Title: Examining the utility and economic returns of different fungicide application programs to manage Leaf blotch complex of wheat. Proposal 2016361
FINAL REPORT

Dr. Nathan Kleczewski[a,b] Extension Field Crop Plant Pathologist
Phillip Sylvester[a] Kent County Agricultural Agent, M.Sc. Candidate

[a]*University of Delaware Cooperative Extension Service* *phillip@udel.edu (302) 242-3389*
[b]*University of Delaware Department of Plant and Soil Science* *nkleczew@udel.edu 302-300-6962*

OverviewFungal diseases of small grains can pose significant limitations to wheat production. These diseases can reduce green leaf tissue and impact both yield and grain quality. In the Mid-Atlantic, foliar diseases, particularly residue-borne fungal pathogens belonging to the Leaf blotch complex of diseases (LBC), are present in many fields to varying degrees each year. This is likely a result of increased conservation tillage in the region, resulting in higher levels of fungal inoculum. If foliar diseases reach the upper 3 leaves or glumes before grain fill is complete, yield losses may occur. Traditional fungicide programs to manage foliar disease of wheat call for a single fungicide spray at Feekes Growth Stage (FGS) 8/9 to protect the flag leaf from foliar disease. However, threats to wheat production by Fusarium head blight (FHB) have forced growers to reevaluate their chemical management programs. FHB is a disease of the head, and can only be suppressed when specific fungicides are applied at flowering (FGS 10.5.1), 1-2 weeks after traditional FGS 8 applications. The application of both an FGS 8 and FGS 10.5.1 fungicide application is not practical in Mid-Atlantic production systems due to applicator limitations and cost. Growers can also apply fungicides early when nitrogen is applied at greenup (FGS 5) which is advertised as a means to protect against early onset of foliar diseases. Fungicide applications at FGS 5 are often combined along with an application at FGS 8/9 or FGS 10.5.1. **These "new" FGS 5 and FGS 10.5.1 timings have not been adequately assessed for their efficacy and potential to promote yields compared to standard, FGS 8/9 applications.**

Fungicide application costs differ depending on product, rate, and number of applications. Most fungicide studies focus on the "best" fungicide in terms of ability to suppress disease and improve yield. Few unbiased, replicated studies examine fungicide programs for their potential to improve grower profits. For example, it is possible that a FGS 5 + 8 fungicide program may be the best in terms of disease suppression and yield protection. However, product and application cost relative to the yield improvement may not result in the greatest net profit. A single application or cheaper product may deliver similar benefit at reduced cost, therefore resulting in greater potential net returns. **Currently there is no information on the potential profitability of fungicides in Mid-Atlantic wheat production systems.**

To address these questions, a two year study was established in Delaware, Maryland, Virginia, and Pennsylvania. Thirteen fungicide application programs plus an untreated control at six locations were evaluated from 2015 through 2016. Five commonly used fungicides were applied at a variety of timings to represent programs currently being used by growers in Maryland and Delaware. Disease severity, test weight, and yield data were collected. In addition, local agriculture businesses were surveyed for fungicide and application costs. Data were analyzed statistically at the end of each season and used to determine the efficacy and profitability of programs relative to FGS 8/9 fungicide applications and untreated controls. At the end of two seasons data were combined and probability of profitability charts were produced for fungicide programs across a range of cost and commodity prices. These charts can be used by producers to assist in fungicide management decisions.

How objectives have been met

This study was replicated at four locations in 2015 (DE and MD) six locations across DE, VA, PA, and MD in 2016. The wheat variety FS 815 [Growmark FS] was planted at all locations. Plots were planted in rows spaced 7" or 7.5" apart into corn, soybean, or wheat residue. Target seeding rate was 1.8 million seeds/A. The experimental design at each site was a randomized complete block with four to six replications of each treatment. Spreader rows were utilized to facilitate even disease development and minimize plot to plot fungicide drift.

The fungicide application programs were evaluated using the fungicides Tilt® (Propiconazole), Quilt Xcel® (Azoxystrobin + Propiconazole), Priaxor® (Fluoxapyroxad + Pyraclostrobin), Stratego YLD® (Prothioconazole + Trifloxystrobin), and Prosaro® (Prothioconazole+Tebuconazole), applied according to **Table 1**. An untreated control was included for comparison. Tilt® was selected because propiconazole fungicides are cheap and often used at greenup (FGS 5) as part of a split-application fungicide program. Quilt Xcel®, Stratego YLD®, and Priaxor® are dual mode of action fungicides that are commonly used in fungicide programs in the region and include strobilurin (Group 11) fungicides, which are touted to improve yields in the absence of significant disease pressure or under stressful conditions, such as drought. Prosaro is one of the industry standards for suppression of Fusarium head blight. All fungicides were applied with a CO_2 backpack sprayer equipped with Twinjet Flat Fan 8002 nozzles at a pressure of 34 psi in 20 gallons of water per acre. Yields, test weights, and foliar and head diseases were assessed. To determine the potential net returns of various fungicide programs, yields relative to untreated controls were compared across a range of grain prices and application costs typical for the region. Each year, five local agriculture businesses were surveyed for input costs, mainly fungicide costs and custom application costs during the growing season.

Table 1. The fungicide programs used, and abbreviated designations used in the following tables and charts.

Treatment	Product	Program Code	Timing (Feekes Growth Stage)	Growth Stage
1	Untreated Control	CK	CK	Untreated
2	Tilt	TSOLO8	FGS 8	Flag leaf Only
3	Tilt	TSPLT5+8	FGS 5 & 8	Greenup and Flag Leaf
4	Tilt+Prosaro	TSPLT5+F	FGS 5 & 10.51	Greenup and Beginning Flower
5	Quilt Xcel	QSOLO8	FGS 8	Flag leaf Only
6	Quilt Xcel	QSPLT5+8	FGS 5 & 8	Greenup and Flag Leaf
7	Quilt Xcel+Prosaro	QSPLT5+F	FGS 5 & 10.51	Greenup and Beginning Flower
8	Priaxor	XSOLO8	FGS 8	Flag leaf Only
9	Priaxor	XSPLT5+8	FGS 5 & 8	Greenup and Flag Leaf
10	Priaxor+ Prosaro	XSPLT5+F	FGS 5 & 10.51	Greenup and Beginning Flower
11	Stratego YLD	SSOLO8	FGS 8	Flag leaf Only
12	Stratego YLD	SSPLT5+8	FGS 5 & 8	Greenup and Flag Leaf
13	Stratego YLD + Prosaro	SSPLT5+F	FGS 5 & 10.51	Greenup and Beginning Flower
14	Prosaro	PSOLOF	FGS 10.51	Beginning Flower Only

Data indicate that, regardless of program or product, fungicide use can increase yield compared to untreated controls, but the degree of yield increase differs significantly (Figure 1). Our data indicate that Quilt Xcel (FGS 5) followed by Prosaro (FGS 10.5.1) and Quilt Xcel (FGS 5 followed by FGS 8), Tilt (FGS 5) followed by Prosaro (FGS 10.5.1), and Priaxor (FGS 5) followed by Prosaro (FGS 10.5.1) resulted in the greatest yields across years (79-80 bu/A) (**Figure 1**). These programs increased yields over the untreated controls by roughly 8 bu/A. When assessing programs based only on timing programs using a 2 pass, flowering fungicide application system or a two pass flag leaf application system yielded 8 or 7 bu/A better than untreated controls, respectively (**Table 2**). Overall, fungicide programs increased yields over controls by 3-8.5 bu/A.

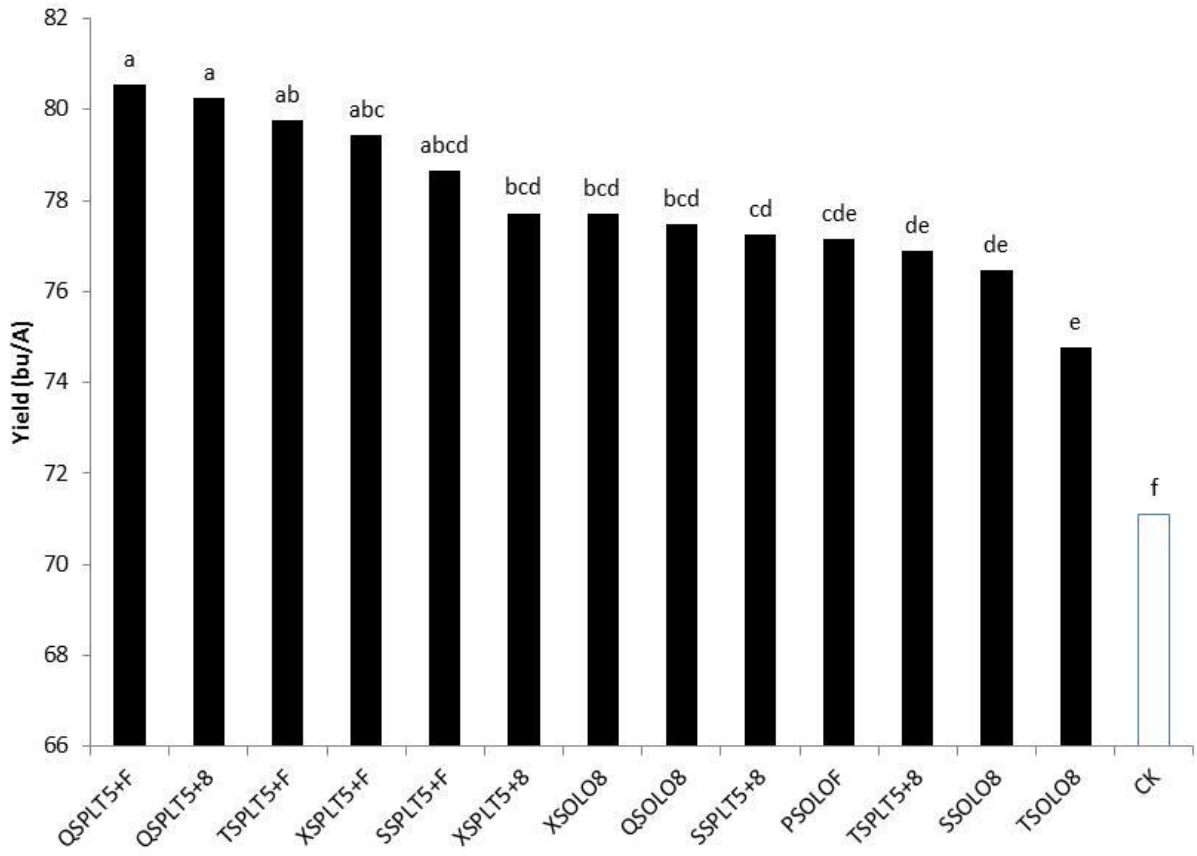

Figure 1. Effects of 13 fungicide programs and an untreated control on yields of soft red winter wheat grown in the mid-Atlantic from 2015 to 2016. Each bar is the average of 57 independent observations. Different letters indicate significant differences using Fisher's Protected LSD (α=0.05).

Table 2. Effects of fungicide timing on measured variables across all experimental sites and years. Different letters indicate significant differences using Fisher's protected LSD (α=0.05).

Timing	Foliar Disease	Glume Blotch	Yield	TWT
F5+F10.51	2.53 B	36.38 C	79.60 A	51.82 A
F5+F8	11.49 B	59.87 C	78.06 AB	50.84 B
F10.51	2.73 B	34.98 B	77.17 B	51.59 A
F8	12.14 B	60.42 B	76.59 B	50.84 B
Control	30.29 A	67.82 A	71.09 C	49.69 C

Test weight, a measure of wheat quality, was significantly impacted by fungicide program (**Figure 2**) with programs containing a FGS 10.5.1 fungicide application increasing approximately 3 lbs/bu more than untreated controls. Programs using an FGS 8 application increased test weight over controls as well, but only by approximately 1-1.5 lbs/bu (**Figure 2**). This was likely due to foliar disease pressure and pressure from Glume blotch, which is discussed in the next section. In addition, effects of variety, late season weather, and timely harvest all impact test weight. We were able to harvest all sites in a timely fashion; however, in cases where wheat is not harvested soon after ripening and rains occur, fungicides are not likely to provide a significant test weight benefit.

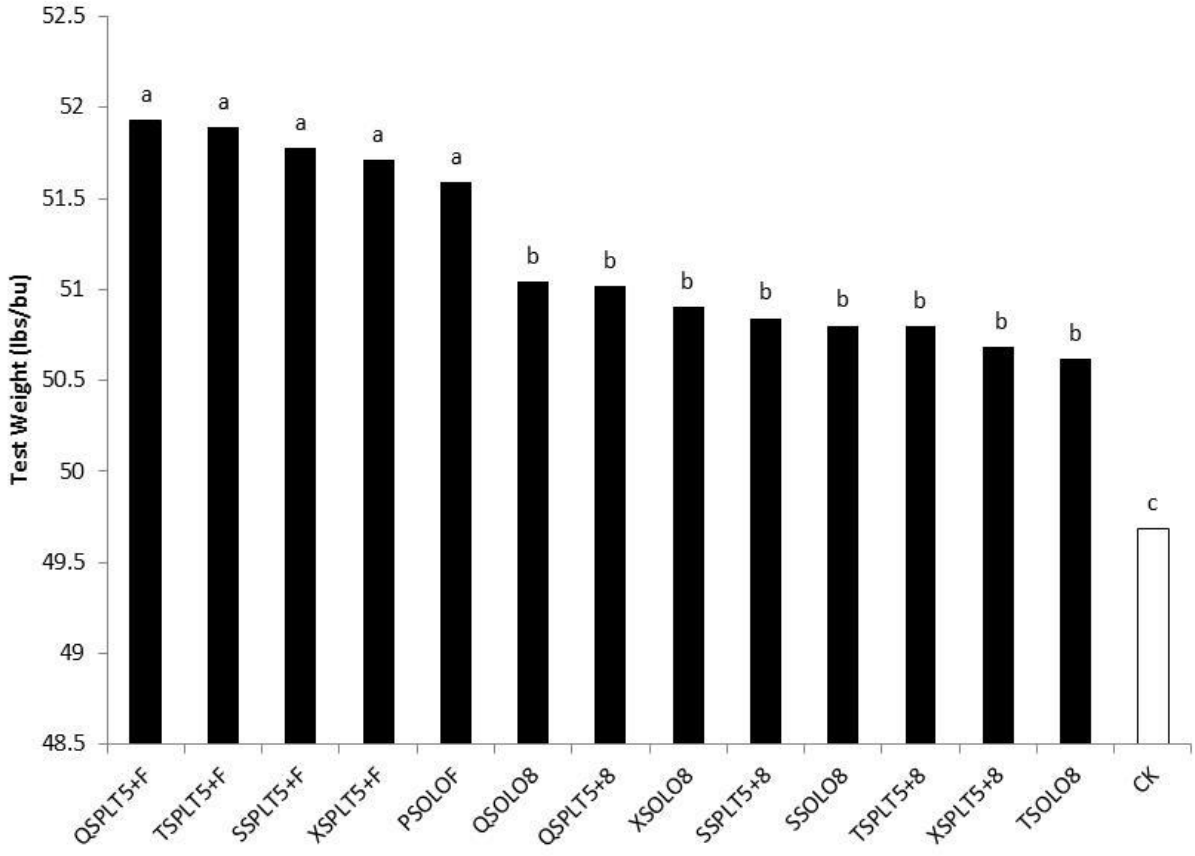

Figure 2. Effects of 13 fungicide programs and an untreated control on test weights of soft red winter wheat grown in the mid-Atlantic from 2015 to 2016. Each bar is the average of 57 independent observations. Different letters indicate significant differences using Fisher's Protected LSD (α=0.05).

Fungicides are marketed to improve yields; however, yield benefits are most likely to occur in situations where fungal disease pressure is high. This was true in this work, as we saw a significant negative association between yield and disease severity on the flag leaf at FGS 11.1 (kernels milky ripe), and Glume blotch on the heads (-0.46 and -0.53, respectively). Thus, the main reason these programs improved yield overall was through reduction of foliar and head diseases.

Data indicate that fungicide programs and timings impacted foliar and head diseases differently, with programs using a FGS 10.5.1 timing resulting in the greatest reduction of foliar and head diseases. In these studies, LBC was the most commonly encountered disease, although powdery mildew and leaf rust was detected at low levels at some locations. When flag leaves were rated, the total amount of disease from all sources was used to determine the percent of affected leaf tissue. Therefore, results encompass a wide range of diseases encountered in the region.

Our data indicate that programs using a FGS 10.5.1 fungicide application resulted in the greatest reduction of disease on flag leaves (**Figure 3**) and Glume blotch on heads (**Figure 4**). This supports the aforementioned statement pertaining to fungicide yield benefits being tied to protection of wheat from disease. When examining the data across fungicides, there was no advantage of a 2 pass program compared to single pass programs for control of foliar disease, but there was a slight advantage in reducing Glume blotch. This may be due to residual control early in the season that may have reduced initial development of Stagonospora. Consequently, this could have resulted in reduced local movement of Stagonospora up the canopy by the end of the season. Regardless, the increase in yield over single pass programs, although statistically significant, was relatively small (approximately 3 bu/A) and therefore, these programs may not ultimately be the most profitable to producers when economic factors are considered.

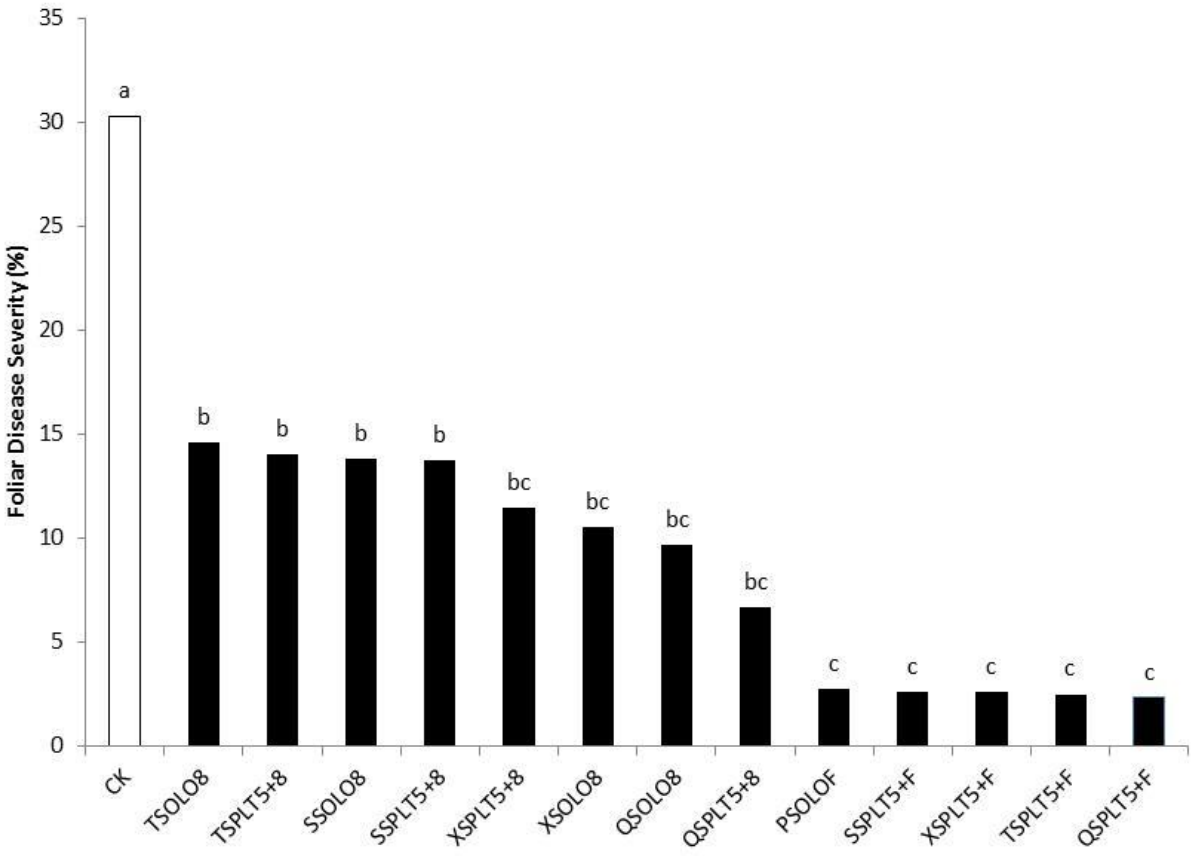

Figure 3. Effects of 13 fungicide programs and an untreated control on foliar disease of soft red winter wheat grown in the mid-Atlantic from 2015 to 2016. Disease was rated on the flag leaf at FGS 11.1. Stagonospora leaf blotch and tan spot were the most commonly encountered diseases, although some powdery mildew and leaf rust were present at some locations. Each bar is the average of 57 independent observations. Different letters indicate significant differences using Fisher's Protected LSD (α=0.05).

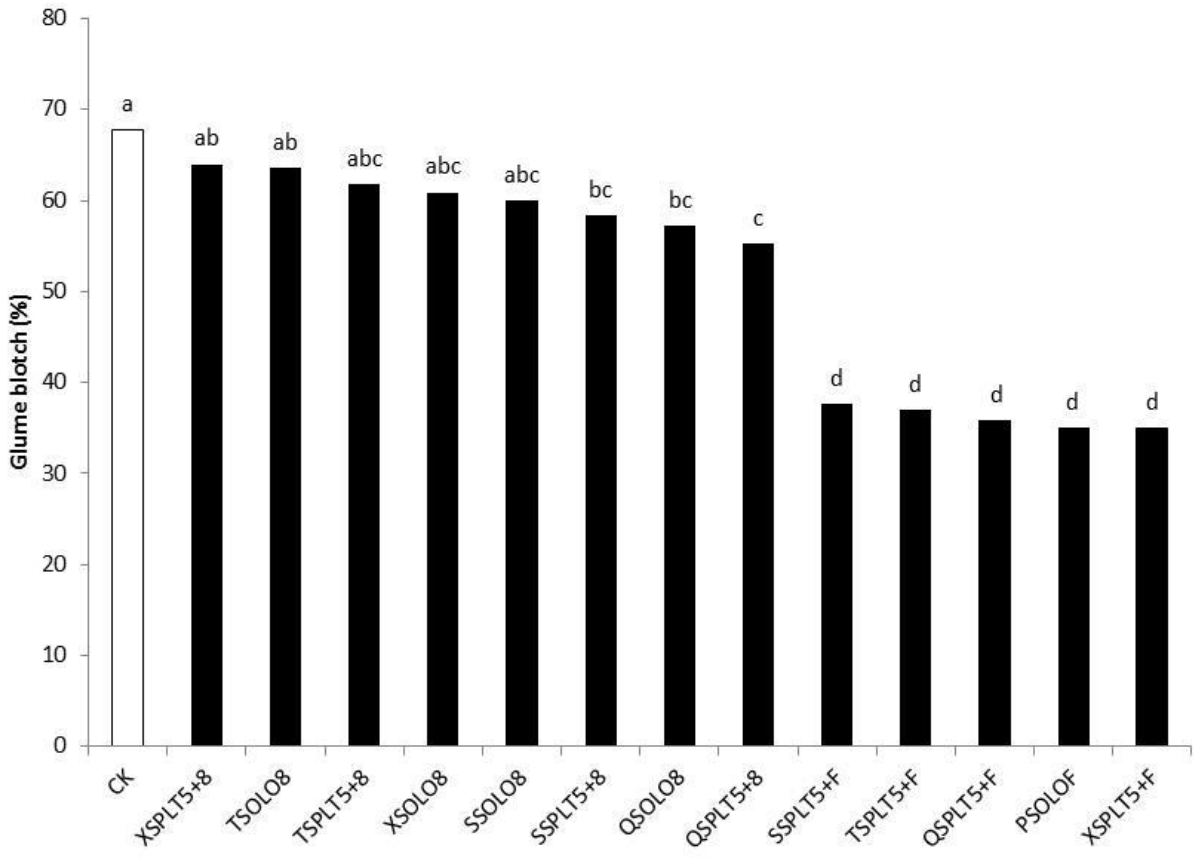

Figure 4. Effects of 13 fungicide programs and an untreated control on Glume blotch of soft red winter wheat grown in the mid-Atlantic from 2015 to 2016. Disease was rated on the flag leaf at FGS 11.1. Each bar is the average of 24 independent observations. Different letters indicate significant differences using Fisher's Protected LSD (α=0.05).

Preliminary economic analysis of the data indicates programs that result in the highest yields are not necessarily the most profitable, although most programs can be profitable as commodity prices exceed $4.00 per bu (**Table 3**). The most profitable programs overall were the Tilt (FGS 5) followed by Prosaro (FGS 10.5.1) and the Tilt (FGS 5) followed by Tilt (FGS 8). These programs resulted in an overall net return across all tested commodity process. When assessed at $5.00/bu, the Tilt/Prosaro program overcame the Tilt/Tilt program in terms of overall profitability, likely as a result of the overall net yield increase. At $5.00/bu, all programs except Priaxor (FGS 5 followed by FGS 8) and Stratego YLD (FGS 5 followed by FGS 8) returned a profit. However, there was a great range in overall profitability ($1.36-$18.82 per bu).

Table 3. Net returns of 13 fungicide programs tested in 2015 and 2016.

Program	Total Cost	Avg Yield	Avg. Increase in Yield	$ 3.00	$ 4.00	$ 5.00
UTC	$ -	71.1				
Tilt 8	$ 11.28	74.8	3.7	-0.31	3.34	7.00
Tilt 5+8	$ 13.02	76.9	5.8	4.39	10.19	16.00
Tilt 5 fb Prosaro 10.51	$ 24.56	79.8	8.7	1.47	10.14	18.82
Quilt X 8	$ 23.42	77.5	6.4	-4.32	2.05	8.41
Quilt X 5+8	$ 33.83	80.3	9.2	-6.35	2.80	11.96
Quilt X 5 fb Prosaro 10.51	$ 33.23	80.6	9.5	-4.87	4.58	14.04
Priaxor 8	$ 25.48	76.5	5.4	-9.38	-4.01	1.36
Priaxor 5+8	$ 34.33	77.7	6.6	-14.46	-7.83	-1.21
Priaxor 5 fb Prosaro 10.51	$ 31.66	79.4	8.3	-6.65	1.69	10.02
Stratego YLD 8	$ 23.96	76.5	5.4	-7.85	-2.49	2.88
Stratego YLD 5+8	$ 32.04	77.3	6.2	-13.55	-7.39	-1.23
Stratego YLD 5 fb Prosaro 10.51	$ 30.90	78.6	7.5	-8.26	-0.72	6.83
Prosaro 10.51	$ 22.82	77.2	6.1	-4.64	1.42	7.48

Data indicate that overall profitability varies greatly between programs, and that the most profitable programs never exceeded a net profitability success rate of more than 63% (**Table 4**). In many cases, fungicide use below $4.00/bu resulted in less than a 50% chance in resulting in a profit. In the two most profitable programs, successful returns were only realized in 54 and 49% of cases for the Tilt (FGS 5 followed by FGS 8) and Tilt (FGS 5) followed by Prosaro (FGS 10.5.1) programs, respectively (**Table 4**) when assessed at $3.00 per acre. These chances increased to 57 and 58% at $4.00/bu and 63% at $5.00/bu. The Quilt Xcel (FGS 5) followed by Prosaro (FGS 10.5.1) program, when assessed at $5.00/bu, resulted in the greatest overall success rate, at 68%. However, net profitability at this price was $14.04 when compared to the most profitable program, Tilt (FGS 5) followed by Prosaro (FGS 10.5.1) which returned $18.82/bu in 63% of cases.

Table 4. Chance of 13 tested fungicide programs resulting in a net profit.

Program	Price Received per bushel		
No Fungicide	$ 3.00	$ 4.00	$ 5.00
Tilt F8	51%	52%	58%
Tilt F5+F8	54%	57%	63%
Tilt F5 fb Prosaro F10.51	49%	58%	63%
Quilt Xcel F8	39%	51%	59%
Quilt Xcel F5+F8	32%	46%	56%
Quilt Xcel F5 fb Prosaro F10.51	55%	66%	68%
Priaxor F8	39%	55%	64%
Priaxor F5+F8	24%	39%	52%
Priaxor F5 fb Prosaro F10.51	40%	56%	67%
Stratego YLD F8	38%	49%	55%
Stratego YLD F5 + F8	27%	44%	53%
Stratego YLD F5 fb Prosaro F10.51	35%	48%	62%
Prosaro F10.51	47%	55%	58%

In summary, our data show that fungicide use can result in significant increases in yield and profitability in SRWW grown in the mid-Atlantic. Data indicate that programs including a treatment at FGS 10.5.1 may result in the greatest reduction in foliar and head diseases and protect yield in many case. Data indicate that fungicide use on a typical wheat variety grown in this region can be profitable at relatively low commodity prices, but their overall chances of success is less than 50% for many programs when commodity prices are less than $4.00. This, of course, does not include dockage for other factors that growers can encounter, including DON, test weight, and falling numbers, all of which may impact overall profitability. In addition, overall profitability may be increased when planting varieties with poor levels of resistance to common fungal diseases, and conversely, may be reduced in high yielding varieties with high levels of disease resistance, when compared to our tested variety. These data will provide growers with excellent unbiased data pertaining to fungicide efficacy and utility and will be used to begin to develop a regional fungicide profitability tool for use by growers in the region.

Preliminary data were shared as a poster at the NEAPS meeting held in Philadelphia, PA in 2016. Data were shared at the Delaware Ag Week Field Crop Disease Update in January 2016. MSGUB was noted in the acknowledgements and the logo used in both cases. The research is being prepared for professional publication and MSGUB will also be noted as a funding source.