CHEMICAL, BIOLOGICAL AND CULTURAL CONTROL

FIELD EVALUATIONS OF CHEMICAL CONTROLS FOR FUSARIUM HEAD BLIGHT IN MICHIGAN.

D.E. Brown-Rytlewski*, W.W. Kirk, R. Schafer and D. Berry

Department of Plant Pathology, Michigan State University, East Lansing, Michigan, 48824
*Corresponding Author: (517) 432-0480; E-mail rytlews1@msu.edu

ABSTRACT

Four uniform fungicide trials were planted in Michigan during 3 – 8 Oct 2005. The sites were at the Plant Pathology Farm, East Lansing MI, (inoculated with *Fusarium graminearum* and mist-irrigated); Bean and Beet Farm, Saginaw, MI (inoculated/not-irrigated); Sanilac, Sanilac County, MI and at Williamston, Ingham County, MI (not-inoculated/not-irrigated). Caledonia wheat, treated with Thiram 42S (thiram 42%, 2.0 fl. oz./cwt), was planted at the rate of 24 seeds/ft of row at each site. Head scab developed at all sites but only severe deterioration was measured at the East Lansing (inoculated) site resulting in high DON levels and low yields and test weights. Scab levels across the state were low in 2006. Very little Fusarium developed at the other three sites and DON levels were negligible.

At the East Lansing location, measurable precipitation occurred on only eight days from the period encompassing the first application of fungicide through harvest. Frequent irrigation kept the heads almost continuously wet during early grain maturation. Powdery mildew was evident but only developed to 6.6% foliar area affected by Feekes 10.5.2 in the non-treated control and there were no significant differences among treatments. Stagnospora leaf blotch also developed and by Feekes 10.5.2 the non-treated control had about 5.5% of the foliage affected. Folicur 3.6F (4.0 fl oz) and Caramba 90SL (13.5 fl oz) had significantly less Stagnospora leaf blotch than the non-treated control but were not different from any other treatments. Daily mist irrigation favored FHB development in spite of moderately cool temperatures during and one week following anthesis. Fusarium head blight developed in the trial however there were no differences in incidence or severity among any treatments or the non-treated control. There were no differences in green leaf area (%) remaining at Feekes 11.1 among any treatments or the non-treated control. Only Caramba 90SL (13.5 fl oz) had significantly higher yield than the non-treated control and was also significantly higher than Topguard 1.04SC (14.0 fl oz). No other treatments had significantly higher yield than the non-treated control. Based on analysis of variance, no treatments were significantly different in terms of test weight, percentage damaged kernels, 1000 grain weight or DON levels (3.9-7.0 ppm).

At the Bean and Beet Farm, there were no significant differences among treatments for powdery mildew or Stagnospora leaf blotch (disease ratings were very low), FHB severity, FHB incidence or FHB index. There were no significant differences among the treatments for yield, test weight, 1000 grain weight, FDK or DON levels (0.2-0.4 ppm). At the Sanilac location, leaf rust was evaluated for severity and incidence. All treatments significantly reduced leaf rust compared to the control, but were not significantly different from each other. Powdery mildew and Stagnospora leaf blotch were rated. There were some differences among treatments in 1000 grain weights at Sanilac, but no differences in test weights or yield. DON levels for all treatments were 0 ppm. At the Williamston location, there were no significant differences among treatments for powdery mildew or Stagnospora leaf blotch Fusarium head blight severity and incidence was significantly lower for Prosaro (6.5 fl oz), compared to the untreated control, but not significantly different from other treatments. The Fusarium head blight index was significantly lower than the control for all treatments except Tilt and one of

the Folicur treatments, but there were no significant differences among treatments. Yield, test weight, 1000 grain weight FDK and DON levels (0.1- 0.2 ppm) were not significantly different, based on ANOVA. No phytotoxicity was observed in any of the treatments at any of the sites.

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THE USE OF CHEMICAL AND PHYSICAL STRESSORS, 8.5 % NaCl AND 47^{O}C, TO ASSAY POPULATIONS OF A *BACILLUS* STRAIN USED TO CONTROL FUSARIUM HEAD BLIGHT ON WHEAT HEADS IN FIELD PLOTS.

Amanda L. Gill[1] and Bruce H. Bleakley[1,2*]

[1]Biology/Microbiology Department; and [2]Plant Science Department,
South Dakota State University, Brookings, SD, 57007, USA
[*]Corresponding Author: PH: (605) 688-5498; E-mail: bruce.bleakley@sdstate.edu

ABSTRACT

Selected strains of *Bacillus* can be used as biocontrol agents (BCAs), to antagonize *Fusarium graminearum* which causes Fusarium Head Blight (FHB) of wheat and barley. To assay numbers of the biocontrol agent *Bacillus* strain 1BA, after spraying its cells onto wheat heads in field plots, a selective and/or differential growth medium/isolation procedure was developed to allow differentiation of *Bacillus* 1BA from native wheat microflora. The ability of *Bacillus* 1BA to tolerate temperature and salt stresses was exploited to allow most probable number (MPN) estimates of its numbers on inoculated wheat heads over time in field plots. *Bacillus* 1BA grew on Tryptic Soy Agar (TSA) and Nutrient Agar (NA) at various temperatures, ranging from 27^{o}C to 50^{o}C. It also grew on TSA and NA amended with various NaCl concentrations, ranging from 2.5 % NaCl to 10 % NaCl. The elevated temperature and NaCl concentrations that *Bacillus* 1BA could withstand were used in preliminary plate counting of the microflora of wheat heads. Little or no growth of the native microflora occurred with these conditions, which led to continued studies involving the recovery of *Bacillus* 1BA from wheat heads after spray application in the field. To produce BCA inoculum for field plot application, *Bacillus* 1BA was grown in a variety of different broth media, including Field Defined Medium (FDM), FDM + 8.5 % NaCl, Tryptic Soy Broth & Yeast Extract (TSB/YE), TSB/YE + 8.5 % NaCl, half-strength TSB/YE, and half-strength TSB/YE + 8.5 % NaCl. Cell counts of *Bacillus* 1BA in these media were obtained using a MPN procedure, on the day cells were sprayed onto wheat heads at flowering. For the MPNs, a selective agar-solidified medium of TSA + 8.5 % NaCl was used, with an incubation temperature of 47^{o}C . Counts of the BCA on inoculated wheat heads were done at days 0, 3, 6, 9, 12, 15, and 20 after inoculation. In addition a few treatments from Day 15 and Day 20 were heat-pasteurized to help determine if *Bacillus* 1BA propagules were mainly present as vegetative cells or endospores. After heat pasteurization, *Bacillus* 1BA colonies formed on the MPN plates , which confirmed the presence of endospores on wheat heads at Day 15 and Day 20. Inocula of *Bacillus* 1BA produced in different broth media behaved differently over time on wheat heads, with some experiencing little or no population increase, and others showing a dramatic increase in numbers several days after spray application. Most of the inocula from different media experienced a rapid drop-off in numbers soon after spray application to wheat heads. However, most treatments stabilized or increased in numbers on the wheat heads over time, and several treatments showed a dramatic increase in numbers by 9 days after application. This suggested that this biocontrol agent can persist and grow for several days after its application, to antagonize *Fusarium* in the field.

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INFLUENCE OF SPRAY VOLUME AND NOZZLE ORIENTATION ON FUNGICIDE EFFICACY FOR CONTROL OF FUSARIUM HEAD BLIGHT.

Halley, S.[1*], Van Ee, G.[2] and Hofman, V.[3]

[1]Langdon Research Extension Center, North Dakota State University, Langdon, ND 58249, USA; [2]Dept. of Agricultural Engineering, Michigan State University, East Lansing, MI 48824, USA; and [3]Dept. of Agricultural and Biosystems Engineering, North Dakota State University, Fargo, ND 58105, USA
[*]Corresponding Author: PH: (701) 256-2582, E-mail: Scott.Halley@ndsu.edu

ABSTRACT

Enhancing the efficacy of fungicides for control of Fusarium head blight (FHB) has been the goal of researchers studying application technology. Fungicides historically have been reported to reduce FHB and deoxynivalenol concentration (DON) by about 50% as compared to untreated. Initial recommendations on the amount of spray volume to apply fungicide to wheat heads from Extension Service Specialists were in part based on greenhouse studies using a fluorescent tracer dye which showed that coverage on the wheat spike increased as spray volume increased up to 54 GPA. A practical limit of 20 GPA has been recommended to growers for applying fungicides to small grains. Many growers apply fungicide in volumes between 10 and 20 GPA. Studies were conducted on barley, hard red spring wheat (HRSW) and durum over several growing seasons at the North Dakota State University Langdon Research Extension Center to determine the effect of spray volume and nozzle orientation on fungicide efficacy. Fungicide was applied at volumes of 5, 10, and 20 GPA with nozzles oriented forward and backward (F+B) and forward (F) with both orientations angled downward 30 degrees from horizontal. On barley, field severity from a 20 GPA F+B treatment was less than the 5 and 10 GPA F treatment but was not different from a 10 GPA F+B treatment. No differences were found among fungicide treatments determined by FHB incidence, plump or deoxynivalenol (DON) concentrations. On HRSW a 10 GPA F+B treatment had less FHB incidence and better test weight than a 10 GPA F treatment and a better test weight than a 20 GPA F+B treatment. On durum there were no differences due to application method among fungicide treatments in FHB incidence, field severity or DON. There was no evidence to suggest that spray volumes greater than 10 GPA enhanced the efficacy of fungicide for control of FHB.

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2006 FHB UNIFORM FUNGICIDE TRIAL ON SPRING AND WINTER WHEATS IN MINNESOTA.

C.R. Hollingsworth[1*], B. Potter[2], C.D. Motteberg[1] and L.M. Atkinson[1]

[1]Northwest Research & Outreach Center and Dept. of Plant Pathology, University of Minnesota, Crookston, MN 56716; and [2]Southwest Research and Outreach Center, University of Minnesota, Lamberton, MN 56152

[*]Corresponding Author: PH: (218) 281-8627; E-Mail: holli030@umn.edu

ABSTRACT

The objective of this trial was to evaluate and compare Fusarium head blight (FHB) control efficacies of non-registered and commercially available fungicide products when applied to spring and winter wheats in Minnesota. Hard red winter wheat (HRWW) 'Jerry' was planted 8 Sept. 2005 and hard red spring wheat (HRSW) 'Steele ND' was planted 6 May 2006 into soybean residue at the Northwest Research and Outreach Center (NWROC). Hard red spring wheat 'Oxen' was planted 12 April 2006 into corn residue at the Southwest Research and Outreach Center (SWROC). The NWROC winter and spring wheat and the SWROC spring wheat experiments were inoculated 22 May, 15 June, and 23 May, respectively with 112 kg ha^{-1} of *F. graminearum* infested corn grain inoculum and misted nightly thereafter to increase disease pressure. Fungicide treatments were applied on HRWW 6 June and HRSW 16 June (SWROC) and 28 June (NWROC) when plants were at the early flowering growth stage (Feekes 10.51). Fungicide treatments were applied using CO_2 backpack-type sprayers adjusted to 40 psi at 18-20 gpa with forward and backward positioned 'XR' Teejet flat fan 8001 VS nozzles. Treatments consisted of: (1) nontreated control; (2) Folicur (tebuconazole) 4 fl oz $acre^{-1}$; (3) Prosaro (tebuconazole + prothioconazole) 6.5 fl oz $acre^{-1}$; (4) Caramba (metconazole) 13.5 fl oz $acre^{-1}$; (5) Topguard (flutriafol) 14.0 fl oz $acre^{-1}$; (6) tebuconazole 2 fl oz $acre^{-1}$ + thiphanate-methyl 8 fl oz $acre^{-1}$; and (7) Tilt (propiconazole) 4 fl oz $acre^{-1}$. A total of 50 spikes $plot^{-1}$ were rated for FHB symptoms from spring wheat tests. Tests were harvested 19 July (HRWW), 28 July (HRSW at SWROC), and 3 Aug (HRSW at NWROC). The tests were arranged in the field as randomized complete block designs with four replicates. ANOVAs were performed with SAS using PROC GLM. Winter wheat results were analyzed using a randomized complete block design while a split plot design was used for HRSW tests (main plot=location, sub plot=fungicide treatments). Fisher's protected least significant difference (LSD) mean comparisons were used to identify differences.

A widespread drought occurred in Minnesota during the 2006 growing season. Disease pressures were light across experiments even under misting. Symptoms of FHB did not develop on HRWW spikes so disease was not rated in that trial. Across locations and treatments, HRSW FHB incidence ranged from 10.8% to 5.0%, FHB severity ranged from 8.5% to 5.9%, and FHB indices ranged from 1.0% to 0.4%. Neither location nor treatment means were significant for FHB incidence, FHB severity, or FHB index. Significant results across wheat classes include yield (HRSW, treatment $P = 0.0198$: HRWW, $P = 0.0215$), thousand kernel weight (HRSW, treatment $P = 0.0311$: HRWW, $P = 0.242$), and deoxynivalenol (DON) content of grain (HRSW, treatment $P = 0.0026$: HRWW, $P = 0.0039$).

Hard red spring wheat yields were greatest with Prosaro (65.3 bu/A), Caramba (62.3 bu/A), and Tilt (60.8/A). Three treatments, Caramba (29.9 g), Tilt (29.4 g), and Folicur (29.2 g) resulted in the largest thousand kernel weights. Two triazole fungicide products, Caramba (0.5 ppm) and Prosaro (0.7 ppm), significantly reduced DON content compared to other treatments.

Hard red winter wheat yields were greatest with Folicur (93.0 bu/A), Caramba (91.0 bu/A), Tilt (86.9 bu/A), tebuconazole + thiphanate-methyl (85.3 bu/A), and Prosaro (83.9 bu/A). Tebuconazole + thiphanate-methyl (34.3 g), the nontreated control (34.7 g), Topguard (34.8 g), and Tilt (35.3) had the smallest thousand kernel weights. Four treatments, Prosaro (0.1 ppm), Caramba (0.1 ppm), Folicur (0.2 ppm), and tebuconazole + thiphanate-methyl (0.3 ppm) resulted in reduced DON levels.

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ADJUVANT EFFECTS ON PERFORMANCE OF FOLICUR AND PROSARO FUNGICIDES FOR FHB CONTROL IN DURUM WHEAT AND BARLEY.

J. Jordahl, S. Meyer and M. McMullen*

Dept. of Plant Pathology, North Dakota State University, Fargo, ND 58105
*Corresponding Author: PH (701) 231-7627; E-mail: marcia.mcmullen@ndsu.edu

ABSTRACT

Folicur (tebuconazole) and Prosaro (tebuconazole + prothioconazole) are two fungicides that have shown promise in reducing Fusarium head blight (FHB) field severity and deoxynivalenol (DON) levels in small grains. Folicur (tebuconazole) has had special exemptions in some states for use on wheat and barley to suppress FHB, while Prosaro is still an experimental product. The manufacturer of both products, Bayer CropScience, is seeking full registration of both products from the Environmental Protection Agency.

A standard adjuvant recommended for use with tebuconazole is a petroleum-based non-ionic surfactant. Various private companies in the U.S. sell other non-ionic surfactants or have other adjuvants for sale that are silicone-based or are encapsulating products, and these companies also are experimenting with many new formulations of adjuvants. We have conducted extensive studies on hard red spring wheat with adjuvants and Folicur. Results indicated that most adjuvants tested with Folicur reduced FHB severity better than when no adjuvant was applied, while a few products were not as satisfactory as the non-ionic surfactants (McMullen, et al. 2005). Additional testing was needed to determine if durum and barley would react similarly to various adjuvants. Durum wheat and barley cultivars grown in North Dakota have very long and prominent awns compared to most spring wheat cultivars; different types of adjuvants could play a role in deposition and penetration past these awns to the site of infection.

Adjuvants were mixed with 4 fl oz/A rate of Folicur or 6.5 fl oz/A rate of Prosaro and applied at early flowering to durum or early head emergence in barley. Plants were inoculated with a spore suspension (10,000 spores/ 20ml) of *Fusarium graminearum* one hour after application of the fungicides + adjuvants. FHB severities were determined at early soft dough stage. Results with adjuvant testing in the greenhouse indicated that all fungicide + adjuvant treatments significantly reduced FHB field severity, but very few differences were observed among types of adjuvants mixed with Folicur or Prosaro.

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UNIFORM FUNGICIDE TRIAL RESULTS ON HRS WHEAT AND BARLEY, FARGO, ND 2006.

S. Meyer, J. Jordahl and M. McMullen*

Dept. of Plant Pathology, Walster Hall, North Dakota State University, Fargo, ND 58105
*Corresponding Author: PH: (701) 231-7627; E-mail: marcia.mcmullen@ndsu.edu

ABSTRACT

Six fungicide treatments were compared to the untreated check for efficacy in reduction of Fusarium head blight (FHB) severity and deoxynivalenol (DON) in 'Tradition' spring barley and 'Steele ND" hard red spring (HRS) wheat, at Fargo, ND. Both crops were planted on May 8 into ground with wheat as the previous crop, and that had been chisel plowed twice prior to planting. Plots were 9'wide and 20' long, with 4 replicates per treatment arranged in a randomized complete block design. Corn grain, inoculated with *Fusarium graminearum*, was spread evenly among each plot two weeks prior to heading. An overhead misting system provided added water to the plots following heading, when the nighttime humidity dropped below 90%. Fungicides were applied at early full head emergence for barley (Feekes 10.4), and at early flowering for wheat (Feekes 10.51), except for the Tilt treatment, which was applied before flowering (Feekes 10.5). Applications were with a backpack-type sprayer equipped with two XR8001 flat fan nozzles oriented toward the grain head at a 30° angle from the horizontal. The fungicides were applied at 18.5 gpa with 40 psi. Disease notes were taken at soft dough stage of development and crops were harvested at kernel maturity. Sub-samples of the harvested grain were ground and analyzed for deoxynivalenol (DON) by the NDSU Veterinary Toxicology Laboratory using gas chromatography and electron capture techniques.

The fungicide treatments included: Folicur 432 SC (tebuconazole – a Bayer CropScience compound) at 4 fl oz/A; Prosaro 421 SC (19% prothioconazole + 19% tebuconazole - a Bayer CropScience compound) at 6.5 fl oz/A; BAS555 1F (metconazole - a BASF compound) at 13 fl oz/A; Topguard 1 SC (flutriafol - a Cheminova compound) at 14 fl oz/A; Folicur 432 SC + Thiophanate-methyl (tebuconazole + CerixAgri product) at 2 fl oz/A tebuconazole + 8 fl oz/A thiophanate-methyl; and Tilt (propiconazole – a Syngenta product) at 4 fl oz/A.

Very high temperatures and no natural rainfall in July resulted in very low disease levels in Fargo in 2006. The untreated FHB field severity was only 0.6 % in barley and 2.0 % in wheat. Despite low disease, all fungicide treatments reduced FHB field severity (P = 0.1) for both crops. DON levels also were low in 2006, 3.0 ppm for untreated barley, and 0.7 ppm for untreated spring wheat. However, most fungicide treatments significantly (P = 0.1) reduced DON in both crops. Compared to other fungicide treatments in barley, the Prosaro treatment resulted in significantly lower DON levels.

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EFFECT OF FUNGICIDES ON FHB AND DON IN WHEAT - 2006 UNIFORM FUNGICIDE TRIALS.

Pierce Paul[1*], Don Hershman[2], Martin Draper[3] and Larry Madden[1]

[1]The Ohio State University/OARDC, Department of Plant Pathology, Wooster, OH 44691;
[2]University of Kentucky, Department of Plant Pathology, Lexington, KY 40546; and
[3]South Dakota State University, Plant Science Department, Brookings, SD 57007
[*]Corresponding Author: PH: (330) 263-3842; E-mail: paul.661@osu.edu

OBJECTIVES

Evaluate foliar fungicides for effectiveness in managing Fusarium head blight (FHB) and deoxynivalenol (DON) accumulation in wheat across multiple trials representing different wheat classes and locations.

INTRODUCTION

FHB, caused predominantly by *Fusarium graminearum* in North America, has had a great impact on every sector of the wheat and barley industries. Wheat growers, millers, bakers, and consumers of wheat products all have been affected by this disease. In addition to causing yield losses associated with reduced kernel size and weight, reduced seed germination, and seedling blight, *F. graminearum* also produces a mycotoxin called deoxynivalenol (DON) (among other toxins) which may accumulate to unacceptable levels in harvested grain. DON levels above 2 ppm may render grain and their by-products unfit for commercialization and consumption. Efforts to minimize the impact of FHB and DON have been centered on the use of management strategies such as host resistance, crop rotation, tillage, and fungicide application. Through collaborative research involving scientists from multiples states, representing various wheat-growing regions, Uniform Fungicide Trials (UFT) have been used to evaluate fungicide effectiveness against FHB and DON. These trials follow standard protocols and have been conducted annually since 1998. The results of the 2006 UFT trials form 17 locations across 8 states are presented herein.

MATERIALS AND METHODS

Each trial consisted of six fungicide treatments and an untreated control in a randomized complete block design, with four replicate blocks (one trial had five block). The core treatments were:

- Non-treated control;
- Folicur 432SC 4.0 fl oz + 0.125% Induce;
- Prosaro 6.5 fl oz/a + 0.125% Induce;
- Caramba 13.5 fl oz/a + 0.125% Induce;
- Topguard 14 fl oz/a + 0.125% Induce;
- Tebuconazole (2 fl oz/a) + Thiophanate-Methyl;
- Tilt 4 fl oz/a + 0.125% Induce.

Treatments were applied at full head emergence (Tilt) and early flowering (all other treatments) using CO_2-pressurized sprayers, equipped with Twinjet XR8002 nozzles or paired XR8001 nozzles mounted at a 60° angle forward and backward.

Planting and crop production practices varied somewhat from trial to trial. See individual trial reports for details. Most plots were planted with a susceptible cultivar. To enhance disease development, plots were either planted into corn or wheat residue and/or artificially inoculated with *F. graminearum*-infested kernels. Many plots were mist-irrigated as a means of enhancing production of, and infection by fungal inocula. In each plot of each trial, percent FHB incidence (INC), diseased-head severity (SEV), index (IND; also known as plot severity), and *Fusarium*-damaged kernels (FDK) were measured as previously described (McMullen, et al., 1999). DON accumulation was measured at one of the two USWBSI-funded DON Testing Laboratories.

For the purpose of data analysis, trials conducted at the same location, but using different cultivars, and trials conducted at different locations in the same state were considered separate studies. Each trial was analyzed separately using a mixed effect model in PROC MIXED of SAS to determine treatment effect on the FHB, DON, yield (bu/ac) and test weight (lb/bu). Linear contrasts were used to make pair-wise comparisons between treatment means and means across groups of treatments. Studies with zero or nominal levels of disease and DON were not analyzed.

RESULTS AND DISCUSSION

Weather conditions in both winter wheat and spring wheat areas were generally unfavorable (dry during flowering) for FHB development. Consequently, non-irrigated trials and a few irrigated trials had nominal disease development. Mean and maximum FHB index, across all replicates of the untreated check plots ranged from 0 to 14.01 and 0 to 26.90%, respectively (Table 1). In 10 of the 17 trials mean index in the untreated check was less that 1% and less than 2% in 13 of the 17 trials.

Fungicide treatment had a significant effect ($P < 0.05$) on FHB in only one of the 17 trials, Fayetteville, AR (Table 1). Treatments 2 (Folicur), 3 (Prosaro) and 4 (Caramba) significantly reduced FHB index relative to the untreated check. Caramba was the most effective treatment, resulting in 65% reduction in IND relative to the check. Based on pair-wise comparisons between treatments means, Caramba was more effective than Folicur but not Prosaro. In three of the other trials with some level of disease (mean IND > 5% in the check) Caramba- and Prosaro-treated plots had the lowest levels of disease, being significantly lower than the check in two of the three cases.

Similar results were observed for DON and other measures of FHB intensity (IND, SEV, INC, and FDK). Since IND is a direct function of INC and SEV (see Paul et al., 2005a,b), only the results for IND are summarized herein. The results for DON are presented in Table 2. The Caramba treatment, treatment 4, was again the most effective. Based on data from Crookston, MN and Fayetteville, AR, this treatment resulted in a significant reduction in DON relative to the untreated check, with percent reduction being between 56 and 64%, respectively. Despite this reduction, however, mean DON levels in Caramba-treated plots still exceeded critical thresholds in the trial conducted at Fayetteville, AR. As was the case with IND, DON levels in Caramba-treated plots was only significantly lower than DON levels in Folicur-treated plots but not Prosaro-treated plots.

A significant reduction in FHB coincided with significant yield increase and higher test weights in Fayetteville, AR. Plots treated with Prosaro and Caramba had significantly ($P < 0.005$) higher yields and test weights than the untreated check plot.

CONCLUSION

In summary, fungicide treatments did reduce FHB intensity and DON relative to the untreated check (based mainly on data from one location). The application of Caramba at a rate of 13.5 fl. oz per acre and Prosaro at 6.5 fl. oz per acre were the most effective treatments overall. Percent control (Hershman and Milus, 2003) was generally higher in trials with low levels of disease than in trials with high levels of disease. This should be interpreted with caution since the ultimate effectiveness of a fungicide treatment should be based on results under high disease pressure. In generally, the overall levels of disease and DON in 2006 were too low for us to make broad conclusions regarding the treatments tested.

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Table 1. Fungicide effect on Fusarium head blight index.

Trial		Wheat	Most effective Treatment[a]				Index (%) Check	
State/PI	Location	Type	Treat	IND (%)	% Control	*P value*	Mean	Max
AR/Milus	Fayetteville	W	4	4.54	65	<0.001	13.64	19.44
IL/Adee	Monmouth	W	NS	…	…	…	0.19	0.75
IL/Paul	DeKalb	W	NS	…	…	…	0.59	1.13
KY/Hershman	Princeton	W	NS	…	…	…	0.05	0.20
LA/Padgett	Macon Ridge	W	NS	…	…	…	0.46	1.40
MN/Hollingsworth	Crookston	S	NS	…	…	…	1.33	2.80
	Lamberton	W	NS	…	…	…	0.50	1.08
MO/Sweets	Columbia 1	W	NS	…	…	…	1.75	2.12
	Columbia 2	W	…	…	…	…	0.48	1.10
ND/McMullen	Fargo	S	4 NS	8.63	26	0.410	14.01	26.90
	Carrington	S/D	3 NS	5.48	61	0.026	11.73	17.75
SD/Draper	Brookings 1	S	4 NS	1.18	79	0.004	5.65	10.54
	Brookings 2	S	NS	…	…	…	1.32	3.03
	Watertown 1	S	…	…	…	…	0.00	0.00
	Watertown 2	S	…	…	…	…	0.11	0.42
	Groton 1	S	…	…	…	…	0.00	0.00
	Groton 2	S	…	…	…	…	0.00	0.00

[a] Treat = the most effective treatment (s) within each trial based on the pair-wise difference between mean IND for each treatment and the check, NS = no significant treatment effect; IND (%) = mean index across plots receiving the most effective treatment; % control = percent control; *P* value = level of significance from *t* test of the difference between mean IND across plots receiving the most effective treatment and the untreated check ($P < 0.05$ ➔ significant different). All tests of significance were done using arcsine-transformed IND.

… = Trials with zero or nominal levels of disease.

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Table 2. Fungicide effect on DON.

Trial		Wheat	Most effective Treatment[a]				Index (%) Check	
State/PI	Location	Type	Treat	DON	% Reduction	*P value*	Mean	Max
AR/Milus	Fayetteville	W	4	4.3	64	<0.001	12.00	13.50
IL/Adee	Monmouth	W	…	…	….	…	…	…
IL/Paul	DeKalb	W	NS	…	…	…	0.03	0.10
KY/Hershman	Princeton	W	…	…	…	…	0.35	0.40
MN/Hollingsworth	Crookston	S	4	0.65	56	0.005	1.47	2.50
	Lamberton	W	…	…	…	…	0.55	0.88
MO/Sweets	Columbia 1	W	…	…	…	…	…	…
	Columbia 2	W	…	…	…	…	…	…

[a]DON data were not available for some trials or available but equally low (below 1 ppm) for all treatments.

[b]Treat = the most effective treatment within each trial based on the pair-wise difference between mean DON for each treatment and the check, NS = no significant treatment effect; DON (ppm = mean DON across plots receiving the most effective treatment; % reduction = percent reduction in DON; *P* value = level of significance from *t* test of the difference between mean DON across plots receiving the most effective treatment and the untreated check ($P < 0.05$ ➔ significant difference). All tests of significance were done using log-transformed.

… = Trials with zero or nominal levels of DON.

2006 UNIFORM FUNGICIDE PERFORMANCE TRIALS FOR THE SUPPRESSION OF FUSARIUM HEAD BLIGHT IN SOUTH DAKOTA.

K.R. Ruden[1*], B.E. Ruden[1], K.D. Glover[1], S.M. Thompson[1], K. Maxson Stein[1] and M.A. Draper[1,2]

[1] Plant Science Department, South Dakota State University, Brookings, SD 57007, USA; and [2]Current address: USDA-CSREES, Washington, DC 20024
[*]Corresponding Author: PH: (605) 688-6246; E-Mail: kay.rude@sdstate.edu

ABSTRACT

Fusarium head blight (FHB – scab) has been a serious concern for wheat and barley producers in South Dakota for ten years and a serious epidemic impacted the state's wheat and barley crop in 2005. The objective of this study was to continue to evaluate the efficacy of various fungicides and fungicide combinations for the suppression of Fusarium head blight and other wheat diseases. Two hard red spring wheat cultivars, 'Briggs' and 'Ingot', were planted at three South Dakota locations (Brookings, Groton, and South Shore/Watertown) and Robust barley was planted at Brookings. 'Wesley' winter wheat study sites were also established at South Shore/Watertown and Andover. Studies at both of these sites were conducted under ambient conditions. A misted study with 'Robust' barley was conducted at the Brookings site. Due to drought conditions, FHB only developed at the Brookings site. Only the spring wheat data from that trial is presented in this report. Trial treatments from the Uniform Fungicide Trial treatments list for the suppression of FHB included an untreated check, Folicur (tebuconazole) applied at 4.0 fl oz/A, Prosaro (a premix of prothioconazole and tebuconazole) applied at 6.5 fl oz/A, Caramba (metconazole) applied at 13.5 fl oz/A, Topguard (flutriafol) applied at 14 fl oz/A, and a tank mix of Folicur (tebuconazole) applied at 2 fl oz/A with Topsin-M (thiophanate-methyl) applied at 8 fl oz/A. All treatments included Induce, a non-ionic surfactant, applied at 0.125% v/v. Spring wheat trials were planted in a factorial randomized complete block design with six replications. Winter wheat and barley locations had four replications. Trial treatments were applied at anthesis (Feekes growth stage 10.51). Plots were inoculated by spreading *Fusarium graminearum* (isolate Fg4) inoculated corn (*Zea mays*) grain throughout the field and providing overhead mist irrigation applied for 3 min out of every 20 minutes from 5:00 pm until 9:00 am each day for two weeks following anthesis at the Brookings location only. Other sites had natural inoculum from corn stalk residue and natural moisture conditions. Twenty-one days following treatment, plots were evaluated for leaf diseases, FHB incidence, FHB head severity, and FHB field severity. Samples were collected for Fusarium damaged kernels (FDK), deoxynivalenol (DON), grain yield, and test weight. Spring wheat under dryland conditions at South Shore/Watertown and Groton FHB had negligible FHB. The same was true for winter wheat at both locations. No significant differences resulted from the barley trial. On spring wheat, Prosaro was the only product to significantly reduce FHB incidence, from 11.5% to 5.7%. While there were no measurable differences in FHB severity, both Prosaro and Caramba reduced FHB index from 3.2% on the untreated to 1.3 and 1.8% respectively. All products significantly increased grain yields from about 12-22%, largely due to leaf disease control. Data is not yet available for FDK and DON.

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This material is based upon work supported by the U.S. Department of Agriculture, under Agreement No. 59-0790-4-097. This is a cooperative project with the U.S. Wheat and Barley Scab Initiative. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

2006 UNIFORM TRIALS FOR THE PERFORMANCE OF BIOLOGICAL CONTROL AGENTS IN THE SUPPRESSION OF FUSARIUM HEAD BLIGHT IN SOUTH DAKOTA.

K.R. Ruden[1*], B. Bleakley[1], S.M. Thompson[1], K. Maxson-Stein[1] and M.A. Draper[1,2]

[1] Plant Science Department, South Dakota State University, Brookings, SD 57007, USA; and [2]Current affiliation USDA-CSREES, Washington, DC 20024
[*]Corresponding Author: PH: (605) 688-6246; E-mail: kay.ruden@sdstate.edu

ABSTRACT

Fusarium head blight (FHB – scab) has been a serious concern for wheat and barley producers in South Dakota for ten years and was very severe in parts of SD in 2005. The objective of this study was to continue to evaluate the efficacy of various fungicides and fungicide combinations for the suppression of Fusarium head blight and other wheat diseasesunder SD conditions. Ingot hard red spring wheat and Robust barley were planted at Brookings, South Dakota. Trial treatments included an untreated check; Folicur (tebuconazole) applied at 4.0 fl oz/A; 1BA (*Bacillus subtilus*) from South Dakota State University, Brookings, SD; 1BA + Folicur coapplied, TrigoCor 1448 (*Bacillus* sp.) from Cornell University, Ithaca, NY; and TrigoCor 1448 + Folicur coapplied; C3 (*Lysobacter enzymogenes*) from University of Nebraska, Lincoln, NE; C3 + Folicur coapplied. Additionally, the 1BA isolate was applied after growth in Trypic soy broth + Yeast extract (TS+YE) at full and half strength; Defined broth medium + salt; TS/TE + salt; and ½ strength TS/YE + salt. Anther set of treatments assessed the activity of different surfactants on the activity of 1BA, Induce non-ionic surfactant, Latron CS7, and Agridex crop oil concentrate (COC). Unless otherwise indicated, treatments were grown on site according to specifications from their originating labs and applied at anthesis. Plots were inoculated by spreading *Fusarium graminearum* (isolate Fg4) inoculated corn (*Zea mays*) grain throughout the field at least ten days prior to flowering (wheat) or head emergence (barley) throughout the field and providing overhead mist irrigation applied for 3 min out of every 20 minutes from 5:00 pm until 9:00 am each day for two weeks following treatment. Twenty-one days following treatment, plots were evaluated for FHB incidence, FHB head severity, and FHB field severity. Plots were harvested for yield and test weight and samples were collected for Fusarium damaged kernels (FDK) and deoxynivalenol (DON). Even with amending the environment in 2006, extreme drought limited disease development. In the final analysis, no assessments of disease components revealed significant effects of the treatments in the barley study.

While 1BA appeared to have no effect on yield with or without Folicur, TrigoCor 1448 and C3 both appeared to have synergistic activity when applied with Folicur. In both cases the response was significantly greater that the Folicur treatment alone, which was not different than the untreated in this trial. There were no differences among the treatments for the components of FHB. While there were no significant differences in incidence, there were striking numeric differences when different surfactants were applied with 1BA. This facet of application of BCAs has not been examined and warrants further study.

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USDA-ARS AND THE OHIO STATE UNIVERSITY COOPERATIVE RESEARCH: USE OF FRACTIONAL FACTORIAL FIELD DESIGNS TO ASSESS THE INTEGRATION OF DIVERSE TREATMENTS AGAINST FHB.

D.A. Schisler[1*], M.J. Boehm[2], C. Dunlap[1], P. Paul[3] and D.E. Palmquist[1]

[1]National Center for Agricultural Utilization Research (NCAUR), USDA-ARS, Peoria, IL 61604; [2]Department of Plant Pathology, The Ohio State University, Columbus, OH 43210; and [3]The Ohio State University/OARDC, Department of Plant Pathology, Wooster, OH 44691
[*]Corresponding Author: PH: (309) 681-6284; E-mail: schislda@ncaur.usda.gov

OBJECTIVES

1) Evaluate, *in vitro*, the suitability of various food grade dyes as UV protectants for use with choline metabolizing FHB biocontrol strain OH 221.3; and 2) evaluate the effectiveness of integrating the use of biocontrol strains OH 182.9 [*Cryptococcus flavescens* NRRL Y-30216 (Dunlap et al. 2006), previously reported as *C. nodaensis* nomen nudum] and OH 221.3, Folicur 3.6F, a UV protectant, and a chemical inducer of acquired resistance.

INTRODUCTION

In previous work, we discovered microbial strains that reduce FHB in the greenhouse and field and demonstrated enhanced reduction of FHB via formulation of biocontrol agents with UV protectants (Schisler et al., 2003), and mixing fungicide-tolerant variants of our biocontrol agents with fungicides (Schisler et al., 2002). In more recent work, we have discovered chemical inducers of systemic acquired disease resistance (SAR) that reduce FHB development in greenhouse tests (Zhang et al., 2005) and choline metabolizing strains (CMS) (Schisler et al., 2006) that reduce FHB in greenhouse and field tests. Determining the relative importance of these factors when simultaneously tested and identifying synergies, if any, when multiplexing these factors is crucial to elucidating which of these factors should be included in any recommended IPM program against FHB and which factors are most critical for inclusion in a final FHB biocontrol product. Additionally, further work on identifying inexpensive, nontoxic UV protectants that are effective in enhancing the survival of biocontrol agents in field environments is needed.

MATERIALS AND METHODS

Tests of food grade dyes as UV protectants: Several food grade dyes (Table 1) were tested, *in vitro*, for their ability to aid survival of dried cells of FHB bacterial antagonist OH 221.3 exposed to artificial sunlight supplied from a xenon light source (Suntest Atlas CPS solar simulator, Heraeus DSET Laboratories Inc., Phoenix, AZ). Cells of antagonist OH 221.3 were grown in flasks containing a semidefined liquid medium (SDCL, Schisler 2002), harvested from 24 h growth cultures, combined or not with UV protectants, added as 2 µl droplets of formulated cells (8 reps/treatment) to 96 well microtiter plates, air-dried for 1 h or not, and exposed or not to 6 h of UV light. Cell counts at the time of introduction to microtiter plates were approximately 9×10^9 CFU/ml. Final dye concentrations were 5.00 and 1.25 µM. Wells were rehydrated with 50 µl of weak growth medium, cell growth determined using a spectrophotometer at 620 nm, and qualitative changes in absorbance versus controls determined after set intervals of cell growth (Table 1). Greenhouse tests confirmed that none of the dyes tested adversely affected plant growth (data not shown).

Field Tests using Partial Factorial Designs: Two-level fractional factorial designs (Table 2) were used for field trials in Peoria, IL (insufficient disease development, data not shown) and Wooster, OH in 2006 (Tables 3,4). Biomass of antagonists was pro-

duced in B Braun Biostat B fermentors charged with SDCL medium (1.5 l working volume). Soft red winter wheat cultivars Elkhart (susceptible) and Freedom (moderately resistant) were grown using standard agronomic conditions (Schisler et al., 2006). Treatments were applied at the beginning of wheat flowering at concentrations of 1 x 10^8 and 2 x 10^9 (CFU/ml) for antagonists OH 182.9 and OH 221.3, respectively. UV protectant naphthol yellow (NY) and SAR chemical Na salycylic acid (NaSA) were applied at concentrations of 5.0 µM and 1.6 g/l, respectively and a rate of 80 gal/acre. The fungicide Folicur 3.6F (38.7% tebuconazole) was applied at the recommended AI rate of 4 fl. oz./acre as a chemical control and untreated plants served as an additional control. Corn kernels colonized by *G. zeae* were scattered through plots (~25-40 kernels/m^2) two weeks prior to wheat flowering and mist irrigation was provided periodically for approximately two weeks after treatment application. Heads were scored for disease incidence and severity 21 days after treatment using a 0-100% scale. Analysis of field data obtained from this fractional factorial design was conducted using SAS version 9.1.3 and Design-Expert version 6.0.3 software.

RESULTS AND DISCUSSION

Of the dyes tested for utility as UV protectants for FHB biocontrol strain OH 221.3, NY was the most efficient in enhancing the survival of cells exposed to 6 hours of artificial sunlight. Naphthol yellow did not have a deleterious effect on the growth of fresh cells or dried cells not exposed to artificial sunlight (Table 1).

Treatment component effects were dependent on the wheat cultivar considered. On cultivar Elkhart in Wooster, Ohio, the presence of Folicur 3.6F (P=0.001) and antagonist OH221.3 (P=0.10) significantly reduced disease severity and incidence (Table 3). Antagonist OH 182.9 reduced the DON content (P=0.04) and NY decreased the test weight (P=0.05) of Elkhart grain. NaSA increased DON in Elkhart but reduced DON in Freedom grain (P=0.02, Table 4). No other treatment component significantly influenced test parameters on Freedom. Formulating NY and NaSA to produce a product more resistant to wash-off may be needed to counter the effects of frequent overhead irrigation in field experiments.

Our results using a partial factorial design do not indicate the presence of first order synergistic effects of combining biocontrol agents, a UV protectant, Folicur 3.6F and a SAR chemical. A Dunnett's analysis of individual runs (Table 2) versus untreated controls rarely indicated significant differences (data not shown), suggesting that higher order synergistic interactions between treatment components did not occur. Additional experiments using partial factorial designs in FHB field studies would be necessary to determine if the design can serve as a useful tool for detecting treatment differences while reducing the amount of field area required.

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DISCLAIMER

Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture. Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

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Table 1. Influence of Food Grade Dyes on Fresh Cell Growth of FHB Antagonist OH 221.3 and the Survival of Dried Cells Exposed or not to 6 h of Artificial Sunlight[a,b]

Treatment	Fresh Cells -UV[c]	Dry Cells -UV[d]	Dry Cells +UV 6h[d]
FD&C Blue #1 (5.00 µM)	-(+)	0	+(-)
FD&C Blue #1 (1.25 µM)	-(+)	+(-)	-(-)
FD&C Yellow #5 (5.00 µM)	0	+(+)	-
FD&C Yellow #5 (1.25 µM)	+(-)	+(-)	+
Fast Green (5.00 µM)	-(+)	-(+)	0
Fast Green (1.25 µM)	0	0	-(-)
FD&C Red #40 (5.00 µM)	+(-)	+	--
FD&C Red #40 (1.25 µM)	0	0	-
Naphthol Yellow (5.00 µM)	0	0(+)	+(+)
Naphthol Yellow (1.25 µM)	0	+	++(+)

[a] Treatment influence on cell survival determined by comparing absorbance of microtiter plate wells containing treated cells with wells containing control cells. Absorbances compared at set intervals of time after 1 ul droplets of fresh cells added to wells and subjected to no treatment (fresh cells –UV), drying (dry cells –UV), or drying and 6 h artificial sunlight (dry cells +UV) and then flooded with 50 uL of growth medium.

[b] Table values are qualitative data and represent major increase , ++; minor increase, +; no change, 0; minor decrease, -; and major decrease, -- in well absorbance compared to the control. Parenthetical values indicate that the reported value is slightly higher (+) or lower (-) than the average qualitative range.

[c] Absorbance (620 nm) determined at 8 to 10 h after growth medium addition to well.

[d] Absorbance (620 nm) determined at 28 h after growth medium addition to well.

Table 2. Fractional factorial, 32 run experimental design for Peoria, Illinois and Wooster, OH field tests integrating multiple factors for reducing FHB (1 indicates presence, -1 indicates absence of the individual treatment factors that make up a treatment "run"). Each "run" was one treated row (Peoria) or plot (Wooster). Design was repeated at each site on FHB moderately resistant cultivar Freedom and susceptible cultivar Elkhart.

Treatment (Run)	Antagonist OH 182.9	Antagonist OH 221.3	UV Protect Naphthol Yellow	Fungicide Folicur 3.6F	SAR chemical NaSalycylic
1	-1	-1	1	-1	-1
2	-1	1	1	-1	1
3	1	-1	1	1	-1
4	-1	1	-1	1	1
5	-1	1	1	1	-1
6	1	-1	-1	1	1
7	1	-1	-1	-1	-1
8	-1	-1	-1	1	-1
9	1	-1	1	1	-1
10	1	1	-1	-1	1
11	-1	-1	1	-1	-1
12	-1	-1	1	1	1
13	1	-1	-1	-1	-1
14	-1	1	-1	-1	-1
15	1	1	1	-1	-1
16	1	1	1	1	1
17	-1	1	1	1	-1
18	-1	1	-1	-1	-1
19	1	1	-1	1	-1
20	1	-1	-1	1	1
21	1	1	1	-1	-1
22	-1	-1	-1	1	-1
23	1	-1	1	-1	1
24	-1	-1	-1	-1	1
25	1	1	-1	-1	1
26	1	1	1	1	1
27	-1	-1	1	1	1
28	-1	-1	-1	-1	1
29	1	1	-1	1	-1
30	-1	1	-1	1	1
31	1	-1	1	-1	1
32	-1	1	1	-1	1

Table 3. 2006 FHB Field Trial Results at Wooster, Ohio: Fractional Factorial Analysis for Main Effects of Wild Type Antagonists OH 182.9, OH 221.3, UV Protectant Naphthol Yellow (NY), Folicur 3.6F, and SAR Chemical Na Salicylic acid (NaSA) on Susceptable Winter Wheat Cultivar Elkhart.

Treatment	% Disease Severity	% Incidence	DON (ppm)	Test Weight (lbs/bu)
+OH182.9	15.1	58.8	11.1	46.5
-OH182.9	15.1	63.6	13.4	46.1
Comparison P	0.86	0.28	0.04*	0.37
+OH221.3	13.5	56.6	12.9	46.5
-OH221.3	16.8	65.8	11.6	46.1
Comparison P	0.07*	0.05*	0.24	0.31
+NY	16.5	64.3	12.2	45.9
-NY	13.7	58.1	12.4	46.7
Comparison P	0.17	0.17	0.83	0.05
+Folicur 3.6F	10.7	51.8	11.9	47.2
-Folicur 3.6F	19.6	70.5	12.7	45.4
Comparison P	0.001*	0.001*	0.46	0.001*
+NaSA	16.1	62.3	13.3	46.0
-NaSA	14.1	60.1	11.2	46.6
Comparison P	0.39	0.62	0.05*	0.20
Overall Model P	0.09	0.07	0.12	0.02

Table 4. 2006 FHB Field Trial Results at Wooster, Ohio: Fractional Factorial Analysis for Main Effects of Wild Type Antagonists OH 182.9, OH 221.3, UV Protectant Naphthol Yellow (NY), Folicur 3.6F, and SAR Chemical Na Salicylic acid (NaSA) on Moderately Resistant Winter Wheat Cultivar Freedom.

Treatment	% Disease Severity	% Incidence	DON (ppm)	Test Weight (lbs/bu)
+OH182.9	2.5	26.7	6.9	51.4
-OH182.9	2.4	26.8	5.8	52.5
Comparison P	0.86	0.98	0.25	0.29
+OH221.3	2.6	28.3	7.0	50.9
-OH221.3	2.3	25.2	5.7	52.9
Comparison P	0.41	0.46	0.31	0.07
+NY	2.7	29.2	5.8	51.4
-NY	2.2	24.4	6.9	52.4
Comparison P	0.32	0.26	0.40	0.37
+Folicur 3.6F	2.1	23.3	6.5	52.6
-Folicur 3.6F	2.8	30.2	6.2	51.3
Comparison P	0.13	0.11	0.72	0.24
+NaSA	2.5	27.7	5.3	51.8
-NaSA	2.4	25.9	7.4	52.0
Comparison P	0.81	0.67	0.02*	0.86
Overall Model P	0.87	0.81	0.47	0.49

2006 RESULTS FROM THE STANDARDIZED EVALUATION OF BIOLOGICAL AGENTS FOR THE CONTROL OF FUSARIUM HEAD BLIGHT ON WHEAT AND BARLEY.

G.Y. Yuen[1*], C.C. Jochum[1], K.R. Ruden[2], L.E. Sweets[3], B.H. Bleakley[2,4] and M.A. Draper[2]

[1]Dept. of Plant Pathology, University of Nebraska, Lincoln, NE 68583; [2]Plant Science Dept., South Dakota State University, Brookings, SD 57007; [3]Dept. of Plant Microbiology and Pathology, University of Missouri, Columbia, MO 65211; and [4]Biology and Microbiology Dept., South Dakota State University, Brookings, SD 57007

[*]Corresponding Author: PH: (402)472-3125; E-mail: gyuen1@unl.edu

OBJECTIVE

To evaluate, using standardized methodology, a set of biological control agents applied alone and in combination with a fungicide for effectiveness in managing Fusarium head blight (FHB) in wheat and barley across a range of environmental conditions.

INTRODUCTION

Among the most extensively studied biological agents for control of FHB in the US are strains of *Bacillus* spp, TrigoCor 1448 (Stockwell et al., 2001) and 1BA (Draper et al., 2001), and *Lysobacter enzymogenes* strain C3 (Jochum et al., 2006). Each bacterial strain was effective in some field tests when evaluated separately (Stockwell et al., 2001; Jochum et al., 2006; Khan et al., 2004; Yuen and Jochum, 2004). They were directly compared for efficacy in 2004 and 2005 as part of the USWBSI-funded program for standardized evaluation of biological agents, and because combinations of biological control agents and fungicides were reported to be more effective in controlling FHB than the microorganisms or fungicides alone (DaLuz et al., 2003; Khan et al., 2004; Yuen and Jochum, 2004), standardized evaluations in 2005 also compared these bacterial strains in combination with the fungicide tebuconazole. In the two years testing, however, results were inconclusive as to the effectiveness of the treatments across a range of environmental conditions and crop genotypes (Yuen et al, 2004; Yuen et al., 2005). Experiments in 2006 were conducted, therefore, to evaluate the same agents and to retest the strategy of applying biological agents with a fungicide.

MATERIALS AND METHODS

Five trials were conducted across three states on barley and a range of wheat market classes (Table 1). In each trial, three bacterial biological agents (Table 2) were tested alone or in tank mix with the fungicide tebuconazole (Folicur 432SC, 4.0 fl oz/A). There also was a treatment with tebuconazole alone and a non-treated control. A broth culture of each organism was propagated by the originating laboratory and sent to the researcher in each location. The pre-application population of each agent in the inoculum was determined by the local researcher using dilution plating. All treatment liquids were amended with 0.125% Induce. One application was made per treatment at early flowering (Feekes 10.51) in 20 gal/acre using a CO_2-pressurized sprayer (approximately 40 psi) equipped with flat-fan nozzles oriented forward and backward. The size and number of replicate plots varied among trials. Some of the trials were inoculated with *Fusarium graminearum* and utilized mist irrigation systems to stimulate infection. In all trials, FHB incidence (% heads infected per plot), severity (% spikelets infected per diseased head), and index (% plot severity) were determined from at least 40 heads per plot around 3 weeks after anthesis. The incidence of Fusarium-damaged, kernels (FDK) were determined after harvest. Samples from each plot were sent to the North Dakota State University Veterinary Diagnostic Laboratory, Fargo, ND for analysis of DON content. Analysis of variance was performed on results from each

trial separately. Results from all trials were analyzed together using ProcMixed (SAS), with trials being treated as blocks.

RESULTS AND DISCUSSION

Dry weather conditions resulted in low FHB development in all trials despite misting being provided in some locations. Incidence was less than 10% in three of the trials while severity generally did not exceed 20% in all locations (Table 3A). Accordingly, index measurements and incidence of Fusarium diseased kernels were very low (Table 3B). None of the treatments with a biological agent alone, tebuconazole alone, or a biological agent-tebuconazole combination had a significant effect on any disease parameter compared to the control across the trials (Table 3A&B). The treatments were ineffective in the individual trials except that tebuconzole alone, *Bacillus* 1BA alone, and the combination reduced FDK incidence in the Missouri trial on 'Roane' and treatments involving TrigoCor 1448 reduced disease index on barley in South Dakota (Table 3B). Available DON measurements from Missouri and Nebraska plots indicated no treatment effects as all samples contained less than 0.5 ppm DON (data not shown).

Biocontrol agent numbers in the inoculum suspensions ranged from approximately 10^7 to more than $5X10^8$ colony forming units/ml. There was less variation in inoculum cell concentrations among agents and among locations than observed in previous years. Although the population threshold required for efficacy has not been established for any of these agents, lack of efficacy in the biological treatments in general does not appear to be related in low population numbers being applied in the trials. The primary complicating factor in these trials could have been environmental conditions not favoring sufficient disease development for good separation of treatments. This was evidenced by tebuconzole treatment also displaying little or no effects on disease levels across these trials. Determination of most efficacious biological agent and assessment of benefit of combining biological agents with fungicides will require further testing under higher disease pressure.

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Table 1. 2006 uniform biological control trial locations, crop cultivars, and researchers

State	Crop market class and cultivar	PI and Institution
MO	Soft red winter wheat 'Roane'	L. Sweets, University of Missouri
MO	Soft red winter wheat 'Truman'	L. Sweets, University of Missouri
NE	Hard red winter wheat '2137'	G. Yuen, University of Nebraska
SD	Hard red spring wheat 'Ingot'	M. Draper, South Dakota State University.
SD	Six-rowed barley 'Robust'	M. Draper, South Dakota State University.

Table 2. Biological control agents tested in 2004 uniform trials.

Organism	Supplier
Bacillus sp.1BA	Bruce Bleakley, South Dakota State University
Bacillus subtilis TrigoCor 1448	Gary Bergstrom, Cornell University
Lysobacter enzymogenes C3	Gary Yuen, University of Nebraska

Table 3A. 2006 results across five uniform biocontrol trials denoted by state and crop

Treatment	MO 'Roane'	MO 'Truman'	NE Wheat	SD Wheat	SD Barley	LS Mean
INCIDENCE (% heads infected)						
Control	5.3	9.0	28.8	7.0	64.5	22.9
Folicur	3.3	7.0	33.3	6.5	ND	23.3
1BA	6.8	10.0	27.5	6.0	66.0	23.3
1BA + Folicur	7.5	4.5	25.1	5.5	67.0	21.9
TrigoCor 1448	6.0	8.2	29.2	5.5	64.5	22.7
TrigoCor 1448 + Folicur	2.0	2.5	24.2	11.5	60.0	20.0
C3	5.2	5.5	22.1	5.5	68.5	21.4
C3 + Folicur	6.0	6.0	31.2	5.5	66.5	23.0
P	0.101	0.083	0.623	0.284	0.910	0.532
$LSD_{0.05}$	-	-	-	-	-	-
SEVERITY (% spikelets infected)						
Control	8.9	6.1	6.9	11.6	6.5	8.0
Folicur	10.6	14.2	11.4	36.2	ND	17.0
1BA	8.2	15.0	11.3	19.2	7.7	12.3
1BA + Folicur	18.8	8.0	7.7	26.4	5.9	13.4
TrigoCor 1448	10.0	10.5	10.5	21.0	5.9	11.6
TrigoCor 1448 + Folicur	5.5	6.0	10.1	11.6	4.9	7.6
C3	11.0	6.5	9.8	16.2	4.8	9.6
C3 + Folicur	19.0	6.8	12.9	7.6	5.0	10.2
P	0.189	0.070	0.429	0.162	0.044	0.120
$LSD_{0.05}$	-	-	-	-	1.6	-

ND=not determined.

Table 3B. 2006 results across five uniform biocontrol trials denoted by state and crop.

Treatment	MO 'Roane'	MO 'Truman'	NE Wheat	SD Wheat	SD Barley	LS Mean
INDEX (plot severity)						
Control	0.5	0.6	2.2	0.9	4.2	1.7
Folicur	0.4	1.2	4.2	1.6	ND	2.4
1BA	0.6	1.6	3.5	1.2	5.2	2.4
1BA + Folicur	1.3	0.3	2.3	1.4	4.1	1.9
TrigoCor 1448	0.6	1.0	2.9	1.0	3.9	1.9
TrigoCor 1448 + Folicur	0.1	0.2	2.5	1.3	3.0	1.4
C3	0.6	0.3	2.2	0.8	3.3	1.4
C3 + Folicur	1.2	0.4	4.6	0.5	3.3	2.0
P	0.021	0.152	0.390	0.445	0.229	0.0827
$LSD_{0.05}$	0.7	-	-	-	-	-
FDK (%)						
Control	0.6	0	1.6	1.2	ND	0.9
Folicur	0	0.2	0.8	1.5	ND	0.6
1BA	0	0.2	1.6	1.2	ND	0.8
1BA + Folicur	0	0.2	1.2	1	ND	0.6
TrigoCor 1448	0.9	0.2	1	1	ND	0.8
TrigoCor 1448 + Folicur	0.3	0.4	0.9	1	ND	0.7
C3	0.2	0.6	1.5	1.2	ND	0.9
C3 + Folicur	0.3	1.0	1.3	1.2	ND	1.0
P	0.047	0.342	0.999	0.895	-	0.558
$LSD_{0.05}$	0.6	-	-	-	-	-

ND=not determined.