timing, Alburgh, VT, 2023.

Treatment	Timing	DON	FHB plot Severity	Average infected head severity	Incidence
		ppm	%	%	%
Control	Heading	10.7*†	**0.39**	5.10*	**3.59**
Fusarium	Heading	16.7	4.68	14.4	32.5
Caramba	Heading	15.5	1.54*	8.24*	15.9*
ChampION	Heading	19.1	3.03	6.67*	39.1
ChampION	Heading & post-heading	19.3	1.99*	7.18*	18.7
Miravis Ace	Heading	11.8*	3.70	7.60*	29.7
Miravis Ace, Prosaro Pro	Heading, post-heading	**7.86**	1.13*	9.37*	11.4*
Miravis Ace, Sphaerex	Heading, post-heading	12.2*	0.60*	**4.63**	7.53*
Prosaro	Heading	19.7	1.84*	10.8	19.0
Prosaro Pro	Heading	18.2	1.39*	10.9	8.53*
Sphaerex	Heading	14.5	2.80	9.51*	19.9

Sphaerex	Post-heading	9.81*	1.36*	7.06*	15.4*
LSD (p=0.10) ‡		6.20	1.60	5.90	13.8
Trial Mean		14.6	2.04	8.46	18.4

†Treatments within a column with an asterik (*) 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, 2023.

Variety	Harvest moisture	Test weight	Yield @13.5% moisture	DON	FHB plot severity	Average infected head severity	Incidence
	%	lbs bu^{-1}	lbs ac^{-1}	ppm	%	%	%
ND Genesis	**18.1**†	42.5	**3080**	17.4	3.11	10.7	26.1
Robust	18.2	**43.0**	3069	**11.8**	**0.96**	**6.26**	**10.8**
LSD (0.10) ‡	NS§	NS	NS	2.50	0.66	2.39	5.62
Trial Mean	18.1	42.8	3075	14.6	2.04	8.46	18.4

†The top performing treatment in each column is indicated in **bold.**
‡LSD - Least significant difference at p=0.10.
§NS; No significant difference between treatments.

There were significant differences between varieties across some of the parameters evaluated. Both varieties were above 14% moisture at harvest and below the industry standard of 48 lbs bu^{-1} for test weight, but harvest moisture, test weight, and yield were not statistically different from each other (Table 7). 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 4).

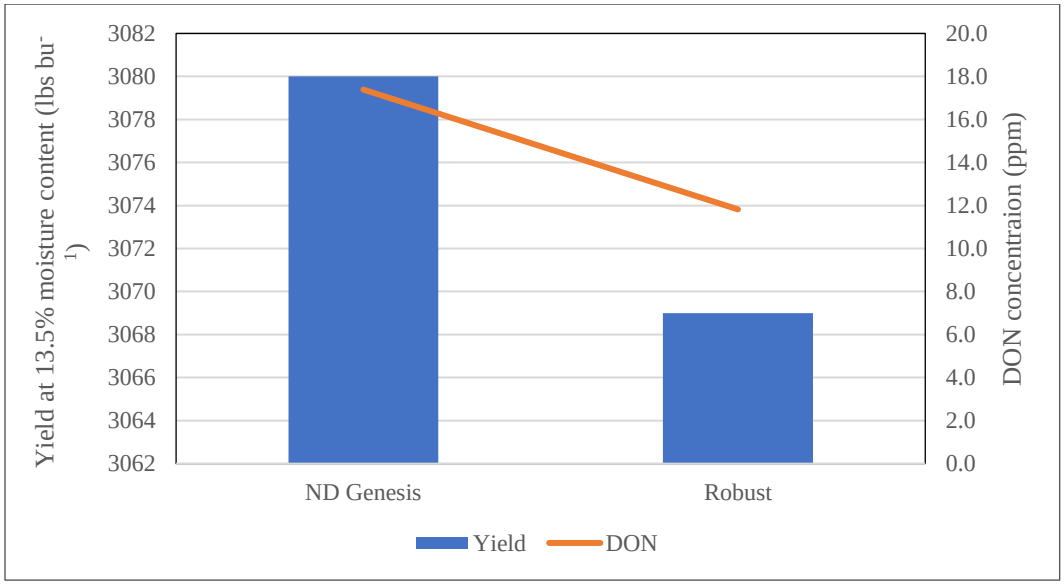

Figure 4. The impact of variety on barley yield and DON concentration, Alburgh VT, 2023.

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. Average temperatures were generally below normal with above normal precipitation through the growing season. Most of this precipitation arrived when the barley was heading which is a critical period for *Fusarium* infection, this combination of cool weather and above average precipitation led to high DON levels across the trial. Even with high DON levels, the dual Miravis Ace and Prosaro Pro treatment and Sphaerex post-heading treatment had lower levels of DON than the control. When ChampION was applied at heading on the Robust variety, there was a large percent of FHB incidence (45.2%) and plot severity (3.21%); however, when ChampION was applied at heading and four days post-heading, there was a reduction in both FHB incidence (3.94%) and plot severity (0.28%). Prosaro Pro applied at heading did have the lowest FHB incidence (0.74%) and plot severity (0.07%) on the Robust variety. However, this was not reflected in the DON concentrations at harvest. When Miravis Ace was applied at heading only on the ND Genesis variety there was a large percent of FHB incidence (52.2%) and plot severity (6.59%); however, when Miravis Ace was applied at heading with Sphaerex, four days post-heading, there was a reduction in both FHB incidence (10.3%) and plot severity (0.85%).

Robust had in general lower DON concentrations than ND Genesis. This may have been a result of better timing of the fungicide application. With the season's weather conditions being cooler than average in combination with significant amounts of precipitation, all treatments saw DON levels well above the 1 ppm threshold for human consumption. Although the levels were higher than 1 ppm for human consumption, the Robust treatments: Miravis Ace applied at heading, Sphaerex applied post-heading, dual Miravis Ace with Prosaro Pro, and dual Miravis Ace with Sphaerex all fell under 10 ppm. The U.S Food and Drug Administration has established DON advisory levels to provide safe food and feed amounts; "10 ppm level is set for grains destined for cattle older than 4 months and for poultry (provided it does not exceed 50% of the diet); and 5 ppm level is set for grains destined for swine (not to exceed 20% of the diet) and other animals (not to exceed 40% of the diet)." The control treatment for ND Genesis was the only treatment that fell under the 10-ppm feed threshold. Again this shows the critical importance of accurate fungicide timing, which can be difficult with constant rain events. This trial is expected to continue for additional years to continue to evaluate new fungicides and combinations of fungicides. It is important to remember that the results only represent one year of data.

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