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 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. No 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 2015, the UVM Extension Northwest Crops and Soils Program initiated year two 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 18-Apr to investigate the effects of cultivar resistance, fungicide efficacy, application timing on FHB and DON infection in spring malt 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 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 spring oats. Prior to planting, the trial area was disked and spike tooth harrowed to prepare for planting. The plots were seeded with a Sunflower seed drill on 18-Apr at a seeding rate of 123 lbs ac^{-1}. Plot size was 10’x 20’.

Table 1. General plot management of the trial.

Trial Information	
Location	Borderview Research Farm Alburgh, VT
Soil type	Benson rocky silt loam
Previous crop	Oats
Row spacing (inch)	7
Seeding rate (lbs ac^{-1})	123
Replicates	4
Varieties	Conlon and Rasmussen
Planting date	18-Apr
Harvest date	27-Jul
Harvest area (ft)	5 x 20
Tillage operations	Spring plow, disk & spike tooth harrow

When the barley reached 50% anthesis (24-Jun), plots were sprayed with one of six fungicides (Table 2). The application was made using a Schaben 3-point Sprayer-110-gallon-8 Pump Roller calibrated to deliver at a rate of 10 gallons per acre. The adjuvant 'Induce' was added to the Porsaro application at a rate of 0.125%. At the recommendation of the manufacturer, Cueva and Double Nickel 55 were combined. All but one plot (Control) of each cultivar was inoculated 24 hours (25-Jun) after the anthesis 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'. Ten days after anthesis (7-Jul), a post-anthesis fungicide spray was applied (Table 2). Due to space constraints, Oso and Sil-Matrix were only applied at anthesis. 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.

Champ WG (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.

Cueva (EPA# 67702-2) fungicide concentrate is a patented, fixed copper fungicide made by combining a soluble copper fertilizer with a fatty acid to form a true soap. This copper soap fungicide protects plants from infection from a wide range of diseases, including downy and powdery mildews. This product is approved for use in organic production systems.

Double Nickel 55 (EPA# 70051-108) is a broad spectrum preventive biofungicide for control or suppression of fungal and bacterial plant diseases. This product is approved for use in organic production systems.

OSO™ 5% SC Fungicide (EPA# 68173-4-70051) is a 5% Polyoxin D zinc salt fungicide that controls diseases on vegetable and fruit crops. 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.

Regalia (EPA # 85059-3) bio fungicides have a unique and complex mode of action, referred to as Induced Systemic Resistance (ISR), and carry a FRAC code of P5. ISR creates a defense response in the treated plants and stimulates additional biochemical pathways that strengthen the plant structure and act against the pathogen. When applied to crops, Regalia products activate ISR and induce the plants to produce specialized proteins and other compounds—phytoalexins, cell strengtheners, antioxidants, phenolics, and PR proteins—which are known to inhibit fungal and bacterial diseases and also improve plant health and vigor. This product is approved for use in organic production systems.

Sil-MATRIX (EPA#82100-1) introduces a novel active ingredient—soluble silica (29% Potassium Silicate)—to crop protection. When spray applied, it controls the mites and insects it contacts suppressing their populations. Sil-MATRIX also forms a physical barrier within the leaf cuticle that prevents penetration of fungal diseases, primarily powdery mildew. This product is approved for use in organic production systems.

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

Treatments	Anthesis application	Post-anthesis application	Application rate
	date	date	
Control	24-Jun	7-Jul	water
Fusarium graminearum	24-Jun	7-Jul	water
Champ WG	24-Jun	7-Jul	1 lb ac^{-1}
Prosaro	24-Jun	7-Jul	6.5 fl oz ac^{-1}, (+ 0.125% Induce)
Regalia	24-Jun	7-Jul	1 qt ac^{-1}
OSO	24-Jun	-	6.5 fl oz ac^{-1}
Sil-MATRIX	24-Jun	-	3 qts. ac^{-1}
Cueva and Double Nickle 55	24-Jun	7-Jul	2 qts. ac^{-1} (+ 0.5 lbs ac^{-1} Double Nickle 55)

When the barley reached the soft dough growth stage, 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 27-Jul, 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 2015 site are shown in Table 3. The growing season this year was marked by lower than normal temperatures in April, June and July and higher than average temperatures in May. Rainfall amounts in June were 2.73 inches higher than average, while the rest of the months were below seasonal norms. From April to July, there was an accumulation of 3408 Growing Degree Days (GDDs) in Alburgh, which is 55 GDDs above the 30 year average.

Table 3. Temperature and precipitation summary for Alburgh, VT, 2015.

Alburgh, VT	**Apr**	**May**	**Jun**	**Jul**
Average temperature (°F)	43.4	61.9	63.1	70.0
Departure from normal	-1.41	5.50	-2.70	-0.60
Precipitation (inches)	0.09	1.94	6.42	1.45
Departure from normal	-2.73	-1.51	2.73	-2.70
Growing Degree Days (base 32°F)	352	930	938	1188
Departure from normal	-32.1	174	-76.4	-10.3

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

Barley Variety x Fungicide/Timing Interactions:

There was a variety by fungicide treatment interaction for test weight and DON concentrations. These interactions indicate that malting barley varieties respond differently to the fungicide treatments. The DON levels in the Conlon plots varied slightly between fungicide+timing treatments and were not significantly different (Figure 1). The lowest DON concentration in the Conlon plots was Prosaro applied at anthesis (0.95 ppm). The Rasmussen plots were significantly different by fungicide+timing applications. In the Rasmussen plots, the Prosaro anthesis (1.67 ppm) resulted in the lowest DON levels, and all other treatments had significantly higher levels of DON concentrations.

The test weights in the Conlon and Rasmussen plots were significantly different by fungicide+timing application (Figure 2). In general, the test weights of both varieties responded similarly to the different fungicide+timing treatments. However, the *Fusarium graminearum* spray and Oso anthesis treatments had the highest test weights in the variety Conlon but produced the lowest test weights in the variety Rasmussen (Figure 2).

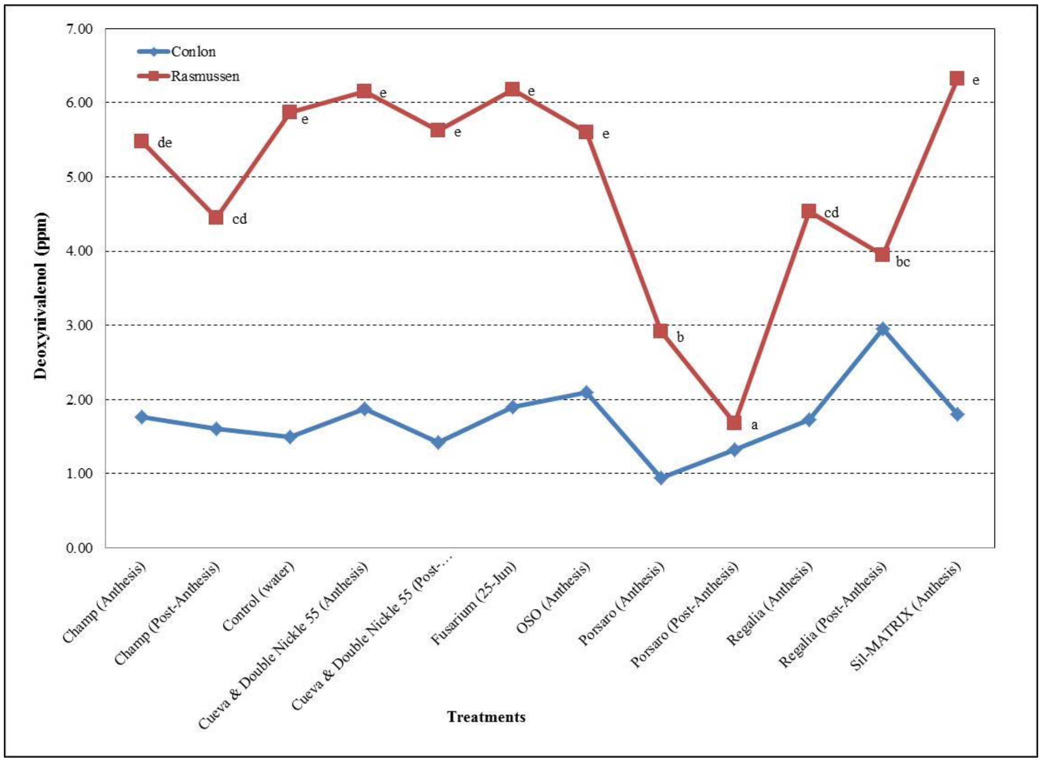

Figure 1. Malting barley variety by fungicide interaction on Deoxynivalenol (DON) level.
Treatments with the same letter did not differ significantly.

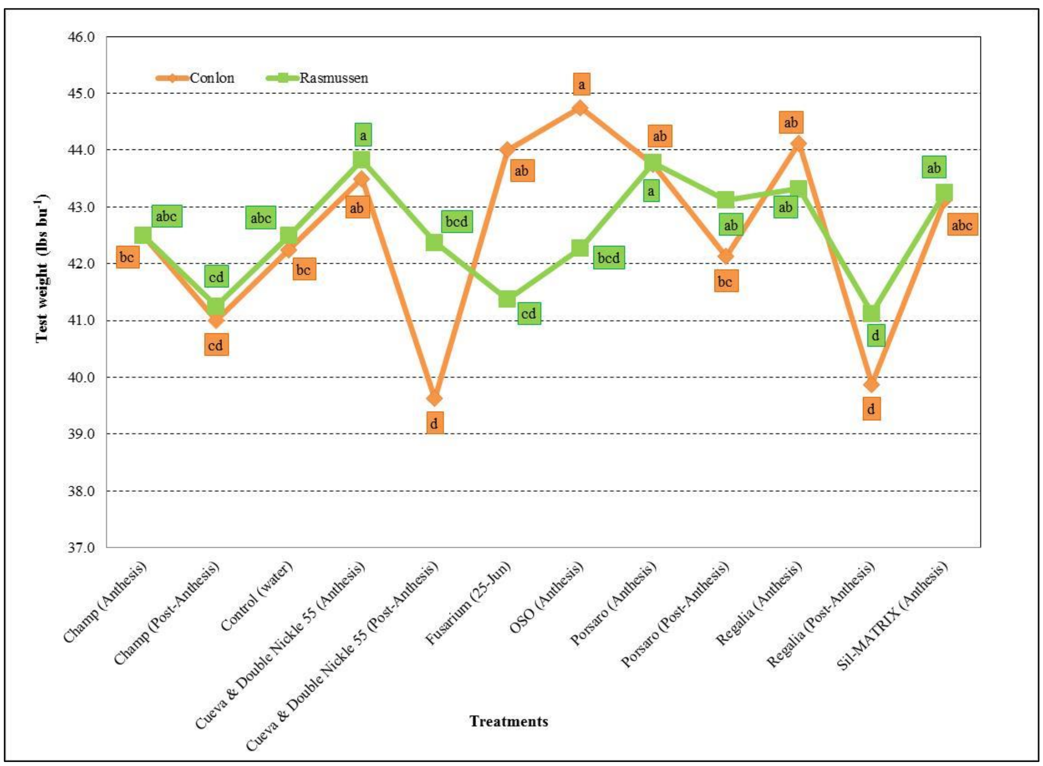

Figure 2. Barley variety by fungicide interaction on test weight.
Treatments with the same letter did not differ significantly.

Impact of Fungicide and Timing

There were significant differences in the average FHB plot severity and incidence of infected heads between fungicide+timing treatments (Table 4). The Prosaro applied at anthesis had the lowest average FHB plot severity (3.17%), average infected head severity (9.01%), and the lowest incidence of infected heads (32.1%). Other fungicide+timing treatments with low FHB severity include; anthesis applied Cueva and Double Nickle 55 (5.33%), OSO (5.53%), Sil-MATRIX (5.80%), Champ (6.56%), and Regalia (6.78%), and the Control (6.46%). The Cueva and Double Nickle 55 applied at anthesis also had a low incidence of infected heads (43.8%). The post-anthesis application of Regalia had the highest average FHB plot severity (12.6%) and infected head severity (20.7%). The highest FBH incidence was the post-anthesis application of Champ (75.9%).

Table 4. The FHB incidence and severity following fungicide treatments at anthesis and post-anthesis, Alburgh, VT 2015.

Treatment	Timing	Average FHB severity	Average infected head severity	Incidence of infected heads
		%	%	%
Control (water)	All	6.46*	11.6	51.0
Fusarium	25-Jun	7.75	11.5	53.7
Champ WG	Anthesis	6.56*	12.4	53.1
Champ WG	Post-Anthesis	8.94	11.5	75.9
Cueva and Double Nickle 55	Anthesis	5.33*	10.7	43.8*
Cueva and Double Nickle 55	Post-Anthesis	11.8	20.4	62.6
OSO	Anthesis	5.53*	10.6	52.7
Prosaro	Anthesis	**3.17***	**9.01**	**32.1***
Prosaro	Post-Anthesis	8.60	13.8	56.2
Regalia	Anthesis	6.78*	13.1	49.9
Regalia	Post-Anthesis	12.6	20.7	64.3
Sil-MATRIX	Anthesis	5.80*	11.6	49.7
LSD (0.10)		4.20	NS	14.1
Trial Mean		7.45	13.1	53.8

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

There were significant differences in yield, harvest moisture, test weight and DON concentration between fungicide+timing treatments (Table 5). All of the post-anthesis fungicide treatments yielded higher than the control, *Fusarium graminearum* spray, and the anthesis applied fungicide plots (Figure 3). The post-anthesis application of Prosaro yielded the highest with 1747 lbs ac^{-1}. Another high yielding fungicide+timing treatment was the post-anthesis applied Champ (1449 lbs ac^{-1}). The lowest harvest moisture was the post-anthesis spray of Regalia at 16.9%. The treatments with the highest harvest moisture were anthesis applied Champ, OSO, and Prosaro. All of the fungicide+timing treatments had moistures above 14%, the optimum moisture for grain storage, and therefore had to be dried down. Prosaro applied at anthesis had the highest test weight of 43.8 lbs bu^{-1}, the lowest test weight was the post-anthesis applied Regalia (40.5 lbs bu^{-1}). None of the fungicide+timing treatments met industry standards of 48 lbs bu^{-1} for barley. The post-anthesis applied Prosaro had the lowest DON level (1.50 ppm) and was not significantly different than anthesis applied Prosaro (1.93 ppm) (Figure 4). The treatment with the highest DON concentration was Sil-MATRIX applied at anthesis (4.06 ppm). However this was not significantly different from the *Fusarium graminearum* treatment, the Control, anthesis sprayed Champ, Cueva & Double Nickle 55, and OSO, and the post-anthesis sprayed Cueva & Double Nickle 55 and Regalia. All fungicide+timing treatments had DON concentrations above the FDA 1 ppm recommendation.

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

Treatment	Timing	Yield @13.5% moisture	Harvest moisture	Test weight	DON
		lbs ac^{-1}	%	lbs bu^{-1}	ppm
Control (water)	All	936	18.2	42.4	3.69
Fusarium	25-Jun	911	18.1	42.7*	4.04
Champ WG	Anthesis	911	18.4	42.5*	3.62
Champ WG	Post-Anthesis	1449*	17.3*	41.1	3.03
Cueva and Double Nickle 55	Anthesis	961	18.2	43.7*	4.01
Cueva and Double Nickle 55	Post-Anthesis	1385	17.1*	41.0	3.53
OSO	Anthesis	652	18.4	43.5*	3.85
Prosaro	Anthesis	757	18.4	**43.8***	1.93*
Prosaro	Post-Anthesis	**1747***	17.9	42.6*	**1.50***
Regalia	Anthesis	969	18.0	43.7*	3.13
Regalia	Post-Anthesis	1378	**16.9***	40.5	3.45
Sil-MATRIX	Anthesis	1067	18.1	43.2*	4.06
LSD (0.10)		315	0.45	1.30	0.82
Trial Mean		1094	17.9	42.6	3.32

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.

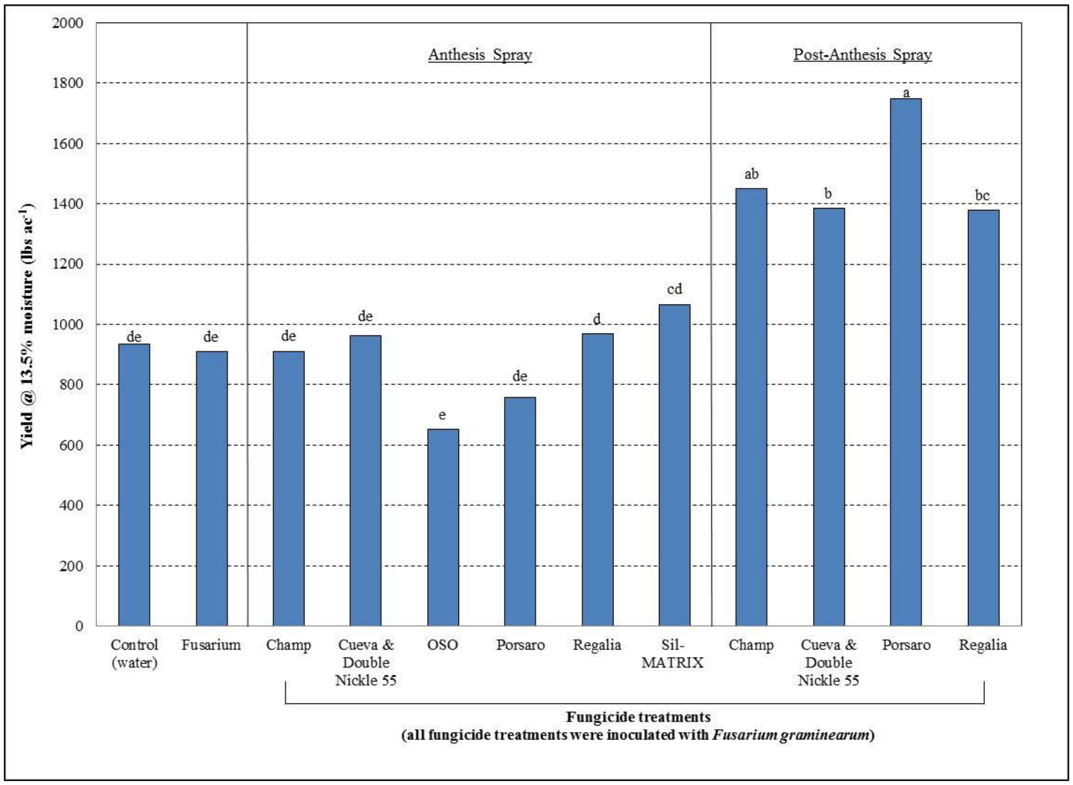

Figure 3. The impact of application timing and fungicide on barley yield.
Treatments with the same letter did not differ significantly.

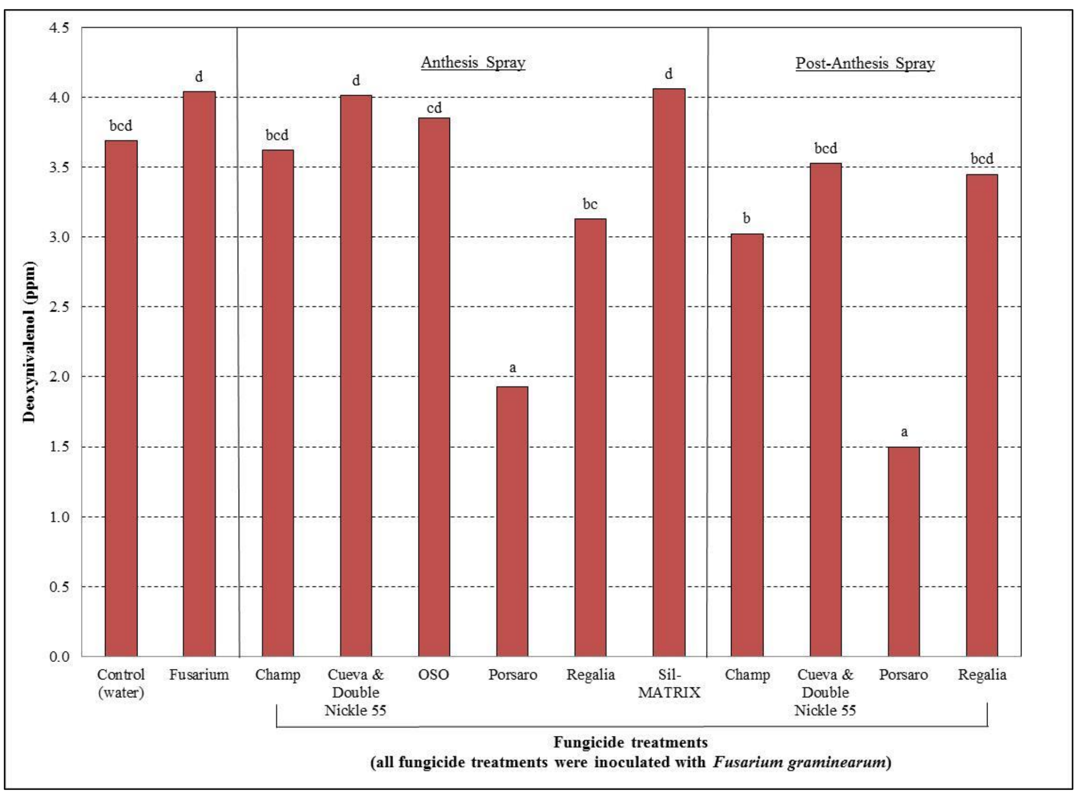

Figure 4. The impact of application timing and fungicide on DON levels.
Treatments with the same letter did not differ significantly.

Impact of Variety

There were significant differences in the average FHB plot severity, infected head severity, and incidence of FHB infection between malting barley varieties (Table 6, Figure 5). Conlon had the lowest average FHB plot severity (5.02%), average infected head severity (11.2%) and the lowest incidence of infected heads (40.9%).

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

Variety	Average FHB severity	Average infected head severity	Incidence of infected heads
	%	%	%
Conlon	**5.02***	**11.2***	**40.9***
Rasmussen	9.87	15.0	66.6
LSD (0.10)	1.72	2.95	5.75
Trial Mean	7.45	13.1	53.8

Values shown in **bold** are of the highest value or top performing.
* Varieties that are not significantly different than the top performing variety in a column are indicated with an asterisk

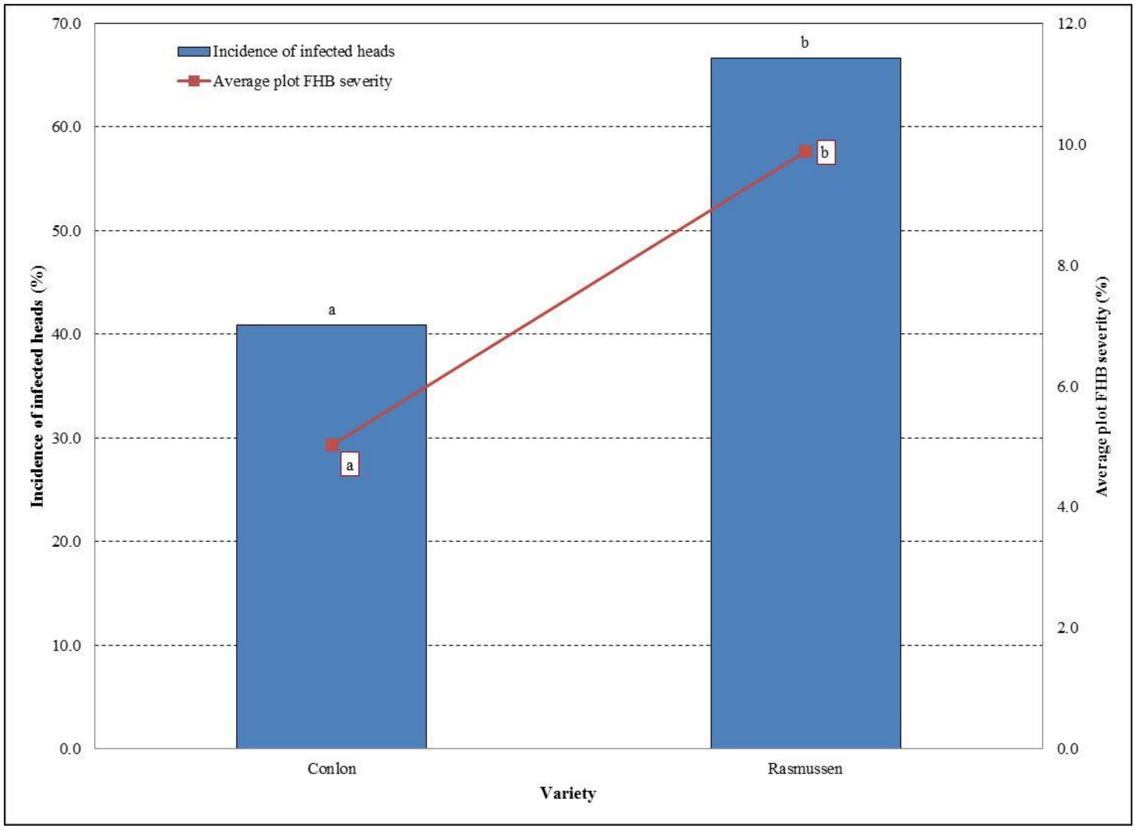

Figure 5. The impact of barley variety on the incidence of FHB infected heads and the average plot FHB severity.
Treatments with the same letter did not differ significantly.

The malting barley varieties were significantly different in yield, harvest moisture, and DON level (Table 7, Figure 6). Conlon yielded the highest (1198 lbs ac^{-1}) and Rasmussen the lowest (989 lbs ac^{-1}). Conlon had the lowest harvest moisture (17.8%). Test weight was not significantly different between varieties; both had test weights of 42.6 lbs bu^{-1}. Conlon had the lowest DON concentration (1.74 ppm) and Rasmussen had the highest at 4.90 ppm.

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

Variety	Yield @13.5% moisture	Harvest moisture	Test weight	DON
	lbs ac^{-1}	%	lbs bu^{-1}	ppm
Conlon	**1198***	**17.8***	**42.6**	**1.74***
Rasmussen	989	18.1	**42.6**	4.90
LSD (0.10)	128	0.18	NS	0.33
Trial Mean	1094	17.9	42.6	3.32

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

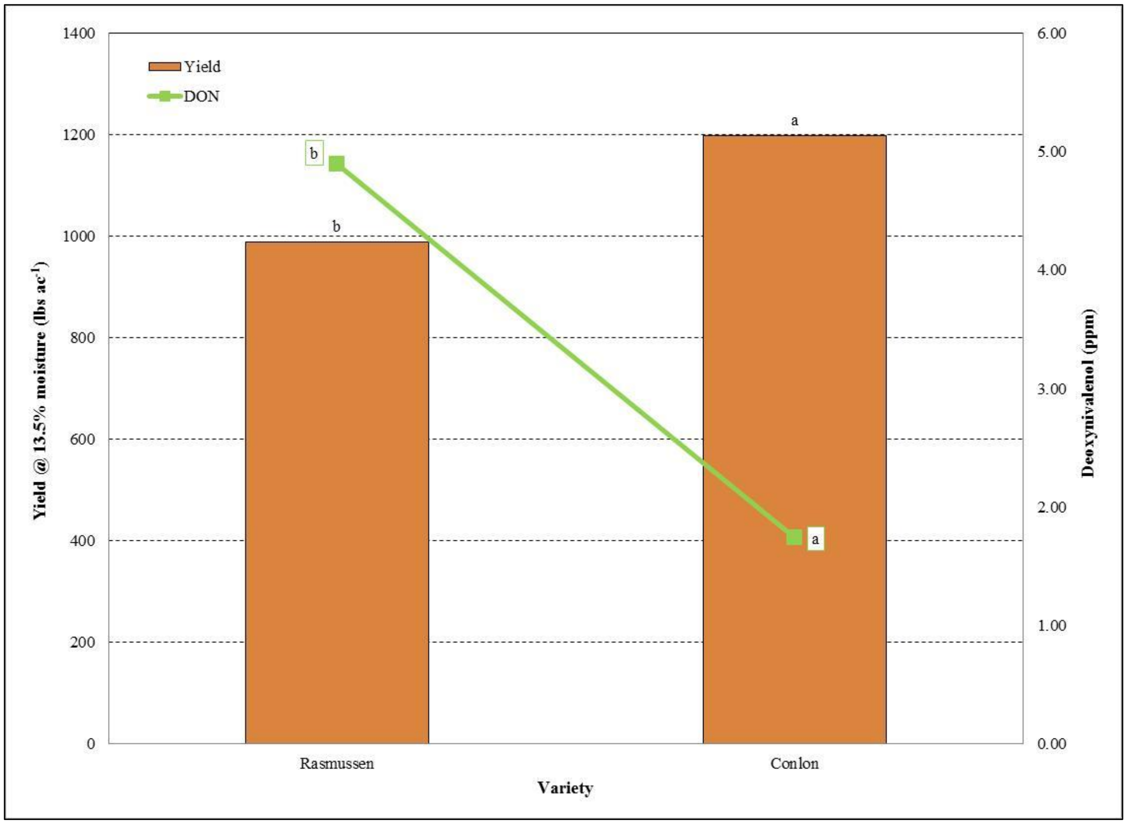

Figure 6. The impact of malting barley variety on yield and DON level.
Treatments with the same letter did not differ significantly.

DISCUSSION

Overall, the 2015 growing season was challenging for growing spring barley. The cooler than average temperatures along with the higher than normal rainfall in June created the ideal conditions for Fusarium growth. This is evident in the high DON concentrations in both varieties. The only treatment that resulted in a DON level below 1ppm was Prosaro, a conventional fungicide, applied at anthesis to Conlon (0.95 ppm).

Even though all but one of the variety+fungicide+timing treatments resulted in DON concentrations above 1 ppm, it's important to note that Conlon, a moderately resistant variety, had lowest incidence of FHB and DON levels, while Rasmussen, a susceptible variety, had DON levels three times greater (4.90 ppm) than Conlon (1.74 ppm). This indicates the importance of selecting resistant cultivars to manage FHB in our region.

The application of a conventional fungicide (Prosaro) at anthesis and post-anthesis reduced DON concentrations in both varieties. In general, the post-anthesis fungicide applications resulted in lower DON concentrations. Interestingly, the yields of the post-anthesis sprayed fungicides were higher than the anthesis sprayed treatments, the Control, and the Fusarium plots. This increase in yield could be attributed to lower DON levels, and therefore less infected and shriveled seed which would reduce yields.

The average yield in 2015 was 1098 lbs ac^{-1} less than the average yield in 2014 (2192 lbs ac^{-1}). This was likely due to the cooler temperatures slowing grain growth along with increased precipitation leading to higher weed 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 2016.

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