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

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**THE EFFICACY OF SPRAYING FUNGICIDES TO CONTROL FUSARIUM HEAD BLIGHT INFECTION IN SPRING MALTING BARLEY**

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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 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 rapidly expanding malting industry is providing farmers with new markets, and end-users readily available local malt. Operating maltsters still struggle to source enough local grain to match demand for their product. In addition to short supplies, the local barley that is available sometimes does not meet the rigid quality standards for malting. One major obstacle for growers is *Fusarium* head blight (FHB) infection of grain. This fungal 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 the primary mycotoxin associated with FHB. The spores are usually transported by air currents and can infect plants at spike emergence through grain fill. Consuming DON at over 1 ppm poses a health risk to both humans and livestock, and products with DON values greater than 1 ppm 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 2018, the UVM Extension Northwest Crops and Soils Program initiated year four 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, Vermont in the spring of 2018 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 Rasmussen, a 6-row malting barley that 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 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 soybeans. 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 24-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.**

| **Location** | Borderview Research Farm<br>Alburgh, VT |
|---|---|
| **Soil type** | Benson rocky silt loam |
| **Previous crop** | soybeans |
| **Row spacing (inch)** | 7 |
| **Seeding rate (live seed m$^2$)** | 325 |
| **Replicates** | 4 |
| **Varieties** | Conlon and Rasmussen |
| **Planting date** | 24-Apr |
| **Harvest date** | 30-Jul |
| **Harvest area (ft)** | 5 x 20 |
| **Tillage operations** | Spring plow, disk & spike tooth harrow |

When the barley reached 50% spike emergence (15-Jun), plots were sprayed with the fungicide treatments (Table 2). The adjuvant 'Induce' was added to the Miravis Ace and Caramba applications at a rate of 0.125%. All but one plot (Control) of each cultivar was inoculated 2 hours 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 (19-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.* 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. 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.

**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.

**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 | 15-Jun | 19-Jun | Water |
| Actinovate | 15-Jun | 19-Jun | 6 fl oz $ac^{-1}$ |
| Caramba | 15-Jun | 19-Jun | 14 fl oz $ac^{-1}$ +.125% Induce $ac^{-1}$ |
| ChampION | 15-Jun | 19-Jun | 1.5 lbs $ac^{-1}$ |
| Miravis Ace | 15-Jun | 19-Jun | 13.7 fl oz $ac^{-1}$+ .125% Induce $ac^{-1}$ |
| SONATA | 15-Jun | 19-Jun | 2 qt. $ac^{-1}$ |
| *Fusarium graminearum* | 15-Jun | | 40,000 spores/ml |

When the barley reached the soft dough growth stage (9-Jul), FHB intensity was assessed by randomly clipping 60-100 heads throughout each plot, counting spikes, and visually assessing each head for FHB infection. 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 in Alburgh with an Almaco SPC50 plot combine on 30-Jul, the harvest area was 5' x 20'. At the time of harvest, grain moisture, test weight, and yield were calculated. Harvest moisture was determined for each plot using a DICKEY-john Mini GAC moisture and test weight meter. Generally the heavier the barley is per bushel, the higher malting quality. The acceptable test weight for barley is 48 lbs $bu^{-1}$.

Following the harvest of spring barley, seed was cleaned with a small Clipper cleaner (A.T. Ferrell, Bluffton, IN). A one-pound subsample was collected to determine quality. Hundred kernel weights were measured in duplicate for each plot and then averaged. Once hundred kernel weights were 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) concentrations were 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 by the FDA.

All data was analyzed using a mixed model analysis where replicates were considered random effects and the treatments and varieties were considered fixed effects. The LSD procedure was used to separate treatment and 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 (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 accompanying 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 shown in bold.

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

# RESULTS

Seasonal precipitation and temperature recorded at a weather station at Borderview Research Farm are shown in Table 3. While April was cooler and wetter than normal, the rest of the growing season was warmer and drier than average. From April through July, there was an accumulation of 3403 Growing Degree Days (GDDs), 50 GDDs above the 30-year average.

**Table 3. Temperature and precipitation summary for Alburgh, VT, 2018.**

| **Alburgh, VT** | April | May | June | July |
|---|---|---|---|---|
| Average temperature (°F) | 39.2 | 59.5 | 64.4 | 74.1 |
| Departure from normal | -5.58 | 3.10 | -1.38 | 3.51 |
| | | | | |
| Precipitation (inches) | 4.4 | 1.9 | 3.7 | 2.4 |
| Departure from normal | 1.61 | -1.51 | 0.05 | -1.72 |
| | | | | |
| Growing Degree Days (32-95°F) | 272 | 853 | 973 | 1305 |
| Departure from normal | -112 | 97 | -42 | 107 |

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 treatment in terms of yield and test weight (Figure 1). Miravis Ace, applied either at heading or at four days after heading, was correlated with decreased yields and test weight in the resistant Conlon variety, and higher yield and test weight in the susceptible variety Rasmussen. Actinovate applied four days after heading is also correlated with lower yield in the Conlon variety and higher yield in the Rasmussen variety. There were no significant interactions between variety and treatment in *Fusarium* incidence or severity or DON levels.

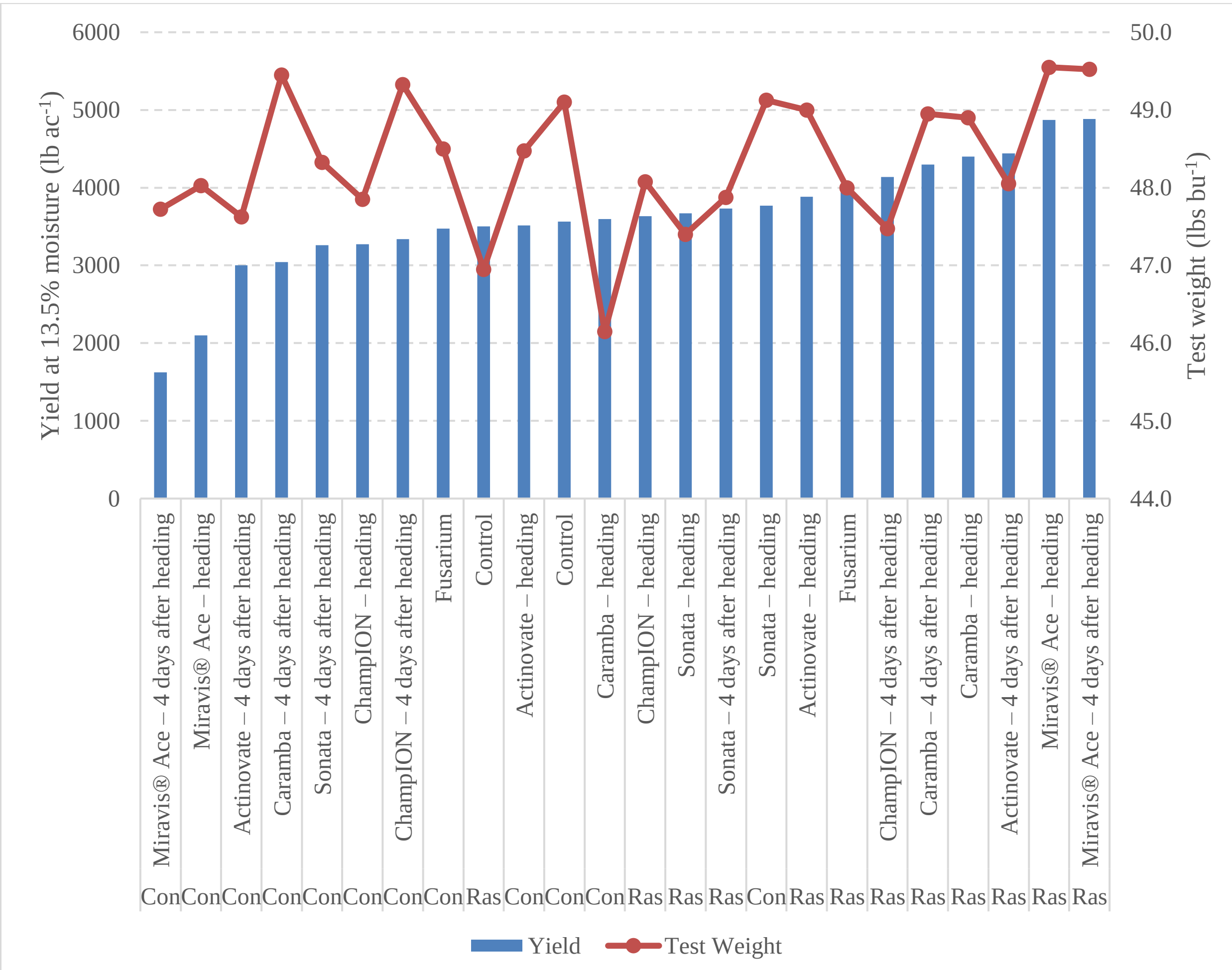


**Figure 1. Barley Variety x Fungicide+Timing Interactions**

***Impact of Fungicide and Timing***

All treatments, including the control and the plots treated with *Fusarium* only, had less than one percent severity of FHB and the incidence of infected heads ranged from a low of just under three percent to a high of just over seven percent. There were significant differences in the average severity and incidence of FHB between fungicide+timing treatments (Table 4). The Miravis Ace – 4 days after heading treatment had the lowest severity and incidence of FHB with a severity of 0.2% and an incidence of infected heads of 3%. These are statistically similar to all treatments except Actinovate – 4 days after heading, and Sonata applied both at heading and 4 days after heading, which had significantly higher levels of severity and incidence of infected heads.

**Table 4. The FHB incidence and severity following fungicide treatments at heading and 4 days after heading, Alburgh, VT, 2018.**

| Treatment | Average FHB severity | Incidence of FHB infected heads |
|---|---|---|
| | % | % |
| Non-sprayed, non-inoculated control | 0.410* | 5.16* |
| Inoculated *Fusarium* spores 23-Jun | 0.427* | 4.51* |
| Actinovate – heading | 0.341* | 4.68* |
| Actinovate – 4 days after heading | 0.468 | 6.01 |
| Caramba – heading | 0.360* | 4.85* |
| Caramba – 4 days after heading | 0.262* | 3.59* |
| ChampION – heading | 0.235* | 3.35* |
| ChampION – 4 days after heading | 0.327* | 4.68* |
| Miravis Ace – heading | 0.279* | 3.82* |
| Miravis Ace – 4 days after heading | **0.215*** | **2.95*** |
| Sonata – heading | 0.513 | 7.33 |
| Sonata – 4 days after heading | 0.525 | 5.94 |
| *LSD (0.10)* | 0.245 | 2.93 |
| *Trial Mean* | 0.363 | 4.74 |

* Treatments that are not significantly different than the top performing variety in a column shown in **bold** are indicated with an asterisk**.**

There were significant differences in yield, harvest moisture, test weight, and Deoxynivalenol (DON) concentration between fungicide+timing treatments (Table 5, Figure 2). The unsprayed, non-inoculated control had the lowest harvest moisture. All treatments had harvest moisture between 14.4% and 15.1% and required very little drying for long-term storage. The Caramba – 4 days after heading treatment had the highest test weight at 49.2 lbs $bu^{-1}$. This was statistically similar to six other treatments. All treatments produced barley with a test weight between 48.0 and 49.2 lbs $bu^{-1}$.The highest yielding treatment was the Caramba – heading treatment with a yield of 3998 lbs $ac^{-1}$ at a moisture content of 13.5%. This was statistically similar to all other treatments except the Miravis Ace – 4 days after heading treatment, which produced a yield of 3252 lbs $ac^{-1}$ at 13.5% moisture content.

All fungicide+timing treatments had DON concentrations below the FDA 1 ppm recommendation. The lowest concentrations occurred in the Miravis Ace – 4 days after heading treatment. This was statistically similar to the Miravis Ace – heading treatment and the non-inoculated control.

**Table 5. The impact application timing and fungicide on barley yield and quality, Alburgh, VT, 2018.**

| Treatment | Harvest moisture | Test weight | Yield @13.5% moisture | DON |
|---|---|---|---|---|
| | % | lbs bu$^{-1}$ | lbs ac$^{-1}$ | ppm |
| Non-sprayed, non-inoculated control | **14.4*** | 48.0 | 3532* | 0.238* |
| Inoculated *Fusarium* spores 23-Jun | 14.5* | 48.3* | 3732* | 0.575 |
| Actinovate – heading | 14.8 | 48.7* | 3699* | 0.538 |
| Actinovate – 4 days after heading | 14.8 | 47.8 | 3722* | 0.488 |
| Caramba – heading | 14.8 | 47.5 | **3998*** | 0.375 |
| Caramba – 4 days after heading | 14.8 | **49.2*** | 3672* | 0.413 |
| ChampION – heading | 14.7* | 48.0 | 3452* | 0.513 |
| ChampION – 4 days after heading | 14.8 | 48.4* | 3738* | 0.613 |
| Miravis Ace – heading | 14.8 | 48.8* | 3487* | 0.288* |
| Miravis Ace – 4 days after heading | 15.1 | 48.6* | 3252 | **0.188*** |
| Sonata – heading | 14.7* | 48.3* | 3720* | 0.613 |
| Sonata – 4 days after heading | 14.6* | 48.1 | 3495* | 0.463 |
| *LSD (0.10)* | 0.364 | 1.04 | 592 | 0.155 |
| *Trial Mean* | 14.7 | 48.3 | 3625 | 0.442 |

* Treatments that are not significantly different than the top performing variety in a column shown in **bold** are indicated with an asterisk**.**

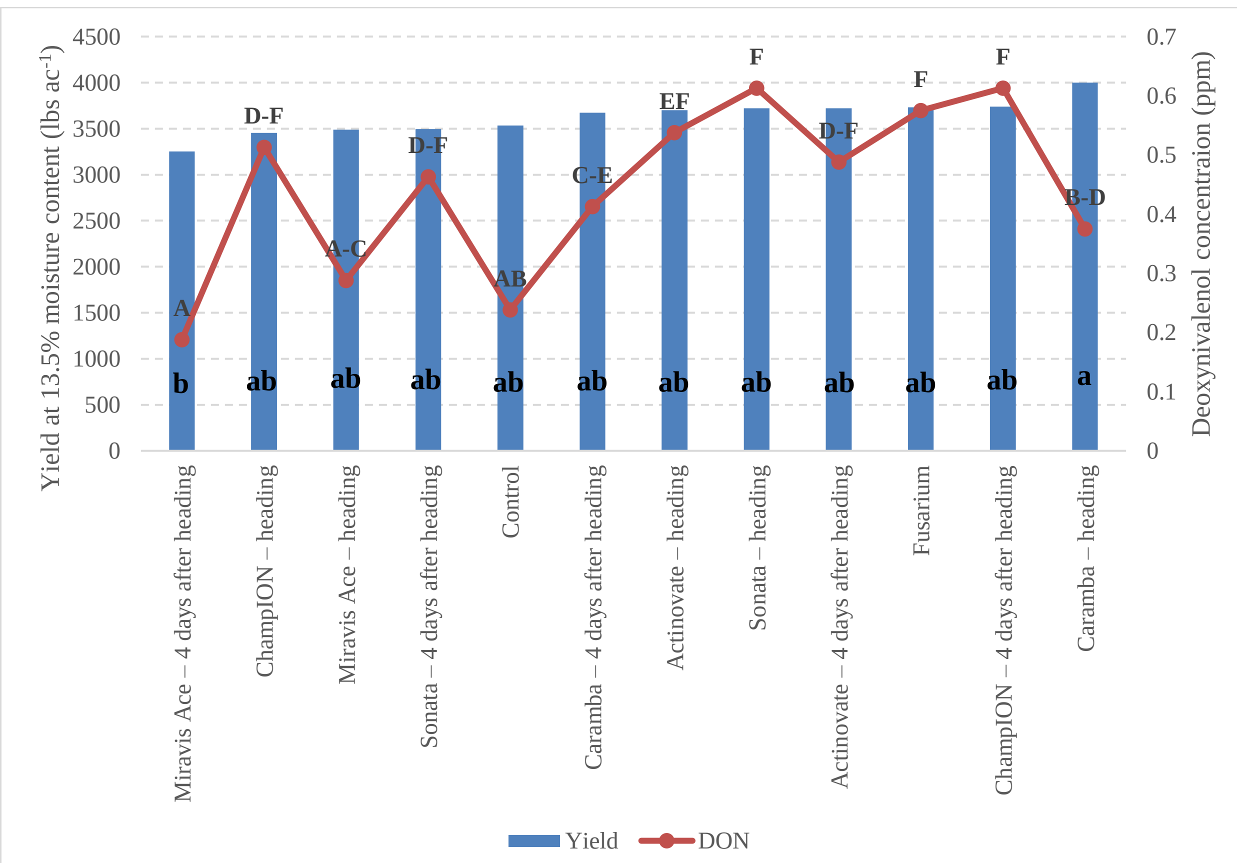


**Figure 2. The impact of application timing and fungicide on barley yield and DON concentration.**
Treatments with the same letter did not differ significantly by DON concentration (capital letters) or yield (lowercase).

***Impact of Variety***

There were significant differences in the average FHB plot severity and incidence of FHB infection between malting barley varieties (Table 6). The FHB resistant variety Conlon had the lowest average FHB severity (0.3%) and incidence of FHB infected heads (4.1%).

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

| Variety | Average FHB severity | Incidence FHB of infected heads |
|---|---|---|
| | % | % |
| Conlon | **0.295*** | **4.09*** |
| Rasmussen | 0.432 | 5.39 |
| *LSD (0.10)* | 0.100 | 1.20 |
| *Trial Mean* | 0.363 | 4.74 |

* Treatments that are not significantly different than the top performing variety in a column shown in **bold** are indicated with an asterisk.

The malting barley varieties were identical in harvest moisture and test weight, and significantly different in yield and DON (Table 7, Figure 3). Both varieties had moistures slightly above 14% and therefore had to be dried down for storage. Both varieties achieved industry standards for test weight of 48 lbs $bu^{-1}$. While both varieties had DON concentrations below the FDA 1 ppm recommendation, Conlon was statistically significantly lower at 0.3 ppm compared to Rasmussen at 0.6 ppm. Rasmussen had significantly higher yield than Conlon (Figure 3).

**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 | 14.7 | 48.3 | 3130 | **0.317*** |
| Rasmussen | 14.7 | 48.3 | **4120*** | 0.567 |
| *LSD (0.10)* | NS | NS | 242 | 0.063 |
| *Trial Mean* | 14.7 | 48.3 | 3625 | 0.442 |

* Treatments that are not significantly different than the top performing variety in a column shown in **bold** are indicated with an asterisk.
NS – No significant difference.

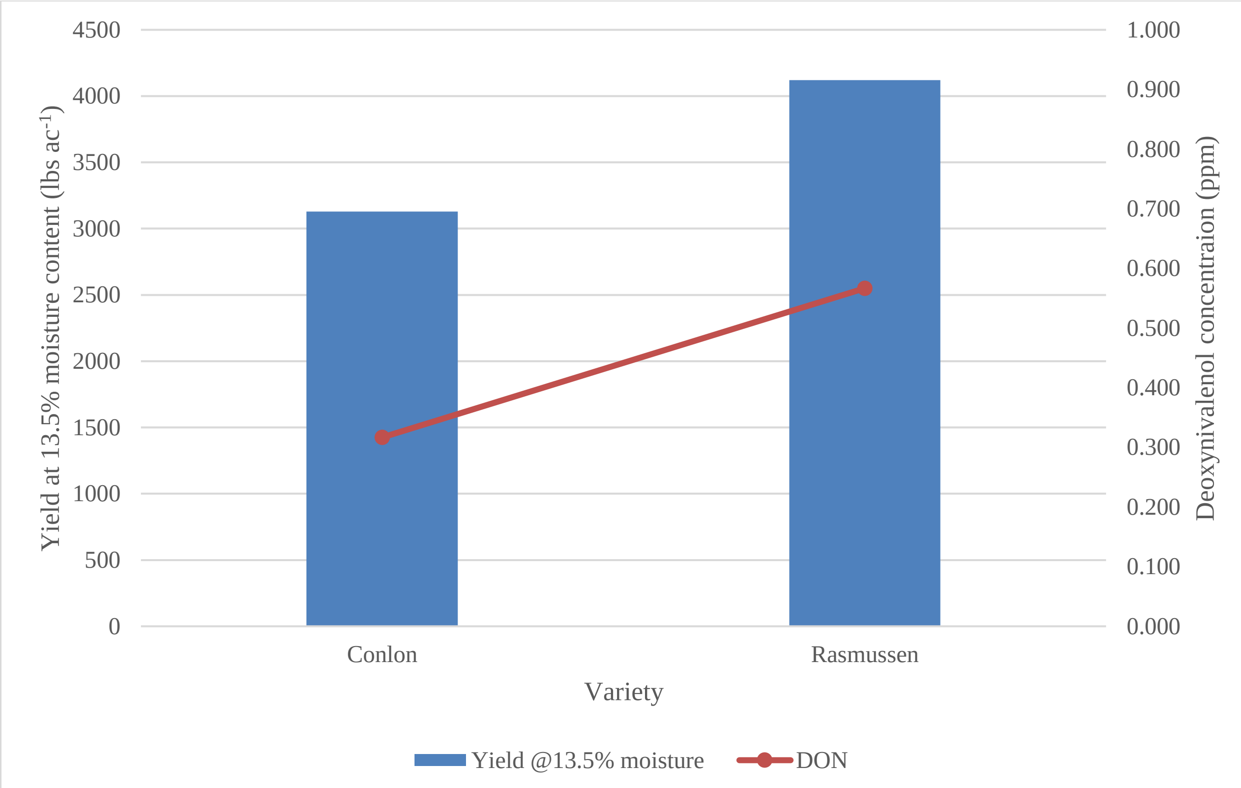


**Figure 3. The impact of variety on barley yield and DON concentration.**

## DISCUSSION

Overall, the 2018 growing season was a good year for growing spring barley. The lower than normal rainfall throughout much of the growing season presented less than ideal conditions for the *Fusarium* fungus growth. This is evident in the low DON concentrations in both varieties, with even those plots inoculated with *Fusarium* but not treated having average DON concentrations below the FDA limit of 1 ppm.

Even though all of the variety+fungicide+timing treatments resulted in DON concentrations below 1 ppm, it is worth noting that Conlon, a moderately resistant variety, had a lower incidence of FHB and DON levels.

The application of the conventional fungicide Miravis Ace was the most effective at reducing DON level, applied either at heading or 4 days after. However, this was not statistically different than the performance of the control plots in this dry year that was not conducive to the growth of the *Fusarium* fungus. Interestingly, the application of this fungicide is correlated with the highest yields of the trial in the susceptible variety Rasmussen and the lowest yields of the trial in the resistant variety Conlon. Caramba, applied either at heading or four days afterwards, was the next most effective at reducing DON levels.

In the 2017 trial (conducted in a cool, wet growing season with much higher FHB incidence and DON levels), we noted that fungicide application at heading was more effective than application at four days after heading. This trend was not evident in the 2018 trial.

It is important to remember that the results only represent one year of data.

# ACKNOWLEDGEMENTS

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