NORTHWEST CROPS & SOILS PROGRAM

2018 The Efficacy of Spraying Organic Fungicides to Control Fusarium Head Blight Infection in Spring Wheat

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THE UNIVERSITY OF VERMONT EXTENSION

2018 THE EFFICACY OF SPRAYING ORGANIC FUNGICIDES TO CONTROL FUSARIUM HEAD BLIGHT INFECTION IN SPRING WHEAT

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Locally grown grains, such as wheat and barley, are in high demand in the Northeast for both livestock feed and human consumption. Hard red spring wheat is most commonly used for bread flour. One major challenge that grain growers encounter is infection by disease-causing fungi, such as the fungus *Fusarium graminearum*, whose spores can infect plants from flowering until grain fill. Fusarium head blight (FHB) can shrivel grain, decrease seed germination, decrease yields, and contaminate grains with mycotoxins. The primary mycotoxin of FHB is deoxynivalenol (DON), a vomitoxin. If DON concentrations are above 1 ppm, they may pose health risks to humans and livestock. While humans should not eat grains with DON concentrations above 1 ppm, some livestock can consume grain with up to 10 ppm DON, depending on the animals species and proportion of their diet which includes DON contaminated grain. Fungicide applications have proven to be relatively effective at controlling FHB in spring wheat in other growing regions. Limited work has been done in this region on the optimum timing for fungicide application on spring wheat to minimize DON. There are also a lack of studies evaluating biofungicides, biochemicals, or biostimulants for the management of FHB that are approved for use in organic systems. In 2018, the UVM Extension Northwest Crops and Soils (NWCS) Program conducted a spring wheat fungicide trial to determine the efficacy and timing of fungicide application to reduce FHB infection and subsequent mycotoxin production on hard red spring wheat cultivars with varying degrees of disease susceptibility.

MATERIALS AND METHODS

The experimental design was a randomized complete block, consisting of two cultivars and seven fungicide+timing treatments with four replications (Table 1). On 24-Apr, Glenn and Prosper hard red spring wheat were planted at Borderview Research Farm in Alburgh, VT, at 350 live seed m^2 with a Great Plains Cone Seeder in 5'x 20' plots. The seedbed was prepared by conventional tillage methods on 23-Apr with a moldboard plow, then a disc, and spike tooth harrow.

Table 1. Spring wheat fungicide trial specifics for Alburgh, VT, 2018.

	Borderview Research Farm Alburgh, VT
Soil type	Benson rocky silt loam
Previous crop	Soybeans
Tillage operations	Spring plow, disc & spike tooth harrow
Row spacing (inches)	7
Plot size and harvest area (feet)	5' x 20'
Seeding rate (live seed m^2)	350
Replicates	4
Varieties	Prosper and Glenn
Planting date	24-Apr
Harvest date	1-Aug

Prior to planting, the area was fertilized with 100 lbs N, 30 lbs P, and 50 lbs K per acre. The previous crop was soybeans. Prosper is a hard red spring wheat that is moderately FHB resistant, and Glenn is a FHB resistant variety of hard red spring wheat. The fungicide+timing treatments are listed in Table 2.

On 22-Jun, when the Glenn spring wheat had reached 75% flowering (anthesis) and the Prosper spring wheat had reached 50% flowering, plots were sprayed with the fungicide treatments (Table 2). All but the control plots of each cultivar were inoculated with *Fusarium* 2 hours after the flowering treatment. The spore suspension of 40,000 spores/ml consisted 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'. On 26-Jun, four days after the anthesis application, the plots that had not yet been treated with a biofungicide were sprayed with the fungicide treatments with the exception of the control plots and the *Fusarium* 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.* The applications were performed with a Bellspray Inc. Model T4 backpack sprayer, which had a carbon dioxide pressurized tank and a four-nozzle boom attachment. It sprayed at a rate of 10 gallons ac^{-1}. The Actinovate treatment was applied at a rate of 6 fl oz ac^{-1}, the Sonata at 2 quarts ac^{-1}, the ChampION at 1.5 lbs ac^{-1}, the Champ WG at 1 lb ac^{-1}, and the Regalia at 1 quart ac^{-1}. Listed below are the descriptions of the fungicide treatments provided by the manufacturer.

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.

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.

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.

Regalia (EPA # 85059-3) biological 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.

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. Treatments: fungicide application dates and rates.

Treatments	Anthesis application	4 days after anthesis application	Application rate
Control	22-Jun	26-Jun	Water
Fusarium graminearum	22-Jun (2 hours after flowering application)		40,000 spores/ml
Actinovate	22-Jun	26-Jun	6 fl oz ac^{-1}
ChampION	22-Jun	26-Jun	1.5 lbs ac^{-1}
Champ WG	22-Jun	26-Jun	1 lb ac^{-1}
Regalia	22-Jun	26-Jun	1 qt. ac^{-1}
Sonata	22-Jun	26-Jun	2 qt. ac^{-1}

When the wheat reached the soft dough growth stage (18-Jul), FHB intensity was assessed by randomly clipping 60-100 heads throughout each plot. A visual assessment of each head was rated for FHB infection in order to calculate average FHB severity, average FHB infected head severity, and the incidence of FHB infected heads by plot. Average FHB severity considers the entire plot, while average FHB infected head severity considers only the infected heads. The incidence of FHB infected heads is the number of infected heads divided by the total number scored. The level of infection rate was determined by using the North Dakota State University Extension Service's "A Visual Scale to Estimate Severity of *Fusarium* Head Blight in Wheat" online publication. On 18-Jul, plots were assessed for ergot in grain heads and whether ergot was present or absent was recorded.

Grain plots were harvested with an Almaco SPC50 plot combine on 1-Aug. The harvest area was 5' x 20'. Following harvest, seed was cleaned with a small Clipper cleaner (A.T. Ferrell, Bluffton, IN). An approximate one-pound subsample was collected to determine DON concentrations and quality characteristics. At the time of harvest, grain moisture, test weight, and yield were recorded with a DICKEY-John M20P meter and pound scale. Generally, the heavier the wheat is per volume, the higher baking quality. The acceptable test weight for bread wheat is approximately 56-60 lbs bu^{-1}. Subsamples were ground into flour using a Perten LM3100 Laboratory Mill in order to be evaluated for mycotoxin levels. Deoxynivalenol (DON) analysis was conducted with the Veratox DON 5/5 Quantitative test from the NEOGEN Corp., which has a detection range of 0.5 to 5 ppm. Samples with DON values greater than 1 ppm are considered unsuitable for human consumption.

Data were analyzed using a general linear model procedure of SAS (SAS Institute, 1999). 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 genetics, soil, weather, and other growing conditions can result in variations in yield and quality. Statistical analysis makes it possible to determine whether a difference between treatments is significant or whether it is due to natural variations in the plant or field. At the bottom of each table, a LSD value is presented for each variable (i.e. yield). Least Significant Differences (LSDs) at the 0.10 level of significance are shown. This means that when the difference between two treatments within a

column is equal to or greater to the LSD value for the column, there is a real difference between the treatments 90% of the time. Treatments that were not significantly lower in performance than the highest value in a particular column are indicated with an asterisk.

In the example to the right, treatment C was significantly different from treatment A, but not from treatment B. The difference between C and B is 1.5, which is less than the LSD value of 2.0 and so these treatments were not significantly different in yield. The difference between C and A is equal to 3.0, which is greater than the LSD value of 2.0. This means that the yields of these treatments were significantly different from one another. The asterisk indicates that treatment B was not significantly lower than the top yielding treatment, indicated in bold.

Treatment	Yield
A	6.0
B	7.5*
C	**9.0**
LSD	2.0

RESULTS

Weather data were recorded with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Table 3). There were 4667 Growing Degree Days (GDDs) accumulated from April to August 2018, 175 above the 30-year normal. The season began with cooler than average temperatures in April, followed by above average temperatures in a hot and dry July and August. A drier than average season resulted in 2.52 inches less of precipitation than normal.

Table 3. Seasonal weather data collected in Alburgh, VT for Apr-Aug 2018.

Alburgh, VT	April	May	June	July	August
Average temperature (°F)	39.2	59.5	64.4	74.1	72.8
Departure from normal	-5.58	3.10	-1.38	3.51	3.96
Precipitation (inches)	4.4	1.9	3.7	2.4	3.0
Departure from normal	1.61	-1.51	0.05	-1.72	-0.95
Growing Degree Days	272	853	973	1305	1264
Departure from normal	-112	97	-42	107	125

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.

Wheat Variety x Fungicide+Timing Interactions

There were no significant interactions between spring wheat variety and fungicide type and timing of application. This indicates that the varieties responded similarly to the fungicide treatments.

Impact of Fungicide and Timing

Table 4 shows the average FHB severity, FHB infected head severity, and incidence of infected heads between fungicide+timing treatments.

Table 4. FHB incidence and severity post treatment at anthesis and four days after anthesis, Alburgh, VT, 2018.

Treatment	Average FHB severity	Average FHB infected head severity	Incidence of FHB infected heads
	%	%	%
Non-sprayed, non-inoculated control	0.213^{abc†}	5.43	2.88^{ab}
Inoculated *Fusarium* spores 22-Jun	0.245^{abc}	6.91	2.99^{ab}
Actinovate - anthesis	0.276^{abc}	**7.88**	3.26^{ab}
Actinovate - 4 days after anthesis	0.159^{b}	5.25	2.28^{b}
ChampION - anthesis	0.205^{b}	5.72	2.59^{b}
ChampION - 4 days after anthesis	0.185^{b}	5.40	2.04^{b}
Champ WG - anthesis	0.187^{b}	5.54	2.33^{b}
Champ WG - 4 days after anthesis	0.377^{ab}	6.66	**4.88^{a}**
Regalia - anthesis	**0.399^{a}**	7.80	4.73^{a}
Regalia - 4 days after anthesis	0.218^{abc}	7.00	3.12^{ab}
Sonata - anthesis	0.292^{abc}	7.50	3.67^{ab}
Sonata - 4 days after anthesis	0.232^{abc}	7.36	2.09^{b}
LSD (0.10)	0.189	NS	2.07
Fungicide+Timing Mean	0.249	6.53	3.07

†Treatments within a column with the same letter are statistically similar.

Top performing treatments are shown in **bold**.

LSD – Least significant difference.

NS – No significant difference between treatments.

All average FHB severities were under 1%. The average FHB infected head severity did not differ significantly by treatment. There was little difference between treatments in incidence of FHB infected heads. Champ WG 4 days after anthesis and Regalia at anthesis had higher incidence of FHB infected heads, which corresponded to the higher DON concentrations (Table 5, Figure 1). The Champ WG post anthesis treatment also had the highest yield and test weight (60 lbs bu^{-1}). Test weights were slightly below the industry standard of 60 lbs bu^{-1}, with the exception of Champ WG - 4 days after anthesis. Ergot was present in 31 plots, with the most in the first replicate. There were no differences by variety (data not shown).

The Regalia post anthesis treatment had the lowest harvest moisture, significantly lower than that of both Sonata treatments, Champ WG at anthesis, both Actinovate treatments, and the *Fusarium* treatment. *Fusarium* inoculated plots had the highest harvest moisture. All harvest moistures were below 14% and did not have to be dried down additionally for storage. For yield, the control did not significantly differ from any of the fungicide+timing treatments. ChampION post anthesis and Regalia post anthesis had significantly lower yields than the top performer, Champ WG post anthesis, and both Actinovate treatments. Champ WG post anthesis and the *Fusarium*-inoculated plots had the highest DON levels. Interestingly, Champ WG applied at anthesis had lower DON concentrations, and the ChampIon applied at anthesis had the lowest DON levels after the non-inoculated control. All DON concentrations were under the FDA recommendation of 1 ppm, and were considered safe for human consumption.

Table 5. The impact of application timing and fungicide on spring wheat yield and quality, Alburgh, VT, 2018.

Treatment	Harvest moisture	Test weight	Yield at 13.5% moisture	DON
	%	lbs bu^{-1}	lbs ac^{-1}	ppm
Non-sprayed, non-inoculated control	12.4^{ab}†	59.9^{a}	2764^{abc}	**0.275^{c}**
Inoculated *Fusarium* spores 22-Jun	12.8^{a}	59.3^{ab}	2749^{abc}	0.663^{a}
Actinovate - anthesis	12.7^{a}	59.3^{ab}	2981^{ab}	0.575^{abc}
Actinovate - 4 days after anthesis	12.7^{a}	59.7^{ab}	2935^{ab}	0.563^{abc}
ChampION - anthesis	12.5^{ab}	59.5^{ab}	2705^{abc}	0.313^{bc}
ChampION - 4 days after anthesis	12.5^{ab}	59.8^{a}	2637^{bc}	0.638^{ab}
Champ WG - anthesis	12.7^{a}	58.8^{b}	2695^{abc}	0.525^{abc}
Champ WG - 4 days after anthesis	12.6^{ab}	**60^{a}**	**3175^{a}**	0.713^{a}
Regalia - anthesis	12.5^{ab}	59.6^{ab}	2798^{abc}	0.425^{abc}
Regalia - 4 days after anthesis	**12.2^{b}**	59.8^{a}	2427^{c}	0.538^{abc}
Sonata - anthesis	12.8^{a}	59.5^{ab}	2833^{abc}	0.638^{ab}
Sonata - 4 days after anthesis	12.7^{a}	59.7^{ab}	2840^{abc}	0.600^{abc}
LSD (0.10)	0.412	0.953	490	0.336
Fungicide+Timing Mean	12.6	59.6	2795	0.539

† Treatments within a column with the same letter are statistically similar.

Top performing treatments are shown in **bold**.

LSD – Least significant difference.

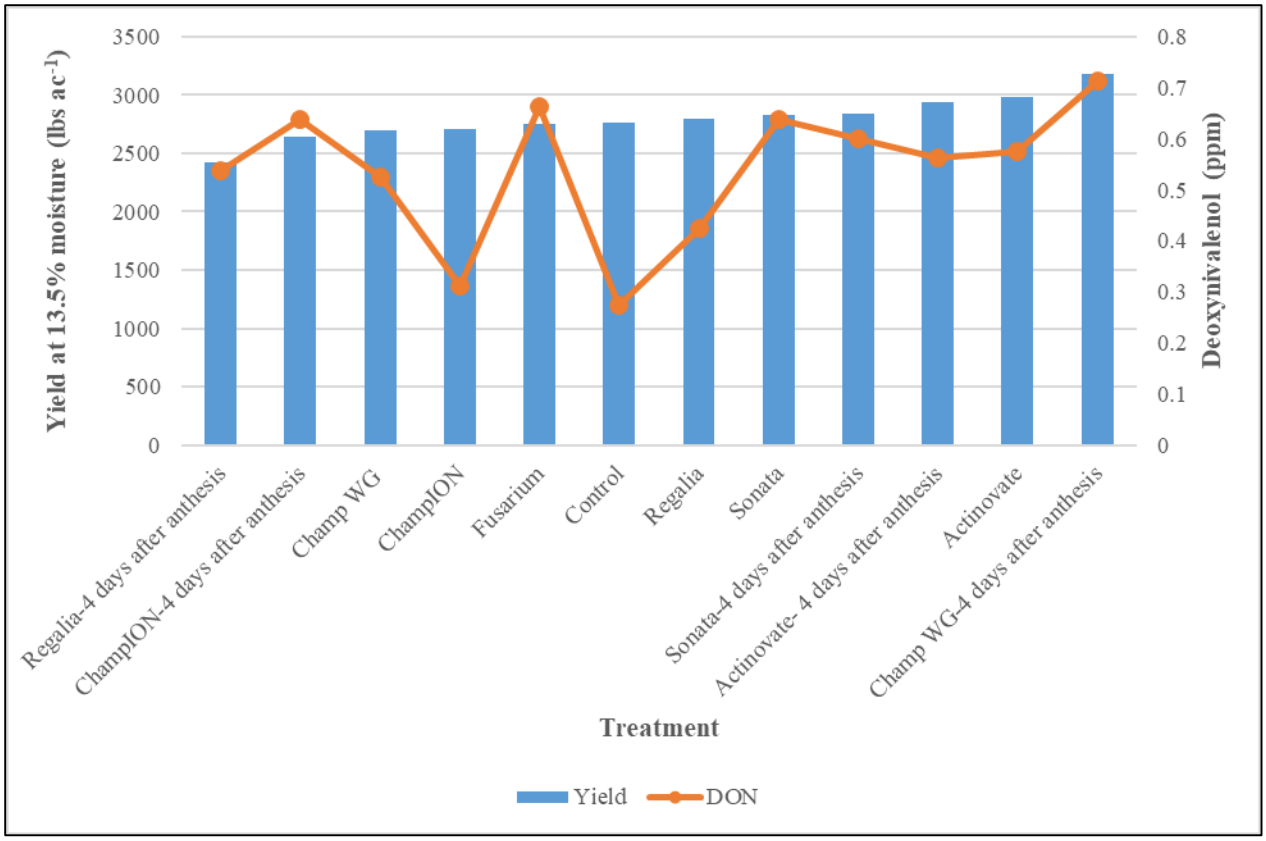

Figure 1. The impact of application timing and fungicide on spring wheat yield and DON concentration.

Impact of Variety

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

Table 6. The impact of spring wheat variety of FHB incidence and severity, Alburgh, VT, 2018.

Variety	Average FHB severity	Average FHB infected head severity	Incidence FHB of infected heads
	%	%	%
Glenn	**0.271**	6.16	**3.39**
Prosper	0.227	**6.90**	2.75
LSD (0.10)	NS	NS	NS
Variety Mean	0.249	6.53	3.07

Top performing treatments are shown in **bold**.
LSD – Least significant difference.
NS – No significant difference between treatments.

The spring wheat varieties were significantly different in harvest moisture, test weight, yield, and DON concentrations (Table 7). Glenn had the lower harvest moisture (12.5%) and higher test weight (60.5 lbs bu^{-1}), and both were significantly different from Prosper. Harvest moistures for both varieties were below 14% and did not have to be dried down for storage. The higher average test weight for Glenn (60.5 lbs bu^{-1}) was approximately at the industry standard (60 lbs bu^{-1}), while the Prosper average test weight was less (58.6 lbs bu^{-1}). Prosper had

significantly higher yield and lower DON concentrations (Figure 2), though all DON concentrations were less than 1 ppm.

Table 7. The impact of spring wheat variety of quality and yield, Alburgh, VT, 2018.

Variety	Harvest moisture	Test weight	Yield @13.5% moisture	DON
	%	lbs bu^{-1}	lbs ac^{-1}	ppm
Glenn	**12.5**	**60.5**	2390	0.706
Prosper	12.7	58.6	**3200**	**0.371**
LSD (0.10)	0.168	0.389	200	0.137
Variety Mean	12.6	59.6	2795	0.539

*Treatments with an asterisk are not significantly different than the top performer in **bold**.
Top performing treatments are shown in **bold**.
LSD – Least significant difference.

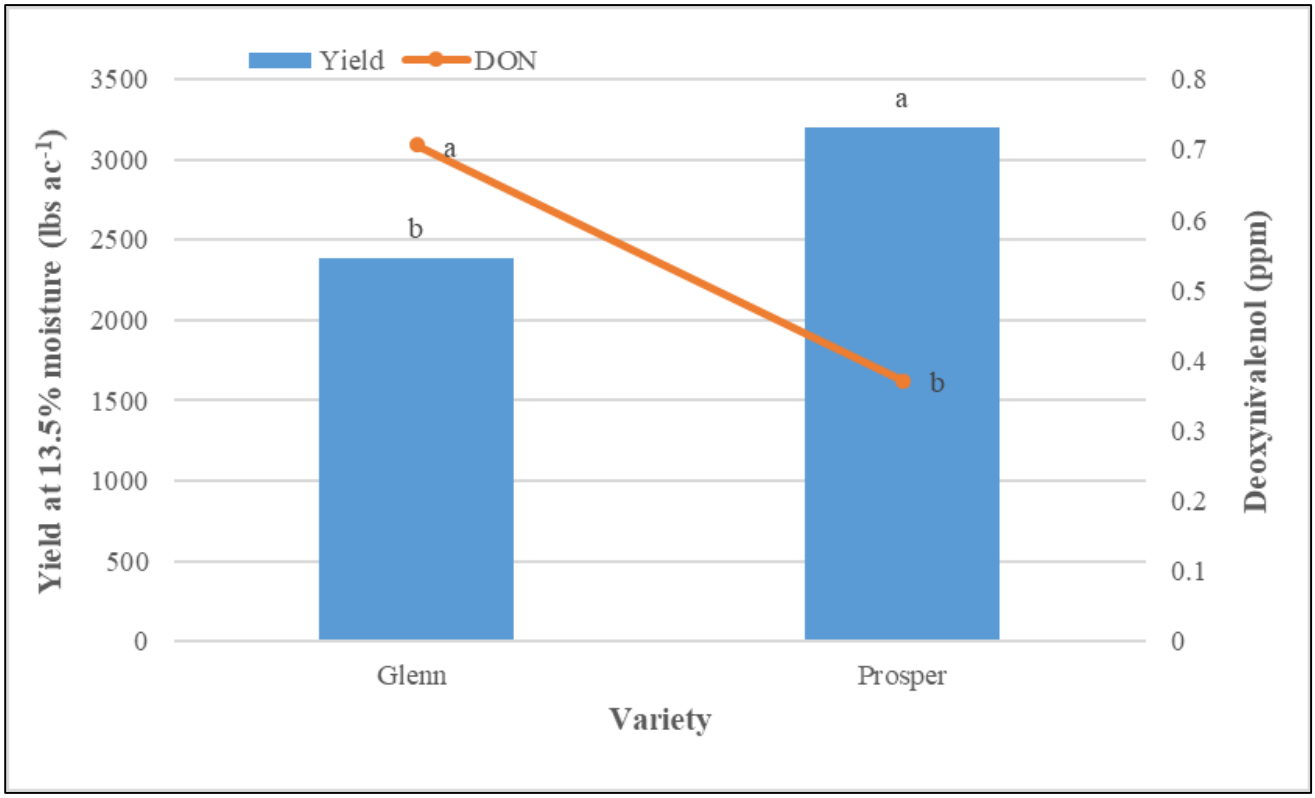

Figure 2. Impact of variety on spring wheat yields and DON concentrations.
Treatments with the same letter did not differ significantly.

DISCUSSION

The 2018 growing season was hotter and drier than normal for long stretches of July and August, which made mid-summer conditions hostile to *Fusarium* growth and nearly ideal growing conditions for spring wheat. This likely played a factor in all DON concentrations being under the recommended 1 ppm, test weights close to the industry standard, and an increase in yield in comparison to other years.

The untreated control had the lowest DON concentrations; this could be attributed to these plots not being sprayed with the *Fusarium* spores (40,000 spores ml^{-1}), indicating the impact of high *Fusarium* inoculum during anthesis. This was statistically similar to seven of the fungicide+timing treatments (Actinovate – anthesis, Actinovate - 4 days after anthesis, ChampION – anthesis, Champ WG – anthesis, Regalia – anthesis, Regalia - 4 days after anthesis, and Sonata - 4 days after anthesis) indicating that these treatments may have been effective in reducing DON levels to nearly those of the uninoculated control.

While some fungicide+timing treatments had significant differences in yield, harvest quality, and indicators of *Fusarium* Head Blight than some of the other fungicide+timing treatments, there are a lack of significant differences from the control and the *Fusarium* inoculated treatment, and the efficacy of the treatments is inconclusive. It is important to remember that the results only represent one year of data.

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