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RESEARCH UPDATE

Pesticide Impact on White Mold (Sclerotinia Stem Rot) and Soybean Yield

Summary

- We performed a meta-analysis on results from multiple research trials conducted in six states over eight years.
- Some pesticide active ingredients significantly reduce white mold disease severity index (DIX) and preserve yield.
- Application timing affected disease reduction and yield benefit.
- Yield loss due to white mold did not occur until 20-25 percent DIX at the R6-R7 growth stage. Considerable yield loss (>10 percent) was observed beginning at approximately 65 percent DIX.
- Our economic analysis revealed a wide range of probability of return on pesticide investment (ROI).

White mold (Sclerotinia stem rot) is caused by the fungal pathogen *Sclerotinia sclerotiorum*, and the disease frequently ranks among the top yield-reducing soybean diseases in the northern United States. Researchers estimate that white mold caused more than 101 million bushels of soybean yield loss (an estimated value $1.2 billion) in the U.S. and Ontario, Canada (Allen et al., 2017; USDA-NASS, 2017).

The pathogen can survive in the soil as sclerotia for a long time. Furthermore, *S. slerotiorum* has a broad host range. Both factors present major management challenges. Most commercial soybean cultivars exhibit little host resistance, so in-season management relies heavily on applying fungicides that protect the flowers from infection.

Researchers commonly test chemical products in white mold management trials across the soybean-growing region. For this publication, we used meta-analysis to collate information from these trials into a single database.

Our goals were to:

- Evaluate the efficacy of pesticide treatments and timings
- Provide regional white mold management recommendations

This study compiled independent pesticide efficacy studies from across the North Central soybean growing region to:

- Investigate the impact of white mold on soybean yield
- Determine efficacy of disease reduction and yield protection for multiple chemical application programs
- Develop an economic model to estimate the expected production value and break-even probabilities for chemical programs
- Develop a smartphone application to guide pesticide decisions based on the probability of return on pesticide investment.

Figure 1. Characteristic white mold symptoms and signs include white, fluffy fungal growth on stems; hard, black sclerotia embedded in infected plant tissue; and bleached stems.

Figure 2. This study used more than 2,000 research plot-level data points across the North Central United States. One application method was using spray rigs capable of applying multiple treatments to research plots.

THE RESEARCH

Table 1. The common active ingredients and associated treatment costs evaluated in white mold pesticide efficacy trials.

Active Ingredient(s)	Trade Name (suggested growth stage for application)	Typical Application Rates	Active Ingredient Cost ($/A)	Application Cost ($/A)	Total Treatment Cost ($/A)[1]
boscalid	Endura® (R1)	8.0 oz.	$38.76	$7.28	$46.05
boscalid +fluxapyroxad/pyraclostrobin	Endura® (R1) fb[2] Priaxor® (R3)	6.0 oz. fb 4.0 fl. oz.	$46.94	$14.57	$61.51
fluazinam	Omega® (R1)	12.0 fl. oz.	$36.85	$7.28	$44.14
fluoxastrobin+flutriafol	Fortix® (R1)	5.0 fl. oz.	$16.33	$7.28	$23.61
lactofen	Cobra® (R1)	6.0 fl. oz.	$9.04	$7.28	$16.33
picoxystrobin	Aproach® (R1) fb Aproach® (R3)	9.0 fl. oz. fb 9.0 fl. oz.	$39.94	$14.57	$54.51
prothioconazole	Proline® (R1) fb Proline® (R3)	5.0 fl. oz. fb 5.0 fl. oz.	$46.18	$14.57	$60.75
prothioconazole+trifloxystrobin	Proline® (R1)fb Stratego YLD® (R3)	3.0 fl. oz. fb 4.0 fl. oz.	$28.64	$14.57	$43.21
tetraconazole	Domark® (R1)	5.0 fl. oz.	$13.32	$7.28	$20.60
thiophanate-methyl	Topsin® (R1)	20 fl. oz.	$7.26	$7.28	$14.54
non-treated control	—	—	$0.00	$0.00	$0.00

[1]Total Treatment Cost is the sum of the chemical list price and application cost.[2]fb = followed by. Several programs involve two fungicide applications. Those are indicated by fb in the trade name column.

Researchers conducted chemical evaluations in Illinois, Iowa, Michigan, Minnesota, New Jersey, and Wisconsin from 2009 to 2016 and obtained more than 2,000 plot-level data points. They tested common active ingredients and application timings, measured white mold severity and grain yield, and combined chemical list prices and application costs for economic analysis (Tables 1 and 2).

RATING DISEASE

Pesticide efficacy trials generally evaluate treatments with measures of disease severity or incidence and yield. For white mold, researchers typically record disease incidence and severity data using a rating scale and combine these into a disease severity index score (DIX). By combining DIX scores with yield loss analyses, we can help identify control thresholds for cost-effective management. These studies will help farmers select cost-effective chemical programs to manage white mold in soybean.

DIX AND YIELD LOSS

There was a significant correlation between white mold DIX and soybean yield despite considerable variability across the dataset. According to the statistical model we used, little yield loss (0.4-0.9 bushels per acre) occurred at 25-30 percent DIX when the crop growth stage was between R6 and R7. When DIX was greater than 40 percent, yield decreased more dramatically –yield loss was considerable starting at approximately 65 percent DIX.

For every 10 percent increase in DIX after 65 percent, there was a corresponding soybean yield loss of approximately 10 bushels per acre.

ACTIVE INGREDIENT

All of the products evaluated reduced overall mean of disease, which offered some level of control and potential yield benefits. While disease pressure did not significantly influence the effect of a treatment, all products provided greater yield benefits when used in high disease-severity situations, except tetraconazole (e.g., DIX>40 percent; Table 3).

Table 2. Common application timings evaluated in white mold pesticide efficacy trials.

Pesticide Application Timing
fifth trifoliate (V5)
beginning flower (R1)
full flower (R2)
beginning pod (R3)
beginning seed (R5)
beginning and full flower (R1 and R2)
beginning flower and pod (R1 and R3)
non-treated control

In particular, we observed lactofen only had positive yield benefits under high white mold severity, a previously observed phenomenon in soybean (Dann et al., 1999). These results are also evident in the yield loss model, which suggests greater yield impacts are observed at greater disease pressure. In the absence of considerable white mold pressure (less than 40 percent DIX), only three of the active ingredients we evaluated resulted in a consistent yield benefit over yield in non-treated plots (Table 3):

- boscalid+fluxapyroxad/pyraclostrobin
- boscalid
- prothioconazole+trifloxystrobin

In the North Central region, a single boscalid application or two picoxystrobin applications are standard recommendations for white mold management. In this study, these active ingredients, along with boscalid+fluxapyroxad/pyraclostrobin, consistently reduced white mold and provided yield benefits under high and low disease pressure (Table 4).

These products reduced white mold 14-19 percent in areas with 60 percent DIX, and they provided yield benefits of 16-23 percent under high disease pressure. With a mean yield across studies of approximately 55 bushels per acre, these products improve yield potential by as much as 13 bushels per acre over non-treated plots when white mold was severe.

Table 3. Influence of disease severity index (DIX) grouping on percent yield benefit in treated soybean plots.

Active Ingredient (AI)	Low Disease Pressure (<40%)		High Disease Pressure (>40%)	
	Yield Benefit Relative to Non-treated (%)	Statistical Significance[1]	Yield Benefit Relative to Non-treated (%)	Statistical Significance[1]
boscalid+fluxapyroxad/pyraclostrobin	8.8	**	24.4	**
boscalid	5.9	**	21.2	**
picoxystrobin	4.8	NS	17.9	**
lactofen	-2.5	NS	8.4	**
fluazinam	5.2	NS	12.3	**
prothioconazole+trifloxystrobin	7.5	**	14.2	**
fluoxastrobin+flutriafol	4.6	NS	11.9	**
prothioconazole	2.8	NS	11.1	**
thiophanate-methyl	3.8	NS	11.1	**
tetraconazole	0.5	NS	4.6	NS

[1]Statistical significance indicates if the treatment effect was statistically different from zero (no effect). ** = significance at α =0.05. NS = no significance, or not different from zero.

Table 4. Mean reduction of disease severity index (DIX) and yield benefit in treated soybean plots.

Active Ingredient (AI)	DIX Relative to Non-treated Plots (%)[1]	Active Ingredient (AI)	Yield Relative to Non-treated Plots (%)[1]
lactofen	-19.3 efg	boscalid+fluxapyroxad/pyraclostrobin	15.9 a
boscalid	-15.8 d-g	boscalid	13.2 a
picoxystrobin	-13.7 d-g	picoxystrobin	11.1 ab
boscalid+fluxapyroxad/pyraclostrobin	-13.7 c-g	prothioconazole+trifloxystrobin	10.9 abc
fluazinam	-12.2 cdf	fluazinam	8.5 bc
prothioconazole+trifloxystrobin	-11.4 cd	fluoxastrobin+flutriafol	8.4 a-d
prothioconazole	-8.2 bc	thiophanate-methyl	7.3 c
fluoxastrobin+flutriafol	-7.2 bc	prothioconazole	7.1 cd
tetraconazole	-3.0 ab	lactofen	3.0 de
thiophanate-methyl	-0.1 a	tetraconazole	2.6 e

[1]Means followed by the same letter are not different from each other according to Fisher's test of least significant difference (LSD) at α = 0.05 significance level.

The researchers consistently found that the active ingredients fluoxastrobin with flutriafol, tetraconazole, lactofen, and thiophanate-methyl had among the lowest efficacies and/or yield benefits. Researchers also observed limited white mold control or yield benefit by thiophanate-methyl (Huzar-Novakowiski et al., 2017). Moreover, researchers have identified thiophanate-methyl insensitivity as a concern (Lehner et al., 2015; Mueller et al., 2002). However, we have not found any reports that S. sclerotiorum is insensitive to tetraconazole, fluoxastrobin, or flutriafol.

APPLICATION TIMING

In the studies, pesticide application timing significantly affected disease reduction and yield benefits. Two applications during flowering provided the most control and greatest yield benefits (Table 5). Single applications at beginning flower (R1) and full flower (R2) resulted in higher disease control than applications at beginning pod. Applications outside these flowering periods provided the lowest white mold control and yield benefits.

Figure 3. White mold can dramatically reduce soybean yield when severe. For every 10 percent increase in DIX after 65 percent, there was a corresponding yield loss of 10 bushels per acre.

Table 5. Mean reduction of disease severity index (DIX) and yield benefit in treated soybean plots.

Application Timing	DIX Relative to Non-treated Plots (%)[1]		Yield Relative to Non-treated Plots (%)[1]	
fifth trifoliate	-5.7	ab	3.9	b
beginning flower	-9.9	bc	7.4	b
full flower	-8.8	a-d	6.8	b
beginning and full flower	-12.8	cd	10.9	ab
beginning flower and pod	-14.6	d	13.1	a
beginning pod	-7.7	ab	6.6	b
beginning seed	-4.8	a	3.6	c

[1]Means followed by the same letter are not different from each other according to Fisher's test of least significant difference (LSD) at α = 0.05 significance level.

These findings corroborate other studies that identified effective application programs during the early flowering periods (Huzar-Novakowiski et al., 2017; Mueller et al., 2004). We further considered the economics of one- and two-spray programs for the best performing products at typically recommended rates and timings.

Under high disease severity (that is, in areas with a history of severe white mold epidemics), the two-application picoxystrobin program had a comparable return-on-investment to the lactofen and boscalid single-application programs. However, fungicide products that require two applications for effective control could be competitive options when the price per unit area is less expensive.

Figure 4. Apothecia germinate from sclerotia and release spores that infect soybean flowers, which makes certain chemical applications during soybean flowering the most effective treatments.

ECONOMIC ANALYSIS

Based on expected farmer returns or break-even probabilities, the active ingredients that maximized ROI were thiophanate-methyl and lactofen (Figure 5). Thiophanate-methyl was one of the least effective products, but it costs less, which provides favorable returns, especially when disease pressure is considered low. Lactofen was among the more effective active ingredients in high-disease pressure situations. Its relatively low cost compared to other products resulted in high estimated ROI.

Often, products that are more effective for white mold management are also more expensive. These more expensive products have a better ROI potential when disease pressure is higher.

Economical disease management balances efficacy and cost. For that reason, boscalid (a highly effective active ingredient) was less likely to offer a positive ROI in some situations because it cost more than products like lactofen. However, growers who take the time to seek out the best prices for products like boscalid can improve their changes for a positive ROI with more effective products.

Something to consider is fungicide resistance. Fungicide resistance in *S. sclerotiorum* is a major concern that could have a long-term negative ROI despite a short-term positive ROI.

This analysis does not incorporate the benefits of resistance management and rotating modes of action across fields and seasons. All treatments generate positive benefits when disease severity and crop value are sufficiently high. For that reason, they can be part of an economical resistance management program.

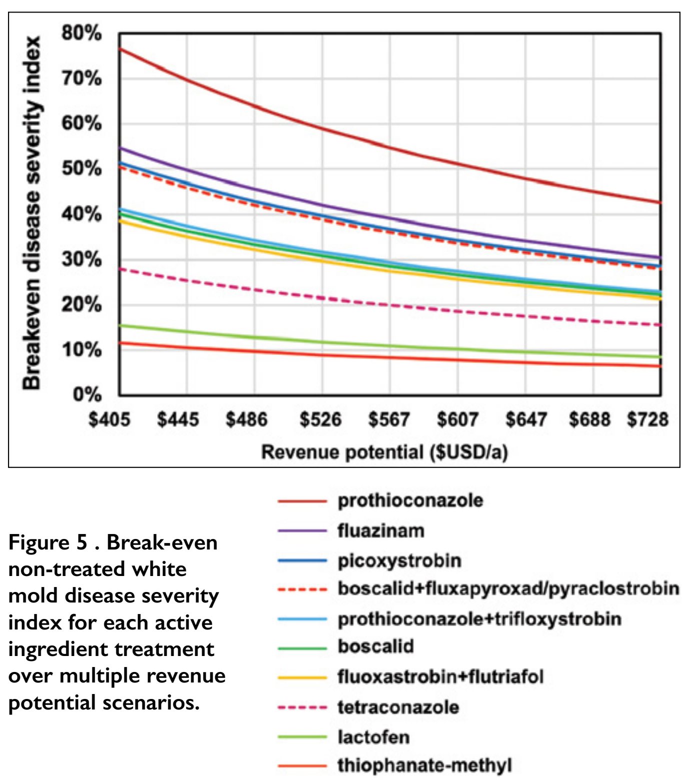


Figure 5 . Break-even non-treated white mold disease severity index for each active ingredient treatment over multiple revenue potential scenarios.

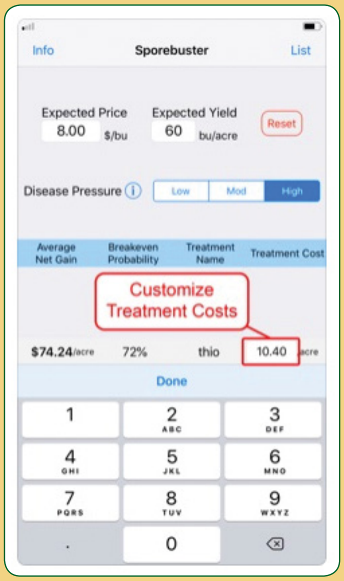
FIND OUT MORE

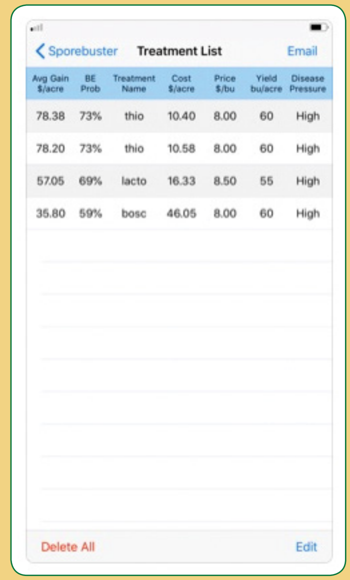
Other publications in the Soybean Disease Management series are available on the [Crop Protection Network website](cropprotectionnetwork.org) (cropprotectionnetwork.org).

SPOREBUSTER

The information and models described in this publication were used to develop Sporebuster, a smartphone application for iPhone and Android platforms. Sporebuster helps farmers make economic decisions when they are selecting pesticides and deciding when to apply them to manage white mold.

Sporebuster can run various scenarios – when disease pressure is low, medium, or high; when revenue potential is different – while adjusting pesticide application cost. This is a dynamic tool growers can use to tailor pesticide programs to specific farms and situations.





Sporebuster is available from iTunes and Google Play.

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