EFFECT OF BACTERIAL GROWTH MEDIUM COMPOSITION ON ANTIFUNGAL ACTIVITY OF *BACILLUS SP.* STRAINS USED IN BIOLOGICAL CONTROL OF FUSARIUM HEAD BLIGHT

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ABSTRACT

Several microbial strains belonging to different taxa, isolated from various parts of the world, have been shown to have the ability to antagonize *Fusarium graminearum* to different extents under various conditions. Some of these microbial strains are being developed as biological control agents (BCAs) for control of FHB. Different BCAs have different mechanisms of antagonizing FHB, such an enzymes, antibiotics, parasitism, and/or competition for nutrients. We have studied four different *Bacillus sp.* strains that show promise for use as BCAs to control FHB. All these strains seem to belong to a phylogenetic group designated as the *Bacillus subtilis* group (group II). Among the many antibiotics that *B. subtilis* and its relatives are known to make are cyclic lipopeptides such as iturin. If one or more iturin-like antibiotics are needed for these bacterial strains to control FHB, it is important that a growth medium be used for culturing the BCAs that encourages production of such antibiotics. In previous studies, we have usually grown the four BCAs in potato-dextrose broth (PDB), which may not have been an optimal growth medium for production of iturin-like antibiotics. Other researchers working with *B. subtilis* have found that dextrose (glucose) is not an optimal carbon source for iturin production, and that the nitrogen source in the growth medium also has a large influence on the amount of iturin produced. All four of our BCAs grew well in a defined growth medium previously described in the literature that may stimulate antibiotic production of our BCAs more than does PDB. The defined medium contains mannitol as a carbon source, and glutamic acid as a nitrogen source, along with inorganic salts. We have conducted studies with both the broth and agar-solidified form of this medium, finding that the bacteria grow well in both. Plate assays were conducted to test the ability of the BCAs to antagonize *F. graminearum* on the agar-solidified form of this growth medium. Antagonism against the fungus was apparent, suggesting that antibiotic was being produced in the medium. Presence of iturin in the growth medium will be tested for chromatographically, and compared to amounts produced in PDB. In addition, greenhouse groundbed trials will compare the effect that BCA cells grown in the defined broth medium have upon wheat challenged with FHB, to the effect that BCA cells grown in PDB have upon wheat challenged with FHB. In uniform field trials to compare the ability of different microbial BCAs to control FHB, it should be recognized that different microbial BCAs can have different mechanisms of antagonism, and that different growth media may promote these mechanisms to varying degrees. Formulation and optimization of growth media for commercial production and application of BCAs to control FHB should also bear this in mind.

TAXONOMIC AFFILIATION OF BACTERIAL STRAINS USED IN THE BIOLOGICAL CONTROL OF FUSARIUM HEAD BLIGHT SUGGESTS POSSIBLE ROLE OF LIPOPEPTIDE ANTIBIOTIC IN FUNGAL ANTAGONISM

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ABSTRACT

For the last several years, our laboratory has been working with four endospore-forming bacterial strains (designated as 1B-A, 1B-C, 1B-E, and 1D-3) isolated from South Dakota wheat foliage and residue that can antagonize *Fusarium graminearum* in laboratory plate assays and in greenhouse and field plot trials. We have attempted to identify these bacterial strains by different techniques, with different identification methods resulting in different genus affiliations for the strains. In previous work, analysis of membrane fatty acid methyl esters (FAME analysis) indicated that strains 1B-A and 1D-3 were *Bacillus lentimorbus*, and that strains 1B-E and 1B-C were *Bacillus subtilis*. Sequence analysis showed that all four strains had identical sequences in the first 500 base pairs of their 16S rDNA genes, and all were most closely related to *Bacillus amyloliquefaciens* with less but significant relatedness to *Bacillus atrophaeus*. The strains differed in the total number and amount of antibiotic compounds produced, and their growth curves in potato dextrose broth also differed. In the work presented here, colonial morphology, microscopic appearance, and 20 different phenotypic traits were evaluated and used to arrive at suggested identities for the strains. Strains 1B-A and 1B-C had similar colonial morphology, with a shiny and wrinkled appearance, whereas colonies of strain 1B-E were shiny but not wrinkled, and colonies of strain 1D-3 were a dull color with bumps instead of wrinkles. All strains had oval endospores which did not cause swelling of the sporangium. Results of 20 different phenotypic tests suggested that all four strains were most closely related to *Bacillus firmus*. These attempts to identify the four strains strongly suggest that they are tied to a phylogenetically and phenetically coherent *B. subtilis* group (group II). However, the four strains may all belong to a previously uncharacterized taxon with relatedness to *B. amyloliquefaciens* and *B. atrophaeus*, taxa which were split out of the old *Bacillus subtilis* taxon. There is a good amount known about the antibiotics produced by members of the *B. subtilis* group (group II). Among the many antibiotics that are known to be produced by *B. subtilis* and its relatives are cyclic lipopeptides such as iturin. We are hypothesizing that one or more cyclic lipopeptides such as iturin are responsible for a significant amount of the biological control these bacterial strains exert against *F. graminearum*, and we are presently engaged in experiments to test this hypothesis.

JAU 6476 FOR THE CONTROL OF *FUSARIUM GRAMINEARUM* AND OTHER DISEASES IN CEREALS

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ABSTRACT

JAU 6476 (tested under the code AMS 21619) is a novel broad-spectrum fungicide belonging to the new chemical class of triazolinthione discovered and developed worldwide by Bayer CropScience. The common name for this molecule is prothioconazole. JAU 6476 is a systemic fungicide showing excellent efficacy against a broad range of diseases in different crops, including wheat, barley, peanuts, canola, etc. In cereal crops, JAU 6476 provides excellent activity against most major diseases, including Fusarium head blight (*Fusarium spp*.), leaf blotch diseases (*Septoria tritici, Leptosphaeria nodorum, Pyrenophora spp., Rhychosporium secalis*), rust (*Puccinia spp*.), powdery mildew (*Erysiphe graminis*) and eyespot (*Pseudocercosporella herptrichoides*). Trial results indicate that JAU 6476 is more effective than currently tested products for the reduction of deoxynivalenol (DON), a mycotoxin caused by *Fusarium graminearum.* JAU 6476 applications provide outstanding cereal disease control along with excellent crop safety to ensure high quality yields.

EFFECT OF FUNGICIDE TREATMENTS ON FUSARIUM HEAD BLIGHT AND LEAF DISEASE INCIDENCE IN WINTER WHEAT

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OBJECTIVES

The objectives of this study were to compare control of Fusarium head blight and leaf diseases of winter wheat with the application of different fungicides and combinations of fungicides.

INTRODUCTION

Winter wheat cultivars grown in western Canada are susceptible to most leaf diseases and Fusarium head blight (FHB). These diseases can cause losses in yield and quality, which affects producers and end-users of the grain. Winter wheat producers routinely apply a fungicide treatment for control of leaf diseases, but not for FHB control. Few fungicides are registered for FHB control. Those that are registered require different application times for control of FHB compared to leaf diseases. Timing of fungicide application for FHB control is critical due to the specific period of host susceptibility. Producers are interested in the efficacy of fungicides for FHB control, and have questioned whether delaying fungicide applications to control FHB would compromise their ability to control leaf diseases.

MATERIALS AND METHODS

Trials were conducted at one location in 1999 (Carman, Manitoba), and two locations (Carman and Winnipeg, Manitoba) in 2000, 2001 and 2002. In 1999 ten cultivars (only cultivar means will be reported) and eight treatments (Table 1) were evaluated in a split-plot, four replicate trial. Treatment was the main plot effect and cultivar was the sub plot effect. In 2000, 2001 and 2002 trials with the same treatments were conducted on a single winter wheat cultivar, “CDC Falcon”, at Carman and Winnipeg, MB.

Where appropriate fungicide treatments were based on label recommendations for FHB control. Tilt was applied at the boot stage for control of leaf diseases since there is no label recommendation for FHB control. Bravo and Folicur were applied according label instructions for FHB control. In the Bravo x 2 treatment the first application was made at the recommended time for FHB control and the second application was made two weeks later. All fungicide treatments preceded FHB inoculation by at least three days.

All plots except for the un-inoculated control were inoculated with a macroconidial suspension of *Fusarium graminearum* at anthesis and four days after the first inoculation. Mist irrigation was applied for 5 min./h for 12 h after each inoculation. Eighteen to twenty-one days after inoculation, 50 spikes/plot were collected from all plots for evaluation of FHB reaction. The number of infected spikes was determined. Of the infected spikes, the percentage of infected

spikelets was determined. From this the FHB index was calculated as (% infected spikes x % infected spikelets)/100.

Percent leaf area affected by leaf spot diseases and leaf rust was evaluated visually on the flag leaf on a per plot basis in 1999. In 2000-2002, leaf area affected by disease was determined by collecting 20 flag leaves and 20 penultimate leaves per plot and evaluating percent disease through digital imaging technology.

Plot yield was measured at maturity.

Table 1: Treatments and timing of treatment application to field trials conducted in 1999, 2000, 2001 and 2002. FHB inoculum was applied to all plots treated with fungicides.

Treatments and Time of Application
Un- inoculated control
FHB inoculated control - Anthesis + 4 days later
Tilt - Boot stage
Bravo - Heading
Folicur - Heading
Bravo x 2 - Heading + 2 weeks later
Tilt (Boot Stage) + Bravo - Heading
Tilt (Boot Stage) + Folicur - Heading

RESULTS AND DISCUSSION

1999

Disease levels were high in 1999. Cultivars differed in susceptibility to FHB, leaf rust and leaf spot (data not reported). The FHB index was higher than the un-inoculated check in all fungicide treated plots (Figure 1a). Treatment with either Bravo or Folicur reduced the FHB Index relative to the inoculated check. Plots treated only with Tilt did not differ in FHB Index compared to the inoculated check. Treatments which included Tilt provided the best control of leaf spot diseases (Figure 1b) and leaf rust (Figure 1c). All fungicides increased yield relative to the untreated checks (Figure 1d). The highest yields were obtained with plots treated with Tilt or combinations of Tilt+Bravo and Tilt+Folicur. Yield was highly negatively correlated with %leaf spot (-0.98) and %leaf rust (-0.90), but was not significantly correlated with FHB Index (0.20).

2000-01

Disease levels in trials conducted in 2000 and 2001 were low at both locations. Significant differences in yield and FHB Index were observed at Winnipeg in 2001, while significant differences in leaf spot were observed at both locations in 2000. Folicur and Bravo provided similar levels of FHB control. All fungicide treatments reduced leaf spot relative to the untreated control. Fungicide treatments did not provide a significant yield advantage compared to the untreated checks.

2002

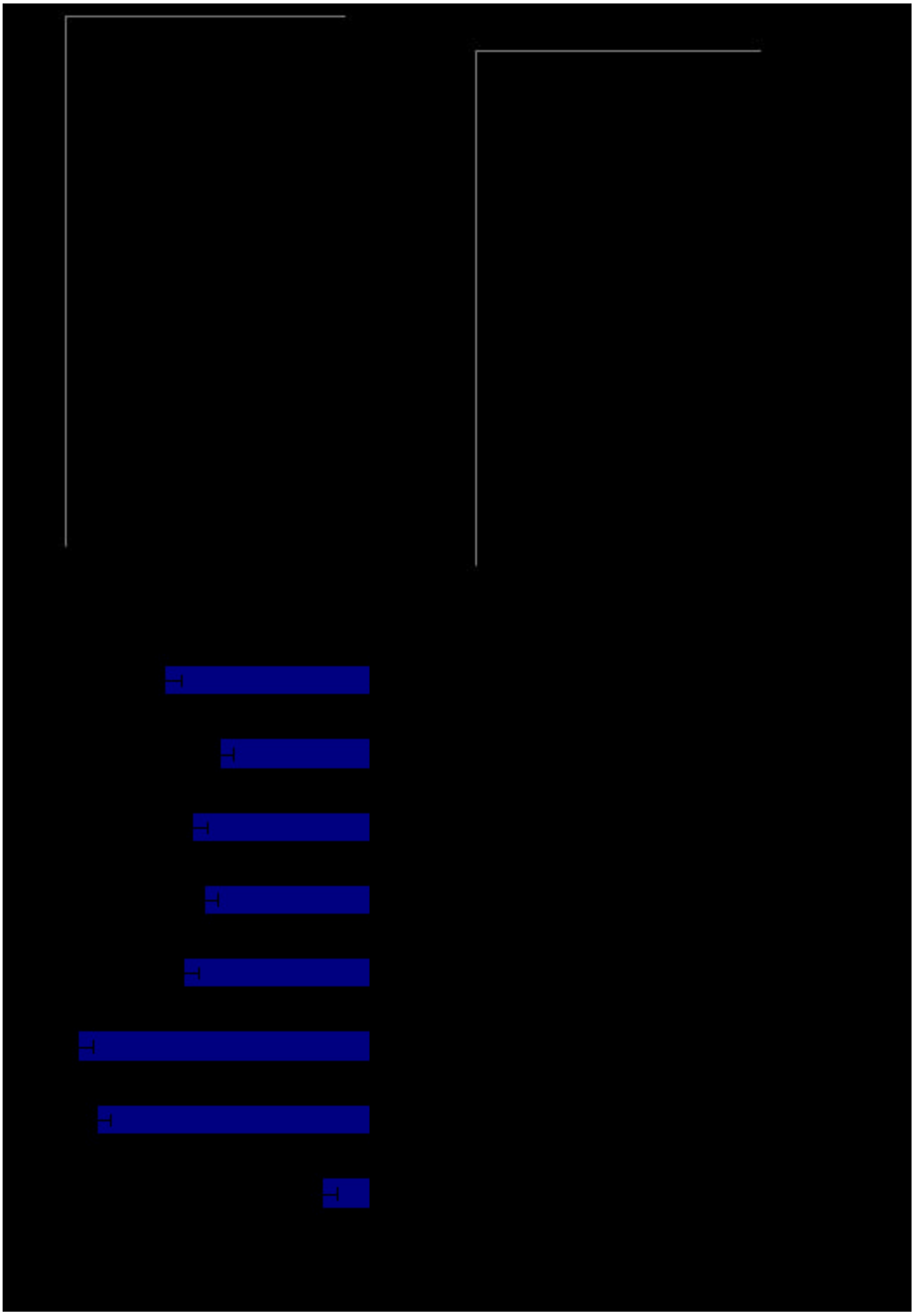
FHB levels were high at both locations in 2002. Leaf disease data has yet to be analysed. At Winnipeg all treatments had higher levels of FHB than the un-inoculated control (FHB Index =7). The FHB Index of the inoculated control was 41. Folicur (FHB Index = 29) and Bravo (FHB Index = 26.5) significantly reduced the FHB Index relative to the inoculated control and were not statistically different from each other. Other treatments were not significantly different from the inoculated control. In Carman, the FHB Index of the fungicide treatments did not differ significantly from the inoculated check (FHB Index = 26). There were no significant differences for yield.

The results from these trials show that even when plots are inoculated and mist irrigation is applied to increase humidity it is difficult to get consistently high levels of FHB on winter wheat in Manitoba. Lower June temperatures (data not shown) in 2000 and 2001 relative to 1999 appeared to be the main reason for lower disease incidence. Disease forecasts would be beneficial in this situation.

Under high disease pressure fungicide treatments with either Bravo or Folicur reduced FHB index. However, the FHB Index of these treatments was still high relative to the un-inoculated control. When either leaf rust or leaf spotting diseases were present, treatments with Tilt and to a lesser extent, Folicur reduced these diseases. Under low disease pressure, fungicide treatments provided little advantage. Overall, there was no association between yield and FHB Index. Leaf diseases appeared to be the main cause of yield differences observed.

CONCLUSIONS

Under high disease pressure fungicide treatments reduced both FHB and leaf diseases. Yield differences were primarily associated with differences in leaf disease control. Tilt provided the best control of leaf diseases. Folicur applied at heading provided some level of leaf disease control. Folicur and Bravo appear to provide similar levels of FHB control. Weather conditions during flowering of winter wheat are often not conducive the FHB development. Disease forecasts would be useful to determine whether fungicide application is necessary in winter wheat.



POPULATION DYNAMICS IN THE FIELD OF A BIOCONTROL AGENT FOR FUSARIUM HEAD BLIGHT OF WHEAT

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ABSTRACT

Gibberella zeae (anamorph *Fusarium graminearum*) is the major causal organism of Fusarium head blight (FHB) on wheat and barley. Wheat is generally most susceptible to infection at anthesis due to exposed anthers being an important site of infection. Application of a *Crytococcus* strain, OH 182.9, originally isolated from wheat anthers in Wooster, Ohio has reduced disease severity by 56% and increased the 100-kernel weight by as much as 100% in field trials. The goal of this research was to determine the ability of OH 182.9 to survive and possibly reproduce on the anthers in the field. Heads of the soft red winter wheat cultivar Freedom were marked to distinguish those that had extruded anthers and those that had no visible anthers. Cells of the yeast antagonist were produced and harvested after a 48-hour growth in a semi-defined liquid medium at 25ºC in 250 rpm and applied ($1x10^7$colony forming units (CFU)/ml) to thoroughly wet the wheat heads. Non-antagonist/buffer treated plants served as controls. Pathogen inoculum consisted of *F. graminearum* colonized corn kernels scattered throughout the plots 3 weeks prior to flowering. Plots were under mist irrigation twice daily throughout anthesis and early grain development growth stages. Anthers were collected for up to 10 days after applying yeast antagonists and CFU per 100 anthers in 0.5 ml buffer were determined. Initial OH 182.9 populations on anthers, at day 0, were $2.6x10^4$ CFU/ml. OH 182.9 population increased to $2.1x10^6$ CFU/ml (80 times) by 6 days after applying the cell suspension. The yeast population was $2.2 x10^6$ by 10 days after application. The population levels were significantly ($P \leq 0.05$) greater than those on the control plants on the heads with exposed anthers and heads with no visible anthers at 6,8,10 days and 8 days, respectively after inoculation. There was no significant difference in disease severity between OH182.9 treated and untreated plants. This one season test will be repeated in 2003 to further determine the population dynamics of OH182.9 on wheat floral structures.

VARIATIONS IN FUNGICIDE APPLICATION TECHNIQUES TO CONTROL FUSARIUM HEAD BLIGHT

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ABSTRACT

The frequency and severity of Fusarium head blight (FHB) on wheat have been on increase during the past decade in Uruguay. Given low level of resistance in the commercial cultivars, chemical control of the disease is widely adopted. The application of Folicur 430 SC (tebuconazol, 432 g/l) or Caramba (metconazol, 90 g/l) at the rate of 450 cc/ha and 1000 cc/ha, respectively, is recommended at the beginning of flowering. In order to increase the efficiency of fungicide application, variations in the spray nozzles and angles were tried.

The treatments, two fungicides (Folicur and Caramba), two types of spray nozzles (hollow cone spray tips, *ConeJet*, and twin even flat spray tips, *TwinJet*, mounted at 0º and 30º angle on the bar), and two application times (beginning of flowering, Zadoks 61 and mid flowering, Zadoks 65), were combined in a factorial design with complete blocks replicated four times. All treatments were applied with a CO_2 backpack type sprayer. Grain yield, test weight, thousand kernel weight, visual disease note on a 1-5/1-5 scale, incidence (percentage of diseased spikes) and percentage of scabby grains were evaluated (Table 1).

The results show that overall Caramba gave better control of the FHB than Folicur. In general, the early control of the disease at Z61 was superior to FHB control in Z65. The utilization of *TwinJet* improved the spike coverage significantly thereby, resulting in better visual score of infection. However, spike infection in the field and grain infection evaluated after harvest demonstrated these differences more clearly in the case of Folicur than Caramba. Although some advantage in using the *TwinJet* at an angle of 30º on the bar was observed, these results need further testing and confirmation. In spite of the fact that grain yield, test weight and thousand kernel weights were affected by moderate infection of foliar diseases, the utilization of Caramba early on and especially using *TwinJet* spray nozzles gave significantly higher grain yield compared to other treatments.

Table 1. Effect of chemical control treatments on FHB infection and grain yield.

Treatments				Fusarium infection (%)			Grain yield	TKW	Test weight
Application Time	Fungicide	Spray nozzle	Degree/ vertical	Visual score	spike	grain	kg/ha	g	kg/hl
Z-61	Caramba	Twin	0º	**22 e**	**37e**	**7**	**2415a**	**27.1ab**	**80.2a**
Z-61	Caramba	Cone	0º	25 de	39cde	7.8	**2474a**	**28.1a**	**79.6ab**
Z-61	Caramba	Twin	30º	**15 f**	38de	7.3	**2083ab**	26.8ab	**79.6ab**
Z-65	Caramba	Twin	0º	28 cd	**37e**	**6**	1599bc	24.9b	79.5ab
Z-65	Caramba	Cone	0º	28 cd	41cde	6.9	1863bc	25.7ab	78.5bc
Z-65	Caramba	Twin	30º	**15 f**	**36e**	**5.6**	2012ab	**27.1ab**	79.5ab
Z-61	Folicur	Twin	0º	25 de	55bc	8.8	1820bc	26.2ab	78.2bc
Z-61	Folicur	Cone	0º	35 b	53bcd	9.6	1759bc	24.4bc	77.6cd
Z-61	Folicur	Twin	30º	35 b	55bc	10.4	1767bc	24.8b	78.6abc
Z-65	Folicur	Twin	0º	35 b	49bcde	9.4	1644bc	24.3bc	77.0cd
Z-65	Folicur	Cone	0º	32 bc	64ab	6.8	1691bc	24.4bc	77.3cd
Z-65	Folicur	Twin	30º	35 b	52bcd	7.2	2045ab	26.4ab	78.6abc
Check without fungicide				52 a	78a	10	1415c	21.5c	76.4d

AERIAL SPRAY COVERAGE TRIALS IN SOUTH DAKOTA – 2002

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INTRODUCTION AND OBJECTIVES

In a state such as South Dakota, wheat fields are typically very large and with 2.5 M acres of wheat and another 400,000 acres of barley, the only practical means of applying fungicide is from the air. As such it is critical to identify methods whereby applicators and producers can optimize the application for efficacy and cost effectiveness. These trials were intended to take initial steps in accomplishing those goals.

MATERIALS AND METHODS

The trial was conducted on August 28, 2002 in collaboration with MJ Aviation, Inc. at Letcher, SD. Treatments, listed in Table 1 were a comparison of three different brands of nozzles with varying combinations of modifications. Each treatment was repeated three times. Airplanes were loaded with water and fluorescent rhodamine dye blended with a pink foam marker dye.

Table 1: Treatment list of nozzle and spray configurations for aerial coverage trial.

Trt #	GPA	Nozzle	Nozzle Spacing	Nozzle Modifications	Boom Ht.	Drop Used	Check Valve	Expected Swath	Spray pressure (PSI)	Airplane Speed
1	5	Lund	14”	None	16’, 19’, 22’	No	Brass TeeJet	60’	39#	130, 130, 130
2	5	CP	7”	Straight Stream	18’, 15’, 14’	No	TeeJet	60’	22#	128, 128, 124
3	5	CP	7”	15º Deflection	16’, 18’, 19’	No	TeeJet	60’	22#	129, 129, 129
4	5	CP	7”	30º Deflection	18’, 18’, 19’	No	TeeJet	60’	22#	125, 128, 128
5	5	Accu-Flow 0.028	7”	3/32 Restrictor	16’, 13’, 18’	No	TeeJet	35’	40#	127, 127, 122
6	5	Accu-Flow 0.028	14”	3/32 Restrictor	16’, 15’, 18’	No	TeeJet	35’	30#	128, 123, 126
7	5	Accu-Flow 0.028	7”	1/8 Black Restrictor	18’, 19’, 16’	No	Internal	35’	30#	128, 131, 131
8	5	Accu-Flow 0.028	7”	3/32 Restrictor	12’, 14’, 14’	6”	TeeJet	35’	30#	126, 125, 125
9	5	Accu-Flow 0.028	7”	3/32 Restrictor	22’, 24’, 23’	6”	TeeJet	35’	30#	125, 125, 125

Measurements were taken of spray pattern deposition on a string line and measurement of drift on a string line suspended from an 18 m high drift tower positioned at 46 m from the center of the spray swath, perpendicular to the prevailing wind. Measurements were also taken for droplet patterns on water sensitive and chrome coat papers. The rhodamine dye was used for measurements on the string line tests and the pink foam marker dye was used for droplet deposition on the chrome coat paper.

Treatment one was applied with an Air Tractor AT-402B Turbo with nozzles spaces every 14 in. and treatments two through nine were applied with an Air Tractor AT-401B radial engine with nozzles spaces every 7 or 14 in. across the boom.

String line patter and drift tower data were read and analyzed by String Analysis/Graphics (WRK) and water sensitive and chromecoat paper data was analyzed by Dropletscan (WRK and DSI). Additional analysis was complied in Excel (Microsoft).

RESULTS AND DISCUSSION

This trial was initially planned for May, but excessive winds through the month prevented completion of the trial at that time. During the period of the August trial, the wind speed ranged from two to nine mph and no deposition was measured on the drift tower string line.

One of the most serious problems encountered with aerial application has been incomplete coverage of the head. One side of the head may receive reasonable coverage while the opposite side may receive no product. In an earlier trial (Draper, unpublished) CP nozzles were compared with hollow cones at five or ten gallons of water delivered. In that trial, CP nozzles gave poor performance for droplet uniformity and head coverage, but increasing the gallons delivered helped offset the coverage deficiency. Nonetheless, CP nozzles are preferred by aerial applicators in South Dakota because they work well for herbicide applications. If we are to improve fungicide application by air, we must identify a preferred configuration for optimized coverage. CP nozzles were retained in this study because of their common usage, Lund nozzles were in place on one of the cooperators airplanes, and the Accu-Flow nozzles (Bishop Equipment, Inc.) were tested because of their use in orchards and that they are noted for good patterns with little drift.

No nozzles tested in this trial overcame the problem of poor deposition on the back of the head.

All Accu-Flow nozzle configurations deposited a slightly narrower swath with less off target movement than the CP or Lund nozzles.

All Accu-Flow nozzle configurations deposited a more uniform droplet pattern than the Lund or CP nozzle configurations.

Additional treatments will be competed in the coming year, looking at different orifice size and other nozzles designed to produce small droplet size with minimal drift.

UNIFORM TRIALS FOR BIOLOGICAL CONTROL AGENT PERFORMANCE IN THE SUPPRESSION OF FUSARIUM HEAD BLIGHT IN SOUTH DAKOTA – 2002

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INTRODUCTION AND OBJECTIVES

Biological control agents (BCAs) have several advantages in the suppression of Fusarium head blight (FHB or scab). When organic crops are grown, fungicide options are not available and crops such as barley are susceptible over a long period of time following head emergence and before maturity. As such, biological control has a good fit for FHB management under those conditions.

The objectives to this study were to evaluate the efficacy of various BCAs relative to the standard fungicide comparisons for the suppression of Fusarium head blight on wheat and barley.

MATERIALS AND METHODS

'Robust' barley was planted in a randomized complete block design with six replications and 'Oxen' and 'Ingot' hard red spring wheat were planted in a factorial randomized complete block design with six replications, both at Brookings, SD. Barley was protected with isolates of *Bacillus subtilus*-type isolates SDSU-1BA and SDSU-1BC, *Cryptococcus nodaensis* OH 182.9, *Bacillus*-type isolate TrigoCor 1448, *Lysobacter* sp. strain 'C3', *Bacillus*-type isolate TrigoCor 2, and *Bacillus*-type isolates BHWJ 4-1 and BHWJ 4-2B. The BCAs were compared to a standard chemical treatment of Folicur (4 fl/oz/A) with Induce non-ionic surfactant (0.125%). Spring wheat was protected with Folicur + NIS, *Cryptococcus nodaensis* OH 182.9, *Bacillus*-type isolate TrigoCor 1448, isolates of *Bacillus subtilus*-type isolates SDSU-1BA and SDSU-1BC, *Lysobacter* sp. strain 'C3', *Bacillus*-type isolate TrigoCor 2, and *Bacillus*-type isolates BHWJ 4-1 and BHWJ 4-2B

At the time that the heads were completely emerged from the boot, a misting cycle was started for 5 minutes out of every 20minutes, 24 hours a day. The mist system was turned off and the BCAs were applied to the heads and allowed to dry before the misting was turned on again. Two days following inoculation with the BCAs, the crop was challenge inoculated with 10^4 macroconidia/ml of *Fusarium graminearum* 'Fg4'. The barley plots were misted for seven days total and the spring wheat plots were misted for three days following anthesis.

RESULTS AND DISCUSSION

During the inoculation period, the environment was very hot and dry. And it was difficult to retain free moisture between misting periods. Very little FHB developed in the either the wheat or barley plots and no significant differences were detected among the barley treatments for FHB incidence, FHB severity, FHB index (incidence x severity), yield, test weight, protein, or deoxynivalenol (DON) levels in the harvested grain, even among the challenge inoculated plots. Only Folicur + NIS resulted in a reduction of any disease component on spring wheat, although there was no significant FHB that developed on the spring wheat either. While Folicur reduced overall leaf disease and leaf rust significantly, no biological controls had a significantly measurable effect on any leaf disease.

UNIFORM FUNGICIDE PERFORMANCE TRIALS IN SOUTH DAKOTA – 2002

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INTRODUCTION AND OBJECTIVES

Fusarium head blight (FHB – scab) has been a serious concern for wheat producers in South Dakota for the past several years. FHB and low market prices are the two reasons most often cited by producers as they decrease the number of acres they plan to plant to wheat. Fungicide alternatives for disease control are available to local producers on special year-to-year labels.

The objectives to this study were to evaluate the efficacy of various fungicides, fungicide combinations, or biological controls for the suppression of Fusarium head blight and other wheat diseases.

MATERIALS AND METHODS

Three South Dakota locations were planted to hard red spring wheat and two locations were planted to hard red winter wheat for inclusion in the Uniform Fungicide Trial for the suppression of FHB.

Two hard red spring wheat cultivars, Oxen and Ingot, were planted at three South Dakota locations (Brookings, Groton, and South Shore/Watertown). Two hard red winter wheat cultivars, Wesley and Arapahoe, were planted at Selby and South Shore/Watertown. Trials were planted in a factorial randomized complete block design. There were six replications of spring wheat and four replications of winter wheat. At anthesis, the trial treatments were applied. The following day, the crop was challenge inoculated with 10^4 macroconidia/ml of *Fusarium graminearum* 'Fg4'. The plots were misted for three days total.

Sixteen days following treatment, plots were evaluated for leaf diseases, FHB incidence, FHB head severity, and FHB field severity, *Fusarium* damaged kernels (FDK), deoxynivelanol (DON), grain yield, test weight, and protein.

RESULTS AND DISCUSSION

The weather in 2002 was very hot and dry in South Dakota. Grain yields were about half of normal in much of the state and yields were progressively lower the farther west the fields were located. In the spring wheat trials at Groton and South Shore/Watertown, very little disease developed and there were no significant differences among treatments. Similar results oc-

curred in the winter wheat trial locations. With the supplemental mist irrigation, while no significant FHB developed, leaf diseases were enhanced and some treatments did significantly improve results over the untreated control.

No significant differences were detected for FHB incidence, FHB head severity, FHB field severity, *Fusarium* damaged kernels (FDK), deoxynivelanol (DON), grain yield, test weigh, and protein. No significant disease response resulted from challenge inoculation with *Fusarium* conidia. However, in greenhouse trials the strain used has been shown to be highly virulent. Presumably, extremely high temperatures and dry conditions minimized the conditions for infection. FHB rating was done at five days earlier than normal due to the dry conditions leading to a rapidly maturing crop.

The presence of a fungicide in the treatment generally resulted in a significant reduction in leaf disease from the untreated (Table 1). Folicur, BAS 505, and AMS 21619 all resulted in a reduction in leaf disease. However, BAS 505 and AMS 21619 did not reduce leaf rust in the trial. The biological control treatments in the trial did not result in reduced disease unless they were co-applied with Folicur or AMS 21619.

Table 1. Disease categories with a significant response to treatments at Brookings[1].

Treatment	Whole Plot Leaf Disease Rating[2]	Leaf Disease (% leaf area)	Leaf Rust (% leaf area)
Untreated	6.25	65.33	9.18
Folicur + NIS	5.08	36.30	1.12
AMS 21619 + NIS	5.25	34.08	6.63
BAS 505 + NIS	5.50	38.92	9.37
OH 182.9	6.33	62.00	11.77
TrigoCor 1448	6.42	55.08	7.97
TrigoCor + Folicur + NIS	5.08	27.03	0.87
AMS 21619 + Folicur + NIS	5.08	28.02	1.25
LSD (P=0.05)	0.57	14.01	3.86

[1]Other measurements of disease and yield were not significant.
[2]Green leaf evaluation based on a scale of 0-9 where 0 is disease free and 9 is completely necrotic.

FUSARIUM HEAD BLIGHT: EPIDEMICS AND CONTROL

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OBJECTIVES

i) To document the effect of two biocontrol agents (TrigoCor 1448, and OH182.9) and three fungicides (Folicur, AMS21619, and BAS 505) on disease development, ii) To evaluate the effect of these materials for managing Fusarium head blight, and iii) To determine the relationships between the disease, DON and yield.

INTRODUCTION

Fusarium head blight (FHB) or scab, caused by *Fusarium graminearum* Schwabe (teleomorph *Gibberella zeae*) is a major disease in many wheat and barley production regions of North America, including Ohio, and throughout the world (Bai and Shaner 1994; Parry *et al*.1995; McMullen *et al*. 1997). This disease has been difficult to control. Although recent advances in host resistance are beginning to improve disease management in some wheat production regions, many wheat and barley producers have few management options. Commonly used methods of disease management including tillage and crop rotations, have not been effective in eliminating wide spread disease epidemics (McMullen *et al*. 1997). Controlling Fusarium head blight will require multiple disease management strategies, coupled with greater understanding of the epidemiology of the disease (Bai and Shaner, 1994; Parry, *et al*., 1995; Shaner and Buechley, 2000).

Effective fungicides could provide growers with management options when susceptible cultivars are grown, and may help protect yield and grain quality of cultivars with partial resistance under conditions favorable for disease. Although a few fungicides have shown some efficacy against scab, their results have been inconsistent over locations and years (Parry, *et al*., 1995; McMullen *et al*. 1997; Shaner and Buechley, 1999; Gilbert and Tekauz, 2000). Treatment with some fungicides reduced DON contamination of grain, but others caused an increase in DON levels (Shaner and Buechley, 1997, 1999 and 2000; Gilbert and Tekauz, 2000).

MATERIALS AND METHODS

Seeds of wheat cultivar Elkhart treated with Raxi-Thiram, were planted using 24 seeds/ft of row on 11 Oct., and 27 Sep., 2000 and 2001, respectively, in Ravenna silt loam soil at the Ohio Agricultural Research and Development Center, Wooster. For each treatment, there were three replicate plots. Each plot was 15-ft long, and consisted of 7-rows with 7 in. between rows. Plots were inoculated by broadcasting colonized corn kernels (0.12 oz/sq ft) over the plot surface on 14 May in 2001, and 30 Apr. in 2002. Plots were misted each day from one week prior to flowering to two week after flowering. Biological agents and fungicides were applied as sprays in 26.2 gal. water/A with a CO- pressurized back pack sprayer at flowering growth stage (GS) 10.5.1. Disease assessments were made twice a week (June 11 - June 26) in 2001 and three times a week (June 07 - June 21) in 2002 for both incidence and severity in one ft. of row at 15 locations in each plot. Plots were harvested on 17 of July in 2001 and on 11 July in 2002. Yield (bu/A) was determined from harvested grain adjusted to 13.5% moisture, and grain was analyzed for DON content.

RESULTS AND CONCLUSIONS

Disease development varied greatly among the different fungicides and biological control treatments tested in the two years. Based on the coefficient of determination (R^2), evaluation of the residual plots, standard error of estimates (SE) and mean square errors (MSE), the Gompertz model was appropriate for describing the disease incidence and severity data sets (R^2 ranged from 82 to 96%). The various treatments had a significant effect on disease development. Rates of disease increase for the various treatments and the control ranged from 0.138 to 0.229 and from 0.054 to 0.129 per day based on disease incidence, and from 0.093 to 0.172 and from 0.066 to 0.125 per day for disease severity in 2001 and 2002, respectively (Table 1). Area under the disease progress curve based on disease incidence (AUDPCI) ranged from 418.0 to 804.2 in 2001, and from 605.2 to 911.8 in 2002; when based on disease severity (AUDPCS) ranged from 125.1 to 315.7 in 2001, and from 176.6 to 383.3 in 2002 (Table 1). Maximum disease incidence (*Ymax*) for the various treatments ranged from 55.0 to 89.6%; from 55.1 to 82.5% and Maximum disease severity ranged from 23.9 to 57.9%; from 27.9 to 54.0% in 2001 and 2002, respectively (Table 2).

Plots treated with AMS21619 or BAS 505 had significantly lower rates of disease increase, low maximum disease, AUDPCI , and AUDPCS values than the untreated control in both 2001 and 2002 (Tables 1and 2). Additionally, plots treated with Folicur had significantly lower rates of disease progress, low maximum disease, AUDPCI, and AUDPCS values than the untreated control plots in 2002.

Plots treated with AMS21619, and BAS 505 had significantly higher yield in both years, higher test weight, and lower DON levels than grain from the untreated control plots in 2001 only. However, plots treated with Folicur had significantly higher yield in 2002. Although the biocontrol agent OH182.9 did not have a significant effect on reducing disease development, grain harvested from plots treated with this biocontrol agent had significantly lower DON than grain from the untreated control plots in 2001. No differences were found among treatments in DON levels, damage kernels, or test weight in 2002.

There were positive correlations between DON and final disease severity, AUDPCI, AUDPCS. On the other hand, there were negative correlations between yield and maximum disease severity, AUDPCI, and AUDPCS.

In conclusion, the treatments exhibited different effects on Fusarium head blight development and control. Treatments AMS21619 and BAS 505 had low maximum disease, low epidemic rates, and small AUDPCI and AUDPCS values that were significantly different from the control. On the other hand, treatments TrigoCor 1448 and OH182.9 had high maximum disease, fast epidemic rates, and large AUDPCI and AUDPCS values that were not significantly different from untreated control. These results indicate the AMS21619 and BAS 505 fungicides have greater potential for management of Fusarium head blight than the other treatments tested.

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Table 1. Fit of models, epidemic rates, and area under disease progress curve of Fusarium head blight incidence (AUDPCI) and severity (AUDPCS) for fungicides and biocontrol agents tested in Ohio, in 2001 and 2002.

Year	Treatment & rate/A	Incidence			Severity		
		Model Fits	Rate	AUDPCI	Model Fits	Rate	AUDPCS
2001	Control	Gompertz	0.212	759.3	Gompertz	0.159	291.9
	Folicur 3.6 EC 4.0 fl oz Induce (0.125%, v/v)	Gompertz	0.194	634.1	Gompertz	0.141	235.9
	AMS21619 480SC 5.7 fl oz Induce (0.125%,v/v)	Gompertz	0.138*	418.0*	Gompertz	0.093*	125.1*
	BAS 505 50G 6.2 oz	Gompertz	0.143*	469.2*	Gompertz	0.117*	159.4*
	TrigoCor 1448	Gompertz	0.231	798.4	Gompertz	0.169	315.7
	OH182.9	Gompertz	0.229	804.2	Gompertz	0.172	307.5
2002	Control	Gompertz	0.114	911.8	Gompertz	0.125	383.3
	Folicur 3.6 EC 4.0 fl oz Induce (0.125%, v/v)	Gompertz	0.068*	655.4*	Gompertz	0.092*	214.7*
	AMS21619 480SC 5.7 fl oz Induce (0.125%,v/v)	Gompertz	0.054*	605.2*	Gompertz	0.066*	176.6*
	BAS 505 50G 6.2 oz	Gompertz	0.068*	668.6*	Gompertz	0.087*	235.0*
	TrigoCor 1448	Gompertz	0.129	819.2	Gompertz	0.124	330.0
	OH182.9	Gompertz	0.102	912.7	Gompertz	0.119	374.2

* Indicates means significantly different ($P \# 0.05$) from untreated control based on Fisher's LSD.

Table 2. Maximum disease (*Ymax*) of Fusarium head blight, yield, and DON content of grain for fungicides and biocontrol agents tested in Ohio in 2001and 2002.

Year	Treatment & Rate/A	*Y max*		Damage Kernels	Yield	DON	Test Weight
		Incidence (%)	Severity (%)	(%)	(bu/A)	(ppm)	
2001	Control	82.5	50.9	61.7	62.3	16.6	56.1
	Folicur 3.6 EC 4.0 fl oz Induce (0.125%, v/v)	75.8	41.5	33.3	66.6	12.0	57.7
	AMS21619 480SC 5.7 fl oz Induce (0.125%,v/v)	55.0*	23.9*	4.3	74.0*	7.2*	59.5
	BAS 505 50G 6.2 oz	60.1*	28.6*	6.7	77.1*	8.4*	60.0
	TrigoCor 1448	89.6	57.9	51.7	56.0	24.0*	54.7
	OH182.9	87.5	51.8	56.7	62.0	13.4	56.7
2002	Control	81.9	54.0	28.8	43.7	23.0	53.2
	Folicur 3.6 EC 4.0 fl oz Induce (0.125%, v/v)	60.7*	33.5*	23.3	50.3*	13.5	56.0
	AMS21619 480SC 5.7 fl oz Induce (0.125%,v/v)	55.1*	27.9*	16.8	52.9*	13.5	55.8
	BAS 505 50G 3.1 oz	62.0*	30.6*	28.3	51.2*	15.5	53.1
	TrigoCor 1448	82.5	49.7	51.3	48.9	26.0	49.5
	OH182.9	81.3	52.3	33.8	43.7	24.0	53.0

* Indicates means significantly different ($P \# 0.05$) from untreated control based on Fisher's LSD.

EFFECT OF THREE *BACILLUS SP.* FROM WHEAT ON FHB REDUCTION

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INTRODUCTION

Fusarium head blight (FHB) of wheat caused by *Fusarium graminearum* Schwabe [Teleomorph = *Gibberella zeae* (Schwein.) Petch] is becoming one of the most devastating crop diseases in Canada (Gilbert and Tekauz, 2000). Many reasons contribute to this and the most important one is the rotations (Dill-Macky and Jones, 2000). In addition, no-till and minimum till practices also contribute to persistence of the pathogen, and disease spread (Fernando, 1999). In 2000, FHB damaged 8.5 percent of the total wheat crop in Manitoba and caused yield losses of about $40 million in total (Tekauz, 2001). At present, available and affordable traditional disease control options, such as resistant varieties, cultural practices (crop rotations, tillage to destroy residues) and foliar fungicides, are only partially effective (McMullen *et al*., 1997). Biological control is an environment-friendly alternative strategy in FHB management and shows considerable promise for reducing FHB (Khan *et al*. 2001). In a bio-ecological view, the understanding of the interactions between FHB and wheat phyllosphere microbes can be a requisite to finding effective antagonist(s) to the pathogen.

The objectives of this study are (a) to screen microbes from various plant parts of wheat and test their ability to inhibit the growth of the pathogen *in vitro*; (b) to investigate the interaction between bacterial isolates and the FHB pathogen in plant assays in the greenhouse.

MATERIALS AND METHODS

Microbes originated from the rhizosphere, leaves, leaf sheaths and heads of field wheat. The bacteria were isolated by serial dilution and single colonies were purified. Bacteria were identified using the MicroLog system (Biolog™ Inc., Hayward CA94545, USA). The ability of isolates to inhibit radial mycelial growth of *Fusarium graminearum* was assayed on PDA and NA plates and percent mycelial inhibition was calculated. Based on *in vitro* test results, three *Bacillus* strains were selected for greenhouse work. In greenhouse (25°C, 14 hrs photoperiod/day), potential FHB antagonistic bacterial strains were individually applied onto the seeds and heads of highly susceptible cultivar AC-Teal in order to investigate the microbial interaction between antagonists and the pathogen *in vivo*. For seed-coating treatment, germinated seeds were immersed into bacterial suspension (4.5×10^8 cfu/ml) for 30 minutes before seeding. When wheat was at 50% flowering, 5 µl of each bacterial suspension was applied onto heads by injecting directly onto the floret. The pathogen macroconidia (5×10^5/ml) was inoculated into the same spot either before or after bacterial inoculation. Head inoculation was undertaken as follows: one floret in the middle spike of head was injected with 2 µl of *Fusarium* macroconidia suspension (5×10^5 macroconidia/ml and 0.04% Tween 80). After inoculation, wheat plants were incubated in a mist chamber for 72 hours at 22°C and transferred to a greenhouse bench. There were six treatments (10 pots/replicate and 5 plants in each pot): (1) seed coating

with bacteria and bacterial application on head 4 hrs prior to *Fusarium* inoculation (BST-BBI); (2) seed coating with bacteria and bacterial application on head 4 hrs post *Fusarium* inoculation (BST-BAI); (3) seed coating with bacteria and no bacterial application on head (BST) prior to *Fusarium* application; (4) bacterial application on head 4 hrs prior to fusarium inoculation on head and no seed coating of bacteria (BBI); (5) bacterial application on head 4 hrs post *Fusarium* inoculation and no seed coating of bacteria (BAI) and (6) no seed coating of bacteria and no bacterial application on head prior to *Fusarium* application (CK). The FHB incidence (the number of heads infected) and severity (the number of diseased spikes on each head) were estimated at 16 days after inoculation.

RESULTS AND DISCUSSION

Sixty-one bacterial and five fungal strains were isolated from various parts of the wheat plant. Forty-nine percent were from rhizosphere, thirty-seven percent from leaves, nine percent from leaf sheaths and five percent from heads. Only 7% of bacterial isolates inhibited the growth of *F. graminearum*. Only one phyllosphere fungus, strain L-07-12, inhibited the growth of the pathogen up to 74%. The inhibitory ability (*in vitro*) of three bacterial isolates, *Bacillus subtilis* strain H-08-02 from the head, *B. cereus* strain L-07-01 from the leaf and *B. mycoides* strain S-07-01 from the rhizosphere was 60%, 52% and 55%, respectively.

Microbial interactions *in vivo* (Table 1) showed that seed coating plus application of bacteria on head prior to fusarium inoculation (treatment #1) gave the best disease reduction results for all three bacteria, of which strain H-08-02 performed the best (49.1%). The treatments with *B. subtilis* strain H-08-02 significantly reduced disease severity (treatments 1-5). This means that it will be beneficial if we select the antagonists from wheat heads because the pathogen and beneficial microorganisms may have co-evolved on heads or the bacterium is capable of using the head as a niche. This is consistent with other studies on bacterial population dynamics. In addition; data suggests bacterial application should be done prior to fungal spore landing and subsequent infection for effective control of the FHB fungus on heads.

Why do we think biocontrol will work? The wheat plant is most susceptible at anthesis. As the window of infection that will lead to economic loss is quite narrow, an application of a biocontrol agent onto heads at or just prior to anthesis should work well. Our results suggests, the antagonist should be applied on heads (infection court) to abort, curtail or delay germination of spores (mainly ascospores), to achieve control. Though the window of infection in the barley plant is supposedly a little longer, if optimum conditions and timing of application are perfected, biocontrol should work. Therefore, our target is to develop a foliar bio-fungicide that will be effective as a chemical fungicide application in reducing the FHB incidence and severity on heads, and in turn reduce DON levels. A biological pesticide capable of reducing initial infection and disease progress should reduce the present economic impact caused by FHB.

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Table 1. Effect of three Bacillus strains on FHB infection in vivo

	***B. mycoides* (S-07-01)**		***B. cereus* (L-07-01)**		***B. subtilis* (H-08-02)**	
	severity(%)	RB (%)*	severity(%)	RB (%)*	severity(%)	**RB (%)***
1	49.3 ^{c}	48.1 ^{a}	33.3 ^{b}	48.1 ^{a}	45.4 ^{c}	**49.1** ^{a}
2	90.1 ^{ab}	5.9 ^{bc}	40.6 ^{ab}	36.7 ^{ab}	58.9 ^{bc}	**34.0** ^{abc}
3	92.8 ^{a}	3.0 ^{c}	50.2 ^{ab}	21.8 ^{ab}	72.0 ^{b}	**19.3** ^{c}
4	63.0 ^{bc}	34.2 ^{ab}	35.5 ^{ab}	44.7 ^{ab}	55.6 ^{c}	**37.7** ^{ab}
5	83.6 ^{ab}	12.6 ^{bc}	59.9 ^{ab}	6.7 ^{ab}	64.3 ^{bc}	**27.9** ^{bc}
6	**95.7** ^{a}	**0.0** ^{c}	**64.2** ^{a}	**0.0** ^{b}	**89.2** ^{a}	**0.0** ^{d}

Note: * RB = relative control
1 — BST-BBI; 2 — BST-BAI; 3 — BST; 4 — BBI; 5 — BAI; 6 — CK.
The data with the same letter within a column are not significantly different based on Fisher's LSD test.

AN EXTENSION AGRONOMIST'S EXPERIENCES WITH FUNGICIDE APPLICATION TECHNIQUES TO IMPROVE CONTROL OF FHB

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ABSTRACT

Fusarium head blight has over the years caused billions of dollars in damage to small grain crops in the U.S. and Canada. Small grain acreage in Northeast North Dakota has declined 38% since 1992 including a 70% decline in durum and barley acres. Genetic resistance is a few years away and cultural control methods of rotation, residue management and choosing tolerant varieties have not prevented disease occurrence. Fungicide use has been shown to significantly reduce *Fusarium* infection when weather conditions are favorable to disease development. Fungicides have shown effectiveness in lab and greenhouse and field situations but *Fusarium* control is often inconsistent and disappointing for growers. Much research has been done since 1993 to improve the effectiveness of fungicides. New fungicides have been labeled for heading application and application techniques have been examined in detail. Application parameters studied have included the following variables for ground application of fungicides.

A. Application timing including split application
B. Spray application angle
C. Spray pressure: 30 psi to 90 psi in 10 psi increments.
D. Spray nozzles: Various nozzles studied. Generally smaller orifice nozzles have better coverage than nozzles providing coarse sprays.
E. Gallons of water per acre (gpa); 9 to 54 gpa.
F. Effects of dew
H. Adjuvants

Techniques learned from these studies and the labeling of more effective fungicides has led to recommendations that have improved fungicide effectiveness for growers. Fungicide use has increased as growers have experienced profitable results from fungicide application in hard red spring wheat. Fungicide effectiveness has been marginal in durum and barley. Achieving an economic reduction in Deoxynivalenol (DON) content with fungicides is a continuing problem as reductions in DON are generally small.

BARLEY CULTIVAR RESPONSE TO FUNGICIDE APPLICATION FOR THE CONTROL OF FUSARIUM HEAD BLIGHT AND LEAF DISEASE

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OBJECTIVES

To determine if efficacy of fungicides Headline and AMS21619 for the control of Fusarium head blight (FHB) and leaf disease is different among barley cultivars.

INTRODUCTION

Barley producers in traditional barley producing areas have been frustrated by the inconsistent performance of fungicides applied to barley. As a result barley acreage has shifted to different regions of the state where diseases have not been as prevalent. However, diseases are developing in these regions and disease levels increasing when environmental conditions are appropriate.

Barley is particularly difficult to research because obtaining adequate disease levels for effective fungicide evaluation has been inconsistent. The extended period of heading among barley main stem and tillers, lack of yield loss due to FHB, and an inability to distinguish losses between leaf diseases and FHB, and near zero tolerance for the presence of the toxin deoxynivalenol (DON) by the malting industry complicate prioritization of research goals.

Fungicides are often evaluated on a specifically selected cultivar. Often the first priority of the cultivar selection is susceptibility to diseases. Little data is available to show that fungicide performance on a particular cultivar will be similar on all cultivars.

MATERIALS AND METHODS

Five cultivars, Conlon, Drummond, Lacey, Legacy, and Robust were selected for evaluation in a field at the Langdon Research Extension Center in spring 2002. Seven rows spaced 6-inches apart were planted with a double-disk Hege drill in plots 16 ft. long in a RCB design arranged as a factorial with four replicates. Border plots of Robust barley were planted between treatment plots to minimize drift potential to adjacent plots. Nutrients were added to attain a yield goal of 120 bu./acre and recommended production practices were followed. Three weeks prior to heading a *Fusarium* spawn grown on spring wheat was hand broadcast at a rate of approximately 200 grams/plot.

Fungicides and fungicide combination treatments included:

1. AMS 21619 5.7 oz/acre (triazole) and Induce 0.125 % v/v (adjuvant).

2. Quadris (azoxystrobin) 12.3 oz/acre + AMS21619 5.7 oz/acre and Induce 0.125 % v/v.

3. AMS 21619 5.7 oz/acre and Induce 0.125 % v/v + AMS 21619 5.7 oz/acre and Induce 0.125 % v/v.

4. Untreated check.

5. Caramba (metconazole) 13.5 oz./acre and Induce 0.125% v/v.

6. Caramba 13.5 oz./acre and Induce 0.125% v/v + AMS 21619 5.7 oz/acre and Induce 0.125 % v/v.

7. Quadris 12.3 oz/acre.

Treatments were applied by CO_2 backpack sprayer at 18 gpa with hydraulic nozzles XR8002 oriented downward from horizontal at Zadoks growth stage 40 and XR8001 nozzles mounted on a double swivel angled 30 degrees downward and oriented forward and backward to improve coverage of the target at Zadoks 59. Visual estimation of flag leaf necrosis, three samples per plot, and FHB incidence and field severity, 20 samples per plot, (spikelet count per individual head multiplied times FHB infected spikes per head) were determined. Each plot was harvested with a Hege plot combine and the grain sample cleaned and processed for yield, plump, and test weight measurement. A sample was ground for DON analysis at NDSU. Data was analyzed with SAS GLM.

RESULTS AND DISCUSSION

Most of the disease present was Septoria speckled leaf blotch, *Septoria passerinni* Sacc. and *Stagonospora avenae* F. sp. tritica T. Johnson, on the six-row cultivars, Drummond, Lacey, Legacy, and Robust. Spot blotch, *Cochliobolus sativus* (Ito & Kirivayashi), was the most common disease on two-row Conlon. Leaf disease levels on all cultivars were small and probably did not contribute significantly to yield differences. Lacey had greater levels of leaf disease than Conlon, Drummond, and Robust (Table 2). Caramba applied alone and two applications of AMS21619 reduced flag leaf necrosis to levels smaller than the check. Although there were differences among cultivars and fungicides in % plump, all levels were excellent.

When yield was compared cultivars responded very differently to fungicide combinations (Table 1 and Figure 1). Drummond had no significant differences among treatments. However, Quadris was the only treatment significantly different than the untreated. Cultivars Lacey and Legacy had a variable response to fungicide. The AMS21619 combination significantly improved yield over the untreated while other fungicide treatments did not. Yield of Robust was improved above the untreated by Quadris and the Quadris-AMS21619 combination

treatments. Conlon had the greatest yields and responded well to fungicide treatments. Caramba alone and all other fungicide combinations increased yield over the untreated in Conlon.

Cultivars had significantly different levels of FHB incidence and severity in untreated plots but there were no differences among fungicide treatments (Table 2). Lacey had both the greatest levels of FHB incidence and severity among cultivars. Drummond had the smallest FHB field severity levels.

Conlon had significantly smaller DON levels than other cultivars (Table 2). Legacy had smaller DON levels than Drummond, Lacey, and Robust. Drummond had the greatest DON levels at 27.1 ppm. Caramba applied at Zadoks 59 had DON level of 23.8 ppm, significantly higher than fungicide combinations that included the AMS21619 fungicide applied at Zadoks 59. Fungicides applied at Zadoks 40 with AMS21619 at Zadoks 59 tended to reduce DON levels compared to similar fungicides applied alone. Reduction in DON due to fungicide application was small (less than 20%) and the reductions would not produce acceptable malting quality.

SUMMARY

In this trial, cultivars without fungicide treatment had significant differences in leaf disease and FHB resulting in differing yields, test weights, and % plump. DON levels were different among cultivars without treatment. Fungicide treatments performed similarly among varieties for all measured factors except yield. More years of research will be needed to confirm yield and fungicide response trends among varieties.

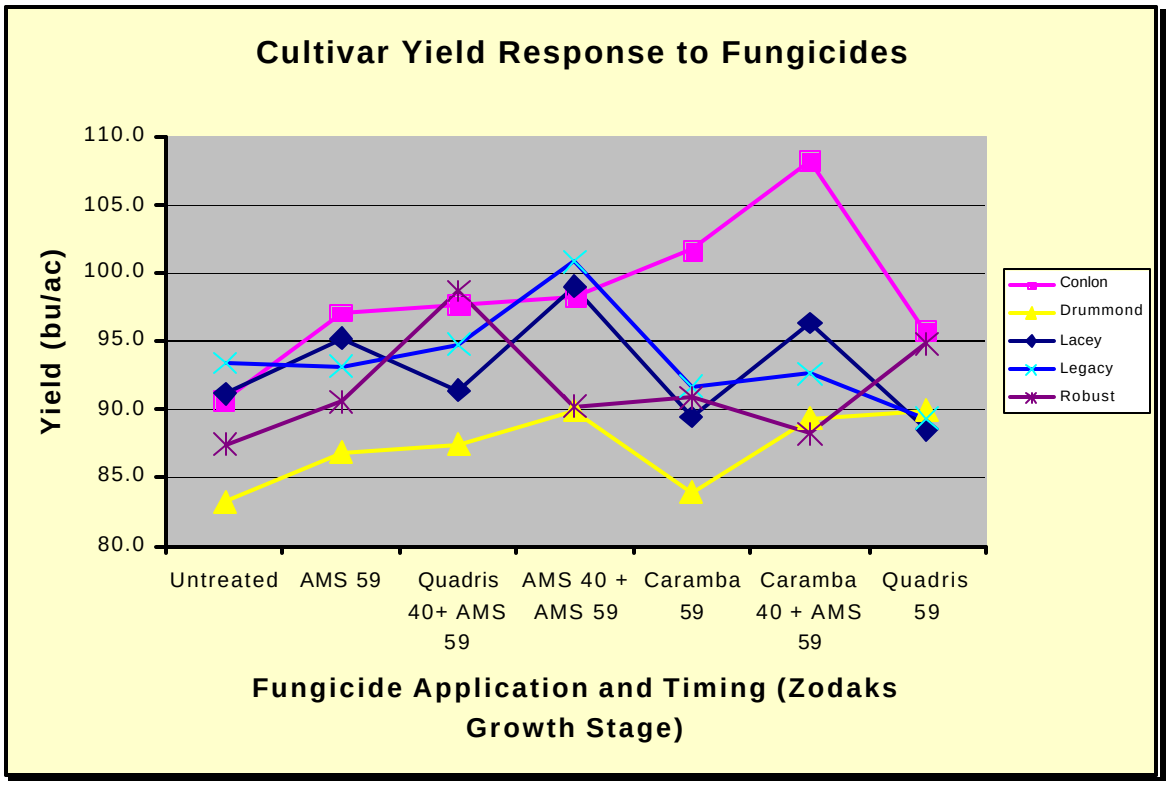

Figure 1. Cultivar yield by fungicide treatment (2002).

Table 1. Disease and quality parameter responses to fungicide treatments by cultivar (2002).

Cultivar	Fungicide	Flag Leaf	FHB		Yield	Test Wt.	Plump	DON*
		Necrosis	Incidence	Field Severity				
		%	%	%	bu/acre	lb/bu	%	Ppm
Conlon	1	1.8	51	7.5	97.1	50.5	96.2	8.7
	2	1.5	55	6.4	97.7	50.4	95.0	8.0
	3	2.3	50	7.5	98.3	50.4	95.2	9.2
	4	10.0	58	8.2	90.7	50.0	94.4	10.2
	5	4.3	48	6.6	101.7	49.5	95.5	9.6
	6	1.3	56	5.9	108.2	50.1	95.2	9.8
	7	4.3	51	8.1	95.7	49.9	94.4	8.6
Drummond	1	1.5	54	4.5	86.8	44.0	82.7	27.3
	2	9.0	55	4.8	87.4	45.0	83.0	29.3
	3	1.3	61	5.6	89.9	45.0	85.7	22.8
	4	2.3	63	7.6	83.2	44.2	76.9	30.8
	5	1.8	54	4.3	83.9	44.3	83.6	32.1
	6	1.8	50	3.2	89.4	44.4	80.2	23.8
	7	1.5	41	3.1	89.9	45.0	81.1	23.7
Lacey	1	3.0	91	18.0	95.2	46.4	88.6	23.5
	2	14.3	90	21.2	91.4	46.2	88.0	20.3
	3	3.0	75	13.8	99.0	47.0	91.2	16.9
	4	11.3	74	20.8	91.1	46.6	83.4	25.2
	5	5.8	93	22.8	89.5	45.8	86.2	35.1
	6	7.5	83	14.8	96.4	46.7	85.4	19.0
	7	7.0	89	21.5	88.5	46.9	87.5	22.2
Legacy	1	5.0	48	4.7	93.1	44.7	87.8	17.4
	2	3.8	71	9.1	94.7	44.7	89.6	12.7
	3	2.5	53	5.2	100.7	44.3	90.5	13.5
	4	9.1	71	14.5	94.9	44.6	89.6	19.6
	5	1.3	69	8.6	91.7	44.4	86.9	21.8
	6	3.0	66	9.8	92.7	44.8	86.2	11.9
	7	12.3	81	16.6	89.4	44.5	84.1	24.1
Robust	1	10.5	59	6.3	90.5	45.9	88.5	20.6
	2	5.5	65	6.9	98.6	47.0	86.4	15.4
	3	2.0	70	9.2	90.2	47.0	89.0	25.2
	4	3.0	60	6.1	87.4	46.5	85.8	18.1
	5	1.5	56	11.0	90.8	46.8	85.4	20.5
	6	2.8	65	10.8	88.2	46.7	87.7	21.8
	7	2.8	70	10.0	94.9	46.0	86.3	25.3
Cult*Trt		NS	NS	NS	6.6**	NS	NS	NS
CV %		120	21	47	6	2	4	32

Treatment 1 AMS21619 applied at Zadoks 59 growth stage
Treatment 2 Quadris applied at Zadoks 40 + AMS21619 at Zadoks 59 growth stage
Treatment 3 AMS21619 applied at Zadoks 40 + Zadoks 59 growth stage
Treatment 4 Untreated
Treatment 5 Caramba applied at Zadoks 59 growth stage
Treatment 6 Caramba applied at Zadoks 40 + AMS21619 at Zadoks 59 growth stage
Treatment 7 Quadris applied at Zadoks 59 growth stage
* Tacke, B.K. and Casper, H.H. Determination of Deoxynivalenol in Wheat, Barley, and Malt by Column Cleanup and Gas Chromatography with Electron Capture Detection: Journal of AOAC International Vol. 79, No. 2. 1996 (p.472-8309)
** Significant at 0.05 probability level for mean comparisons.

Table 2. Disease and quality parameter responses by cultivar and fungicide treatment across cultivars (2002).

Cultivar	Fungicide	Flag Leaf Necrosis	FHB		Yield	Test Wt.	Plump	DON*
			Incidence	Field Severity				
		%	%	%	bu./acre	lb./bu.	%	Ppm
Conlon		3.6	52.7	7.2	98.5	50.1	81.9	9.2
Drummond		2.7	53.9	4.7	87.2	44.5	95.1	27.1
Lacey		7.4	84.8	19.0	93.0	46.5	87.2	23.2
Legacy		5.3	65.6	9.8	93.9	44.6	87.8	17.3
Robust		4.0	63.6	8.6	91.5	46.6	87.0	21.0
	1	4.4	60.5	8.2	92.5	46.3	88.8	19.5
	2	6.8	67.3	9.7	94.0	46.7	88.4	17.1
	3	2.2	61.8	8.3	95.6	46.8	90.3	17.5
	4	7.1	65.0	11.5	89.5	46.4	86.0	20.8
	5	2.9	63.8	10.7	91.5	46.2	87.5	23.8
	6	3.3	64.0	8.9	95.0	46.5	86.9	17.3
	7	5.6	66.5	11.8	91.7	46.4	86.6	20.8
Cult LSD**		3.2	6.6	2.2	2.8	0.4	1.6	3.8
Trt LSD**		4.0	NS	NS	4.0	NS	2.2	4.5***
CV %		120	21	47	6	2	4	32

Treatment 1 AMS21619 applied at Zadoks 59 growth stage
Treatment 2 Quadris applied at Zadoks 40 + AMS21619 at Zadoks 59 growth stage
Treatment 3 AMS21619 applied at Zadoks 40 + Zadoks 59 growth stage
Treatment 4 Untreated
Treatment 5 Caramba applied at Zadoks 59 growth stage
Treatment 6 Caramba applied at Zadoks 40 + AMS21619 at Zadoks 59 growth stage
Treatment 7 Quadris applied at Zadoks 59 growth stage
* Tacke, B.K. and Casper, H.H. Determination of Deoxynivalenol in Wheat, Barley, and Malt by Column Cleanup and Gas Chromatography with Electron Capture Detection: Journal of AOAC International Vol. 79, No. 2. 1996 (p.472-8309)
** Significant at 0.01 probability level for mean comparisons.
*** Significant at 0.05 probability level for mean comparisons.

ANALYSIS OF THE 2002 UNIFORM WHEAT FUNGICIDE AND BIOCONTROL TRIALS ACROSS LOCATIONS

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OBJECTIVES

Evaluate a common set of foliar fungicide and biological control agent (BCA) treatments, across a wide range of environments, for effectiveness in managing Fusarium head blight (FHB) and associated yield and seed quality parameters.

INTRODUCTION

Identifying fungicides and BCA's that significantly reduce the incidence and severity of FHB in the field, and mycotoxins in the grain, would have widespread benefits to growers and end-users of all market classes of wheat. The Uniform FHB Fungicide and BCA Test was established as a means of rapidly identifying fungicide and/or BCA treatments that are effective, economical and environmentally safe to use in FHB management programs across the United States.

MATERIALS AND METHODS

Plant pathologists from 12 states (Table 1) conducted 22 trials across a range of wheat classes, including durum, hard red spring, soft red winter, and soft white winter wheat. Each trial evaluated eight uniform treatments (Table 2), including two advanced BCA's, OH 182.9 Yeast [USDA/ARS] and TrigoCor 1448 bacterium [Cornell University]; three foliar fungicides (AMS 21619A [Bayer], BAS 505H [BASF], and Folicur [Bayer]); and a non-treated control.

All treatments were applied at early flowering stage using a CO_2 pressurized sprayer equipped with twinjet XR8001 nozzles, mounted at a 60-degree angle forward and backward. Details such as plot size, crop husbandry, spray volume and pressure, sprayer type, and number of treatment replications varied from location to location. Consult individual state trial reports for specific details.

Data from individual trials were grouped and statistically analyzed with other winter wheat or spring wheat trials, respectively. This was done in order to detect any treatment differences that may be linked to production of winter vs. spring wheat, respectively. Treatment means from each location served as treatment replications. Data summary tables include treatment means, in actual units measured, as well as means of treatment rankings from within individual tests. Treatment rankings are provided as an alternative approach to treatment comparison.

RESULTS AND DISCUSSION

Winter wheat trials– Of 13 winter wheat trials conducted, data are presented for 12 trials (Tables 3-5); circumstances precluded the collection of disease data at one location in VA. Table 3 summarizes all FHB data, including a ranked treatment means. Table 4 presents all yield and seed quality parameters. Table 5 summarizes analyzed disease, yield and seed quality means from trials that had moderate to severe FHB. All three tables indicate that treatments involving AMS 21619A were generally superior to other treatments when compared with the check. Most fungicide treatments reduced disease levels compared to the check plots, but only the treatments involving AMS 21619A translated into statistically significant yield results in the absence of foliar disease (Tables 4 and 5). Treatments involving Folicur or BAS 505H, although not always as effective as treatments involving AMS 21619A, were often superior to the BCA treatments. Neither of the BCA's tested, when applied alone, were statistically different than the check for any parameter except for a more favorable plot severity ranking (Table 3). Test weights were statistically similar among all treatments (Table 4). Percent VSK was significantly lower than the check only when AMS 21619A was applied (Table 4, 5). Similarly, DON levels tended to be lowest in treatments involving AMS 21619A, but differences among treatments were not always significantly (Tables 4, 5).

Spring wheat trials – Of nine spring wheat trials conducted, four had extremely low levels of FHB and/or no FHB ratings were collected. These four tests were excluded from this summary. The results of the remaining five trials (all from North Dakota, and with moderate to severe FHB levels) are summarized in Tables 6 and 7. When actual data are considered (Table 6), all solo fungicide treatments provided similar levels of FHB control. In contrast, no treatment resulted in significantly higher yields compared to the check. Similar results were seen with treatment mean rankings (Table 7) except that crop yields associated with the above fungicide treatments ranked significantly higher than the check plots. This may be an artifact of foliar disease management in those tests, rather than any specific activity against FHB. Test weights tended to be significantly improved when fungicides were applied. There was insufficient VSK or DON data collected to make any general comments in regard to treatment effectiveness. Consult individual state trial reports for further details on VSK and DON data that was collected.

Summary - In winter wheat trials, treatments involving AMS 21619A were generally superior to the other treatments tested. Neither BCA tested provided control of FHB when compared with the check. Treatments involving Folicur or BAS 505H tended to provide an intermediate level of FHB control. In spring wheat trials, all fungicide treatments performed more or less similarly. Better results in spring wheat trials for Folicur and BAS 505H may be related to differences in demands placed on treatments between winter and spring wheat. BCA's tested in spring wheat trials were ineffective in managing FHB. Overall, seed quality parameters associated with FHB from both winter and spring trials were less impacted by foliar fungicides than were FHB symptoms expression. DON levels were reduced by fungicide treatments in winter wheat trials, but levels were often unacceptably high where moderate to severe FHB existed.

Table 1. States, principal investigator (PI), institution, number of uniform trials conducted, and wheat class evaluated.

State	PI	Institution	No. trials	Wheat Class
AR	Gene Milus	University of Arkansas	1	SRWW*
IL	Wayne Pederson	University of Illinois	1	SRWW
IN	Greg Shaner	Purdue University	2	SRWW
KY	Don Hershman	University of Kentucky	1	SRWW
MD	Arv Grybauskas	University of Maryland	1	SRWW
MI	Pat Hart	Michigan State University	1	SRWW
MO	Laura Sweets	University of Missouri	2	SRWW
ND	Marcia McMullen	North Dakota State University	6	HRSW
NY	Gary Bergstrom	Cornell University	1	SWWW
OH	Pat Lipps	Ohio State University	1	SRWW
SD	Marty Draper	South Dakota State University	3	Durum, HRSW
VA	Erik Stromberg	VPI and SU	2	SRRW

*SRWW = Soft red winter wheat
SWWW = Soft white winter wheat
HRSW = Hard red spring wheat

Table 2. Treatment, rate, and adjuvant used in the uniform trials in 2002.

#	Treatment	Rate of Product/A	Adjuvant
1	OH 182……	varied among locations	
2	Folicur 3.6F…….	4 fl oz	0.125% Induce
3	AMS 21619A 480SC……..	5.7 fl oz	0.125% Induce
4	AMS 21619A 480 SC…… + Folicur 3.6F	3.6 fl oz + 4 fl oz	0.125% Induce
5	BAS 505F 50WG ……	6.4 fl oz	0.125% Induce
6	TrigoCor 1448…….	varied among locations	
7	TrigoCor 1448……. + Folicur 3.6F	varied + 4 fl oz	0.125% Induce
8	Non-treated check		

Table 3. Treatment and rank means for FHB incidence, head severity, and plot severity from winter wheat trials[a].

	Incidence		Head severity		Plot severity	
Treatment	(%)	Rank	(%)	Rank	(%)	Rank
OH 182.9……..	26.4ab[b]	5.5ab	25.5ab	4.6ab	13.2ab	4.2b
Folicur……..	22.5ab	3.5cd	24.1ab	3.7bc	9.2bc	3.6b
AMS 21619A…….18.4b		1.8e	19.8b	3.1bc	6.8c	1.9c
AMS 21619A + Folicur… 18.5b		2.5de	18.8b	2.1c	7.6c	2.1c
BAS 505…… 21.5ab		2.6de	24.1ab	4.0bc	9.6bc	3.1bc
TrigoCor 1448……... 28.9ab		4.8a-c	25.4ab	4.6ab	13.9ab	4.4b
TrigoCor 1448 +Folicur… 25.5ab		4.2b-c	22.4ab	4.3a-c	10.2bc	4.1b
Non-treated…… 30.4a		6.2a	29.7a	6.4a	16.4a	6.1a

[a]AR, IL, IN (2 trials), KY, MD, MI, MO (2 trials), NY, OH, VA.
[b]Means within a column followed by a common letter are not significantly different P=0.05, Student-Newman-Keuls; arcsine-transformed percentage data were used in statistical analyses.

Table 4. Treatment and rank means for yield, test weight, visually scabby kernels (VSK), and DON from winter wheat trials.

	Yield[a]		Test Weight[b]		VSK[c]		DON[d]	
Treatment	(bu/A)	Rank	(lbs/bu)	Rank	(%)	Rank	(ppm)	Rank
OH 182.9…….	59.2ns[e]	5.9a	54.8ns	5.8ns	35.0a	5.2a	11.0ns	5.7a
Folicur……..	62.2	4.2ab	55.6	3.7	30.3ab	4.2ab	8.3	2.7cd
AMS 21619A……...	75.4	2.0c	56.2	2.4	24.0b	2.2c	4.5	1.3d
AMS 21619A + Folicur...	63.1	3.4bc	56.2	3.7	24.3b	2.8c	5.0	2.3d
BAS 505……...	60.9	4.9ab	55.6	3.8	28.6ab	3.6a-c	7.6	2.8cd
TrigoCor 1448……..	61.9	4.4ab	54.8	4.2	34.1a	4.6ab	11.3	6.0a
TrigoCor 1448 + Folicur..	62.5	3.8a-c	55.5	3.7	32.3a	5.4a	9.2	4.0bc
Non-treated……..	58.2	5.9a	54.8	4.9	32.8a	4.8ab	10.2	4.3b

[a]data from AR, IL, IN, KY, MD, MO(2 trials), NY, OH, VA.
[b]data from AR, IN (2 trials), KY, MD, MO (2 trials), NY, OH, VA.
[c]data from AR, KY, MO(2 trials), NY, OH, VA.
[d]data from IN (2 trials), KY, MD, MO (2 trials), NY, OH, VA.
[e]Means within a column followed by a common letter are not significantly different P=0.05, Student-Newman-Keuls; ns = not significant; VSK percentages were arcsine-transformed for statistical analysis.

Table 5. Treatment means for FHB incidence, head severity, plot severity, yield, visually scabby kernels (VSK), and DON from winter wheat trials in AR, IL, KY, MI, NY, and OH that had moderate to severe levels of FHB and little interference from other diseases.

Treatment	Incidence (%)	Head severity (%)	Plot severity (%)	Yield[a] (bu/A)	VSK (%)	DON[b] (ppm)
OH 182.7…….	50.4a[c]	43.0ab	28.3ab	54.3c	38.3a	19.8a
Folicur…….….	42.4ab	37.0b	27.5ab	61.0a-c	31.8ab	14.9ab
AMS 21619A……..….	33.6bc	32.7b	14.0c	66.0a	24.5b	7.8b
AMS 21619A + Folicur…	28.6c	31.8b	15.8bc	62.7ab	24.3b	8.5b
BAS 505……...….	40.0ab	39.0b	20.3a-c	60.0a-c	30.5ab	13.7ab
TrigoCor 1448……..	49.6a	44.2ab	29.3ab	56.0bc	37.8a	20.4a
TrigoCor 1448 + Folicur..	41.2ab	37.6b	21.0a-c	61.7a-c	34.0ab	16.7ab
Non-Treated…….....	51.2a	50.8a	33.3a	54.3c	37.6a	19.7a

[a]No yield data for MI.
[b]No DON data from AR, IL, and MI.
[c]Means within a column followed by a common letter are not significantly different P=0.05, Student-Newman-Keuls; arcsine-transformed percentage data were used in statistical analyses.

Table 6. Treatment means for FHB incidence, head severity, plot severity, yield and test weight from five of nine spring wheat trials that had moderate to severe levels of FHB and foliar diseases.

Treatment	Incidence (%)	Head severity (%)	Plot severity (%)	Yield (bu/A)	Test weight (lbs/bu)
OH 182.7……..….	71.0ab[a]	34.5ns	26.5a	40.8ns	56.8bc
Folicur…….….	66.2a-c	22.8	16.8b	47.0	58.0ab
AMS 21619A……...….	57.2bc	22.8	16.3b	38.0	58.3ab
AMS 21619A + Folicur...	57.6bc	23.0	17.0b	50.3	58.3ab
BAS 505……...….	51.6c	22.5	15.0b	51.3	59.0a
TrigoCor 1448…….…….	76.8a	32.8	25.8a	41.5	57.0bc
TrigoCor 1448 + Folicur...	71.0ab	32.0	23.5ab	47.8	57.8a-c
Non-treated……..	80.8a	34.8	29.3a	39.8	56.3c

[a]Means within a column followed by a common letter are not significantly different P=0.05, Student-Newman-Keuls; arcsine-transformed percentage data were used in statistical analyses; arcsine-transformed percentage data were used in statistical analyses; ns = not significant.

Table 7. Average rankings for FHB incidence, head severity, plot severity, yield, and test weight from five of nine spring wheat trials that had moderate to severe levels of FHB and foliar diseases.

Treatment	Incidence	Head severity	Plot severity	Yield	Test weight
OH 182.7……...…..	4.2ab[a]	4.7ns	4.6ab	4.5a	2.8ab
Folicur……...…...	2.8b	2.4	2.2c	3.5ab	2.0a-c
AMS 21619A……....	2.4b	3.3	2.8bc	1.5b	1.8bc
AMS 21619A + Folicur...	2.6b	2.3	3.4bc	2.0b	1.5bc
BAS 505…….…..	2.2b	3.4	2.2c	1.8b	1.3c
TrigoCor 1448……...…	4.8ab	3.9	4.4ab	5.0a	2.8ab
TrigoCor 1448 + Folicur..	3.8ab	3.4	3.6bc	2.5b	2.3a-c
Non-treated……...	5.8a	5.0	5.8a	5.0a	3.3a

[a]Means within a column followed by a common letter are not significantly different P=0.05, Student-Newman-Keuls; ns = not significant.

MANAGEMENT OF FUSARIUM HEAD BLIGHT IN WHEAT USING SELECTED BIOLOGICAL CONTROL AGENTS AND FOLIAR FUNGICIDES, 2002

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OBJECTIVES

Evaluate selected foliar fungicides and biological control agents (BCA) for potential use in soft red winter wheat Fusarium head blight (FHB) management programs in Kentucky. Also, to generate data as a cooperator in the 2002 National Fusarium Head Blight Uniform Fungicide and Biocontrol Trial.

INTRODUCTION

FHB is a significant disease concern in all wheat and barley producing regions of the United States. FHB epidemics are rare in Kentucky, but each year some fields are severely damaged by the disease. Currently, the only options available for the management of FHB are the use of cultural practices that encourage escape from disease. These include the use of multiple planting dates and varieties representing different flowering dates and periods. Moderate resistance is also available in several different wheat varieties, but severe FHB will occur under conditions that favor FHB. Preliminary studies conducted in various states indicate that foliar fungicides (Milus, Hershman, and McMullen, 2001) and BCA's may be capable of providing safe, effective and economical management of FHB. Nonetheless, specific and consistent data are lacking in regards to which products and rates are most suitable for use in FHB management programs. The National FHB Uniform Fungicide and Biocontrol Test was established as a means of addressing this deficiency in data. This test involves cooperators at various locations across the county, the use of a standard set of promising treatments, and a reasonably standardized testing protocol. Each state, including the one in Kentucky during 2002, also evaluates unique treatments of local interest.

MATERIALS AND METHODS

The test site was established at the University of Kentucky Research and Education Center in Princeton, KY. The core set of treatments evaluated was determined by collective agreement of the scientists involved in the National FHB Uniform Fungicide and Biocontrol Test. Treatments included a variety of foliar fungicides and two BCA's. An additional fungicide treatment of local interest was also included at the Kentucky trial location. The test site was planted in a conventionally-tilled seed bed on October 22, 2001. Plots were maintained according to standard crop husbandry practices for soft red winter wheat production in west Kentucky (Bitzer and Herbek, 1997). The wheat variety planted was 'Patton'. This variety expresses FHB "Type 2" resistance, which is resistance to spread of FHB within a spike. Maize was the previous crop grown in the test site.

Plots were inoculated on April 1, 2002 with sterilized, cracked corn infested with a mixture of several highly pathogenic isolates of *Fusarium graminearum*, the primary causal agent of FHB. Test plots were mist-irrigated according to a strict regime in order to encourage the causal fungus to produce infectious spores and infect the test plots. Between inoculation and the onset of flowering, plots were mist-irrigated for two hours daily, between 7 pm and 9 pm. Following the onset of flowering, plots were mist-irrigated eight times each day for 15 minutes each misting cycle. Fungicides were applied to plots on April 30, 2002 when the crop was in the early flowering. Treatments were applied using a CO^2-propelled hand-held sprayer delivering at 40 PSI in 18-20 GPA. The spray boom was equipped with twinjet XR8001 nozzles oriented at a 60-degree angle forward and backward. FHB incidence, severity, and field severity data were obtained by collecting, and visually rating, 100 heads from each test plot. Plots were harvested with a small plot combine and grain yield and test weight where calculated. Deoxynivalenol (DON) levels were determined for 50-gram grain subsamples collected from each test plot. DON analyses were conducted at the Michigan State University Don Testing Laboratory. Tests to ascertain percent seed infected by *Fusarium* spp., as determined by plating seed, were conducted at Dr. TeKrony's Seed Technology Laboratory in Lexington, KY. Percent visually scabby kernel (VSK) percentages were determined by segregating healthy from scabby kernels for two sets of 100-seed samples for each treatment replication.

RESULTS AND DISCUSSION

Test conditions were favorable for FHB. Plot yields and test weights were significantly reduced by excess soil moisture. The two treatments involving AMS 21619A and TrigoCor 1448 when applied alone, significantly reduced FHB incidence compared the check. The same treatments, plus TrigoCor 1448 + Folicur also significantly reduced FHB plot severity. No treatment significantly reduced FHB head severity compared with the check. Only TrigoCor 1448 applied alone, resulted in significantly higher yield compared with the check. No treatment significantly impacted crop test weight, % visually scabby kernels (VSK), *Fusarium* spp. colonization of grain or DON levels. There were no foliar diseases of consequence in this trial.

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Bitzer, M. and Herbek, J. 1997. A comprehensive guide to wheat management in Kentucky. University of Kentucky Extension Service Publication ID-125, University of Kentucky Press.

Milus, E., Hershman, D., and McMullen, M. 2001. Analysis of the 2001 uniform wheat fungicide trials across locations. Pages 75-79 in Proceedings of the 2001 Fusarium Head Blight Forum, Erlanger, KY, University Press, Michigan State University.

Table 1. Effect of foliar fungicides and biological control agents on FHB, yield, seed quality in Kentucky, 2002.

			FHB Ratings[@]						
Plot Treatment and rate	Head Inc (%)	Plot Sev (%)	Yield Sev (%)	Test wt (bu/A)	VSK* (lbs/bu)	FC** (%)	DON+ (%)	(ppm)
OH 182.7 variable……	29.8 ab[#]	10.3ns	3.0ab	41.5ab	50.6ns	28.6ns	66.0ns	1.8b
Folicur 4.0 fl oz Induce 0.125% v/v……	27.0ab	10.8	3.0ab	45.3ab	50.2	26.3	76.7	1.8b
AMS 21619A 5.7 fl oz + Induce 0.125% v/v……	17.5b	8.5	1.5b	51.2ab	49.9	18.8	63.3	1.9b
AMS 21619A 3.6 fl oz + Folicur 4 fl oz + Induce 0.125% v/v……	19.0b	7.8	1.5b	45.9ab	52.2	16.4	60.0	2.1ab
BAS 505H 6.4 fl oz + Induce 0.125% v/v……	26.5ab	11.8	2.8ab	44.5ab	50.7	24.0	72.7	2.0ab
TrigoCor 1448 variable….	19.8b	9.0	1.5b	55.2a	51.1	19.0	84.0	2.2ab
TrigoCor 1448 variable + Folicur 4 fl oz + Induce 0.125% v/v……	22.8ab	8.8	1.5b	47.5ab	51.5	20.8	76.7	2.0ab
CGA 64250 13.7 fl oz + Induce 0.125% v/v……	33.3a	11.0	3.5a	40.5b	50.3	16.9	82.7	3.2a
Non-Treated……	..32.0a	11.5	3.8a	42.8b	51.1	25.9	76.6	2.1ab

@: Inc = FHB incidence in plots; Sev = Average severity of FHB for diseased spikes; Plot sev = Average FHB severity across plot.
* = Visually "scabby" kernels.
** = Seed colonized by *Fusarium* spp.
+ = Vomitoxin
#Means followed by a common letter are not significantly different P=0.05, Student- Newman-Keuls; ns=no significant differences.

MULTIPLE INFECTION EVENTS AND SPLIT TIMING OF FOLICUR FUNGICIDE APPLICATIONS FOR CONTROL OF FHB IN HARD RED SPRING WHEAT, DURUM WHEAT, AND SPRING BARLEY, 2002

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ABSTRACT

Studies at North Dakota State University and at other research locations have indicated that wheat is most vulnerable to infection by the Fusarium head blight fungus (*Fusarium graminearum)* during anthesis, while spring barley cultivars are most susceptible to infection after the grain head fully emerges from the leaf sheath. However, if environmental conditions are very suitable for disease development over a long time span, multiple infections may occur up to soft or mid-dough stage, and not just at the most susceptible stage of the crop. Despite the possibility of multiple infection events, fungicide applications to durum and barley to control this disease have generally been applied once and targeted to the single-most critical infection periods. Cost of spray applications and time restraints of producers often prohibit multiple applications. Information was needed on the effect of multiple infection events on the level of FHB and on the effect of multiple applications of split rate fungicides in controlling multiple infection events.

A study was established in a controlled greenhouse environment in which spring wheat, durum wheat, and spring barley were exposed to multiple infection events and treated with either a single full rate (4 fl oz) or multiple, reduced rate applications of Folicur (tebuconazole) fungicide. Inoculations and/or fungicide applications were applied at single or multiple growth stages: Feekes growth stage 10.3 (head half emerged); Feekes 10.5 (head fully emerged but not flowering); Feekes 10.51 (early flowering in wheat); Feekes 10.54 (kernel watery ripe). Ten ml of a dilution of *Fusarium graminearum* spores (10,000 spores/ml) were atomized onto grain heads at the appropriate growth stage. For fungicide treatments, Folicur was applied approximately four hours before inoculation, using a track sprayer equipped with XR8001 flat fan nozzles oriented forward and backward at 60^0 from the vertical. FHB incidence, head severity and field severity were determined at the soft dough stage of kernel development.

Multiple infection events resulted in higher FHB field severities than did a single inoculation event at the most susceptible growth stage. However, split applications of reduced rates of Folicur across multiple growth stages generally did not significantly improve disease control over a single treatment of the full label rate at the most susceptible growth stage. For all three crops, the least satisfactory control of FHB among fungicide treatments tested was when a single application of the full label rate of Folicur was applied late, at Feekes 10.54 (kernel watery ripe).

EVALUATION OF FOLIAR FUNGICIDES AND BIOPROTECTANTS FOR CONTROL OF FUSARIUM HEAD BLIGHT OF WINTER WHEAT IN NEW YORK IN 2002

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OBJECTIVES

To quantify the ability of promising fungicides and bioprotectants, applied to flowering wheat spikes, to control Fusarium head blight (FHB) and to reduce deoxynivalenol (DON) contamination of the harvested grain.

To assess the efficacy of the bioprotectant TrigoCor 1448 to act synergistically with foliar fungicides in control of FHB and reduction of DON contamination.

INTRODUCTION

Efforts are being made through the USWBSI to provide safe, affordable and efficacious fungicides and biological protectants for the integrated management of FHB of wheat and barley. This study provided a New York site for the Uniform Fungicide and Biocontrol Tests in 2002. In addition to uniform core treatments, we assessed additional biocontrol agents at two locations. The reduction of DON contamination of the harvested grain to acceptable levels remains of critical importance in the management of this disease. We were especially interested in assessing the ability of *Bacillus subtilis* isolate, TrigoCor 1448, to enhance the reduction of DON when applied to flowering wheat spikes in mixture with fungicides, based on initially promising results with the combination of TrigoCor 1448 with Folicur 3.6F (Stockwell *et al*., 2001).

MATERIALS AND METHODS

Uniform Fungicide/Bioprotectant Field Trial – Musgrave Farm, Aurora, NY

Twelve treatments were included in the uniform fungicide/bioprotectant trial conducted at Aurora, NY. Treatments were replicated four times and arranged in a randomized block design. In addition to AMS 21619A, AMS 21619A plus Folicur, Folicur, BAS 500, TrigoCor 1448 and the USDA/Peoria Yeast which were included as core treatments tested at all locations, this trial included the commercial *Bacillus subtilis* bioprotectant product, Serenade (AgraQuest; Davis, CA) and an experimental, endophytic *Streptomyces* EN27 (courtesy Justin Coombs, Cornell University). Commercial products were applied at labeled rates. In this same trial, TrigoCor 1448 was combined in treatments with AMS 21619, BAS 500, or Folicur to determine if the combination would give enhanced FHB control over either bioprotectant or fungicide alone. TrigoCor 1448 was grown for 5 days in nutrient broth with

yeast extract, NBYE, (2-4 X 10^8 cfu/ml) and applied undiluted as whole broth. Yeast cells were supplied as a paste by Dr. Shisler and were suspended in distilled water. Corn grain infested with *G. zeae* was scattered in the alleys between the plots one month prior to anthesis. Treatments were applied to wheat at anthesis with a backpack type sprayer at 40 psi, 18-20 gpa using a nozzle arrangement that allowed angled spraying of the heads. After the heads had dried, they were inoculated with *G. zeae* at a rate of 2.7 x 10^{10} macroconidia per acre. The plots were rated visually for the incidence and severity of Fusarium head blight. Test weight, yield, % Fusarium damaged kernels (fdk), % seed infection (on SNAWS selective medium) and DON were determined from the harvested grain. Seed from each plot were sent to Michigan State University for DON analysis.

Bioprotectant Trial - McGowan Field, Ithaca, NY
Five treatments were included in a biocontrol trial conducted at Ithaca, NY on Caledonia soft white winter wheat. Treatments were replicated 6 times and arranged in a randomized block design. Wheat heads were sprayed with the treatments on 7 June, 2002. After the heads had dried, they were inoculated with *G. zeae* at a rate of 2.7 x 10^{10} macroconidia per acre. The plot was wetted for 15 min each afternoon with a fine mist from overhead irrigation. The plots were rated visually for the incidence and severity of Fusarium head blight. Test weight, yield, % *Fusarium* damaged kernels (fdk), % seed infection (on SNAWS selective medium) and DON were determined from the harvested grain. Seed from each plot were sent to Michigan State University for DON analysis.

RESULTS AND DISCUSSION

Uniform Fungicide/Bioprotectant Field Trial – Musgrave Farm, Aurora, NY
Of all the fungicides and bioprotectants tested, only AMS 21619A showed great promise for control of FHB under the epidemic conditions experienced in New York in 2002 (Table 1). None of the treatments reduced DON contamination to levels acceptable to the grain trade, though AMS 21619A reduced DON significantly. The performance of any of the three synthetic fungicides was not increased in combination with the bioprotectant TrigoCor 1448.

Bioprotectant Trial - McGowan Field, Ithaca, NY
None of the biocontrol treatments or the fungicide Folicur controlled Fusarium head blight or reduced DON contamination in the harvested grain (Table 2).

CONCLUSIONS

If results from other test locations (summary report in this volume by D. Hershman) are similar to those in New York, extensive evaluation of the foliar fungicide AMS 21619A for its potential in the integrated management of Fusarium head blight of wheat and barley will be warranted.

REFERENCE

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Table 1. Effect of foliar treatment with fungicides and bioprotectants at anthesis on scab incidence, *Fusarium*-damaged kernels, yield, test weight, and DON contamination in Caledonia winter wheat in Aurora, NY in 2002.

Treatment and amount	**Scab (spike) incidence on 21 Jun (%)**	***Fusarium* damaged kernels (%)**	**Test weight @ 13.5% moisture (lb/bu)**	**Yield @13.5% moisture (bu/A)**	**DON ppm**
Nontreated	38.2	15.1	50.9	62.5	31.0
AMS 21619A (5.7 fl oz/A) + Induce (0.125% v/v)	14.0	9.9	58.0	76.1	8.0
AMS 21619A (5.7 fl oz/A) + Folicur 3.6F (4 fl oz/A) + Induce (0.125% v/v)	21.1	10.8	57.6	73.5	10.0
AMS 21619A (5.7 fl oz/A) + Induce (0.125% v/v) + TrigoCor 1448 (2.1×10^{10} cfu/A)	23.4	10.8	57.5	76.6	12.0
BAS 500 50WG (0.4 lb/A) + Induce (0.125% v/v)	37.6	12.1	55.3	69.9	20.5
BAS 500 (0.1 lb a.i./A) + Induce (0.125% v/v) + TrigoCor 1448 (2.1×10^{10} cfu/A)	32.1	14.1	54.7	70.4	21.0
Folicur 3.6F (4 fl oz/A) + Induce (0.125% v/v)	32.0	12.8	52.1	67.8	29.5
Folicur 3.6F (4 fl oz/A) + Induce (0.125% v/v) + TrigoCor 1448 (2.1×10^{10} cfu/A)	32.8	14.9	53.8	68.8	25.5
OH 182.9 Yeast (2.2×10^{9} cfu/A)	37.7	17.6	52.7	63.9	33.5
Serenade (6 lb/A)	43.7	18.9	51.0	59.2	35.0
EN27 Streptomyces (3.8×10^{9} cfu/A)	35.9	16.1	50.7	69.0	36.6
TrigoCor 1448 (2.1×10^{10} cfu/A)	43.2	13.6	52.0	61.0	33.0
LSD (*P*=0.05)	8.6	0.4	2.5	NS	8.2
CV (%)	38.2	10.4	3.3	12.8	23.1

Table 2. Effect of foliar treatment with bioprotectants at anthesis on scab incidence, *Fusarium*-damaged kernels, yield, test weight, and DON contamination in Caledonia winter wheat in Ithaca, NY in 2002.

Treatment and amount	**Scab (spike) incidence on 24 Jun (%)**	***Fusarium* damaged kernels (%)**	**Test weight @ 13.5% moisture (lb/bu)**	**Yield @13.5% moisture (bu/A)**	**DON ppm**
Nontreated	29.9	12.1	53.5	72.1	28.0
Folicur 3.6F (4 fl oz/A) + Induce (0.125% v/v)	29.7	9.9	53.9	72.1	30.7
OH 182.9 Yeast (2.2 X 10^9 cfu/A)	28.8	12.0	53.2	68.9	31.0
Serenade (6 lb/A)	38.2	12.5	51.3	65.4	35.0
TrigoCor 1448 (2.1 x 10^{10} cfu/A)	31.5	11.8	53.2	70.8	28.3
LSD (*P*=0.05)	6.2	0.1	1.6	NS	NS
CV (%)	16.5	15.4	2.5	12.8	17.8

HISTORY AND ACCOMPLISHMENTS OF THE USWBSI UNIFORM FUNGICIDE AND BIOLOGICAL CONTROL TRIALS, 1998-2002

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ABSTRACT

The devastating Fusarium head blight (FHB) epidemics in the US in the early 1990s resulted in intensive individual and regional efforts to evaluate fungicides for control of this disease. These early evaluations did not use the same treatments and procedures, and this made comparisons among locations difficult or impossible. A cooperative effort was needed to assure that tests of chemical and biological control agents (BCAs) would provide useful information on efficacy and yield parameters each year.

A group of researchers met at the first National Fusarium Head Blight Forum in 1997 in St. Paul and established the Fungicide Technology Network. This group developed a set of five uniform fungicide treatments to be tested on three classes of wheat and spring barley in seven states (IN, KY, MO, MN, ND, OH, SD) during the growing 1998 season. At the 1998 National FHB Forum in East Lansing, Michigan, the Fungicide Technology Network became part of the Chemical and Biocontrol research area of the USWBSI. At that meeting, plant pathologists from 14 states (AR, IL, IN, KY, MD, MI, MN, MS, NY, NC, ND, OH, SD and VA) agreed to cooperate in a uniform trial with a total of seven treatments. In succeeding years, protocols for applying treatments and recording data were improved and standardized. Each year, selection of the uniform treatments was decided by the Chemical and Biocontrol Committee, with new treatments being tested for at least two years. In 2001, the first BCAs were included in the uniform treatments.

During its first five years, the Uniform Fungicide and Biocontrol Trials have evaluated ten fungicides provided by six crop protection companies and BCAs from EMBRAPA/Cornell University and the USDA/Ohio State University. Reductions in FHB field severity across locations have averaged about 50% and have been as high as 78% with the best fungicide treatment. Most of the tested treatments have been eliminated from further consideration because of poor efficacy, tendency to increase DON levels, and/or termination by the crop protection company. Folicur and AMS 21619A from Bayer have had the most consistent efficacy against FHB, controlled other important diseases, and generally increased yield and test weight. Data generated in the Uniform Trials were instrumental for justifying Section 18 registrations for Folicur in several states and likely will be important for any future registrations. Furthermore, a team of experienced collaborators has been established across the US that uses common protocols for evaluating fungicides and BCAs across multiple environments and grain classes, and that readily shares data and ideas for improving the evaluations.

ND UNIFORM WHEAT FUNGICIDE AND BIOLOGICAL AGENT TRIALS, 2002

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OBJECTIVE

To evaluate registered and experimental fungicides and biological agents for control of Fusarium head blight (FHB) in hard red spring and durum wheat at multiple locations in ND.

INTRODUCTION

Uniform fungicide trials on wheat in ND in recent years (McMullen *et al*. 2000, 2001) have shown statistically significant reductions in Fusarium head blight (FHB) field severity with some registered and experimental fungicides. Similar results have been observed in the national uniform trials (Milus *et al*. 2001). Biological agents tested (from Cornell University and the USDA at Peoria, Illinois) were less successful in reducing FHB severity (Milus *et al*. 2001). In 2001, treatments containing the experimental fungicides AMS 21619 or BAS 505 resulted in the lowest FHB field severity and lowest DON levels among treatments in both the ND trials and the national uniform trial summary. Experiments in 2002 were designed to further test the efficacy of these two experimental fungicides, applied alone or in combination, and to further evaluate the biological agents, applied alone or in combination with a fungicide. Tests in ND were established across two wheat classes and four locations to enhance evaluation across multiple environments and crops.

MATERIALS AND METHODS

A uniform set of four fungicide treatments and three biological agent treatments were evaluated on spring wheat and four fungicide treatments and one biological agent were evaluated on durum wheat in ND in 2002 (Tables 1 and 2). Treatments for each wheat class were tested across three locations and three cultivars: Oxen spring wheat at Fargo, Russ spring wheat and Munich durum at Carrington, Ingot spring wheat and Plaza durum wheat at Langdon, and Ben durum at Minot. Artificial inoculum in the form of inoculated grain was dispersed in plots at Fargo and Langdon, wheat straw was distributed at Carrington, and infections at Minot were from natural inoculum. Natural rainfall was augmented by mist irrigation at Fargo and Langdon and by some overhead irrigation at Carrington.

All treatments were applied at early flowering (Feekes 10.51) with a CO_2 backpack type sprayer, equipped with XR8001 nozzles mounted at a 60^0 angle forward and backward toward the grain heads. Spray was delivered in 18- 20 gpa at 40 psi. All treatments were applied between 6:00 and 8:00 am. Treatments included Folicur (tebuconazole) fungicide, AMS 21619A (experimental fungicide from Bayer Crop Science), BAS 505 (experimental fungicide

from BASF), a yeast biological (*OH 182.9 - Cryptococcus nodaensis*) from Dr. Dave Schilser with the USDA, Peoria, a bacterial biological agent (*TrigoCor 1448 - Bacillus subtilis*) from Dr. Gary Bergstrom, Cornell University, a combination treatment of TrigoCor and Folicur, and a combination treatment of AMS 21619 and Folicur (Table 1). TrigoCor was not tested on durum wheat at Carrington and Langdon. Fusarium head blight incidence and head severity and leaf disease ratings were taken at soft dough kernel stage. Plots were harvested with small plot combines. DON (vomitoxin) data was determined by the NDSU Toxicology Lab using gas chromatography and electron capture techniques. Plots were in a randomized complete block design and data were statistically analyzed across locations using ANOVA.

RESULTS AND DISCUSSION

Hard red spring wheat: All fungicide treatments significantly reduced Fusarium head blight field severity over the untreated check (47-59%), while treatments with the biological agents did not (Table 1). DON levels were not significantly reduced by the fungicide or biological treatments. All fungicide treatments significantly reduced leaf rust severity at Fargo and Langdon. Leaf rust ratings were a part of overall leaf disease ratings at Carrington, where leaf rust was much more severe than at Fargo or Langdon. All fungicide treatments significantly reduced leaf diseases on spring wheat, while the biological treatments did not (Table 1). Yields were significantly increased by fungicide treatments, from 18 to 28%. Test weights were increased by fungicide treatments, but not significantly.

Durum wheat: At the Minot site, visible Fusarium head blight (FHB) symptoms were too low to rate, due to drought and heat stress at that site. However, harvested grain at Minot was tested for DON and treatments ranged from 0.7 (AMS treatment) to 2.3 ppm (untreated). The AMS 21619A and BAS 505 fungicide treatments resulted in the lowest FHB field severities, but differences among treatments were not significant (Table 2). DON levels were significantly reduced by fungicide treatments containing AMS 21619A or BAS 505. Leaf spots were significantly reduced by all fungicide treatments but not by the OH 182.9 biological treatment. Yields and test weights were significantly improved by all fungicide treatments (19% to 32% yield increase and 1 to 1.8 lb test weight increase), but not by the biological (Table 2). Heat stress in July during the time of flowering and grain development may have made differences among treatments less significant in 2002 than in previous years.

ACKNOWLEDGMENTS

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Table 1. Spring wheat: Effect of fungicides and biological agents on Fusarium head blight (FHB), DON, leaf rust, fungal leaf diseases, yield and test wt. across Fargo, Carrington, and Langdon , ND, 2002.

Treatment and rate/acre[1]		FHB FS[2] %	DON[3] ppm	Leaf rust[4] % on flag	Leaf spot[5] % on flag	Yield bu/a	Test Wt. lbs/bu
Untreated check		17	7.5	5.6	55	39	56.5
Folicur 3.6 F	4 fl oz	7	6.5	0.4	26	46	57.8
AMS 21619A 480 SC	5.7 fl oz	9	5.3	1.5	22	49	58.0
BAS 505 50 WG	6.4 oz	7	5.5	1.5	21	50	58.8
OH 182.9 (*Cryptococcus nodaensis*)		15	6.6	3.5	51	41	56.8
TrigoCor 1448 (*Bacillus subtilis*)		14	7	4.5	45	42	57.0
TrigoCor 1448 + Folicur	4 fl oz	12	6.7	0.2	21	46	57.4
AMS 21619A 3.6 fl oz + Folicur	4 fl oz	8	6.3	0	15	48	57.6
LSD P = 0.05		6	NS	1.8	19	6	NS

[1] All fungicide treatments had 0.125% Induce added; AMS 21619A an experimental fungicide from Bayer; BAS 505 an experimental fungicide from BASF; OH 182.9 an experimental yeast from the USDA, Peoria; and TrigoCor 1448 an experimental bacterium from Cornell University
[2] FHB FS = Fusarium head blight field severity; field severity = incidence x head severity
[3] DON levels were not available from Langdon at time of report
[4] Leaf rust reported only at Fargo and Langdon
[5] Leaf spot diseases primarily tan spot and Septoria leaf spot complex at Fargo and Langdon, but leaf spot readings at Carrington included leaf rust, which was severe at that site

Table 2. Durum wheat: Effect of fungicides and a biological agent on Fusarium head blight (FHB), DON, fungal leaf diseases, yield and test wt. across Carrington, Langdon, and Minot, ND, 2002.

Treatment and rate/acre[1]		FHB FS[2] %	DON[3] ppm	Leaf spot[4] % on flag	Yield[5] bu/a	Test Wt.[5] lbs/bu
Untreated check		36	2.3	43	37	59.5
Folicur 3.6 F	4 fl oz	24	1.9	12	45	60.5
AMS 21619A 480 SC	5.7 fl oz	19	0.7	13	46	61.0
BAS 505 50 WG	6.4 oz	21	0.9	12	49	61.3
OH 182.9 (*Cryptococcus nodaensis*)		32	2.6	35	39	60.0
AMS 21619A 3.6 fl oz + Folicur	4 fl oz	23	0.8	12	49	60.7
LSD P = 0.05		NS	1.3	14	5	1.1

[1] All fungicide treatments had 0.125% Induce added; AMS 21619A an experimental fungicide from Bayer; BAS 505 an experimental fungicide from BASF; OH 182.9 an experimental yeast from the USDA, Peoria; TrigoCor 1448 was NOT tested on durums at Carrington and Langdon
[2] FHB FS = Fusarium head blight field severity; field severity = incidence x head severity; ratings only from Carrington and Langdon as Minot did not have enough visible FHB in 2002 due to drought and heat
[3] DON levels were available from Carrington and Minot at time of this report; significance at P = 0.1 confidence level
[4] Leaf spot diseases primarily tan spot and Septoria leaf spot complex
[5] Yield and test weight data from Carrington and Minot only

NEW AND EFFECTIVE FUNGICIDES AGAINST THE FHB IN WHEAT

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OBJECTIVES

To describe the antifusarium effect and efficacy of several novel fungicides including the four years experiences with the AMS 21619.

INTRODUCTION

Among the fungicides used for the control of FHB until now the tebuconazole, metconazole and bromuconazole were identified with larger effect against the disease (Mesterházy 1996, 1997, 2001). However in our tests the tebuconazole containing fungicides with higher rate were the most effective, bromuconazole and metconazole were only of medium effect because the rate used in Hungary were significantly lower than that of suggested in Western Europe. A part of the results was made public last year (Mesterházy and Bartók 2001). In the last years extensive investigations were made with the new Bayer experimental fungicide, signed as AMS 21619 in US or JAU 6476 in Europe. Besides its efficacy the question was also what would be the best formulation and rating of the product. For this reason also leaf rust was rated when epidemics occurred.

MATERIALS AND METHODS

The methodology the methods were the same as published last year (Mesterházy and Bartók 2001). FHB % means disease severity, e. g. the ratio of spikelets showing infection. In all years three cultivars with differing resistance were used and they were inoculated by two *Fusarium graminearum* and two *F. culmorum* isolates at full flowering, one day after the fungicide treatment. From 2001 we modified the duration of covering the head of groups by polyethylene bags from 24 hrs to 48 hrs to allow better disease development under dry conditions. FHB was rated five times, mean infection severity was calculated together with AUDPC, but here only arithmetical means are given as the two parameters originating from the same data show a relationship above 0.998. Leaf rust was rated as ACI, average coefficient of infection, where the coverage of the whole leaf system as a % was multiplied by 1 at S, 0.8 at MS, 0.6 at MR, 0.4 at R and 0.2 at VR reaction type.

Every year FHB severity, FDK, and relative yield loss were rated. Deoxynivalenol was measured in 1998 for the AMS 21619, however in 1999 and 2000 the experimental fungicides were not measured, as the formulations tested were not the products yet for commercial use. For this reason no DON data are listed for 1999-2001. In the tables only the averages are given across isolates and cultivars, e. g. the mean of 12 epidemic situations. Active ingredients of the fungicides used for a L product: Folicur Solo: 250 g tebuconazole, Folicur Top: 125 g tebuconazole, Falcon 465 EC: 167 g tebuconazole, spiroxamine 250 g + triadimenole 43, Kolfugo Super carbendazime 200, Caramba SL metconazole 60, Juwel: Kresoxym-methyl 125

+ epoxyconazole 125, Granit SC: bromuconazole 200, Tango: epoxyconazole 125 + tridemorph 375, Flamenco: fluquinconazole 100, Stratego: trifloxystrobin 125 + propiconazole 125EC, Sphera: trifloxystrobin 188 + cyproconazole 080 EC.

RESULTS AND DISCUSSION

Table 1 shows the 1998 data. As some lower effective fungicides were mentioned last year, we present here only the more effective ones to see the performance of the new experimental fungicide. The AMS 21619 was the most effective, 30-50 % better than the second best fungicide.

In 1999 (Table 2) a wider set of fungicides were tested. Last year we presented only those that had also DON analysis. Here the whole set is printed to see also products that are maybe less known in US. In this year we added the carbendazime to 0.8 L/ha Falcon rate (1 L/ha) and this mixture was equivalent with the lower rate (0.8 L/ha) for AMS 21619. Lower rates of this experimental fungicide produced less control, the situation is the same we hade with the different tebuconazole containing fungicides, too. The epidemic severity measured by the *Fusarium* check or Folicur Solo was about the same, and the best fungicides were significantly better than this. However the leaf rust epidemic showed that this new product has only medium or lower protection ability. From the spraying on about three weeks controlled leaf rust well, but thereafter the infection by rust increased rapidly. Other fungicides like kept their activity against rust until the end of the vegetation period allowing lower than 10 % infection. For this reason the task was to find another fungicide that does not decrease the antifusarium effect, but increases the efficacy against rust.

For this reason tebuconazole was chosen as partner fungicide in the 2000 trials. The whether was dryer and warmer, so the infection severity was lower than in 1999 or 1998 that were favorable for disease development. The AMS concentration was lower and tebuconazole was also half of the concentration of Folicur Solo, being equivalent with Folicur Top. The results showed that the new mixtures at 0.8 and 1 L/ha rate were about as effective as Folicur Solo itself, however slightly lower within the LSD 5 %. All kept FDK lower than 0.5 %.

In the 2001 trials therefore this new combination was tested at two rates (0.8 and 1 L/ha) and we applied as check the 0.8 L/ha rate of AMS 21619. The results clearly show that the new combination is as effective as the AMS 21619, but controls leaf rust as good as Folicur Solo does. All three AMS fungicides were more effective than Folicur Solo even the disease development was better than in 2000, but the humidity period was longer. These combinations were also better than our carbendazime-tebuconazole version. It is remarkable that Caramba at 1.2 L/ha performs better than at 1 L/ha. An increase of the rate to 1.5 L/ha may provide further improvement. The result support the data of El-Allaf *et al*. (2001), Hart *et al*. (2001), Hershman *et al*. (2001), McMullen *et al*. (2001), Milus *et al*. (2001), however this positive efficiency could be demonstrated also at higher epidemic severity. This means that it will be effective also under more severe epidemic conditions than at mostly moderately infected field trials.

Summary. The data show that AMS 21619 or JAU 6476 combined with tebuconazole provided more powerful control of FHB and was effective also against leaf rust. At susceptible

cultivars a higher dosage (1 L/ha, or somewhat higher) can give hope that food safety could be secured better until more resistant cultivars will grow on the Great Plain, in Hungary or elsewhere. In Hungary the standard antifusarium fungicide is Falcon at 0.8 L/ha. It is clear that any of the new combinations decreases at least 50 % the infection severity in comparison to Falcon 0.8 L/ha. Therefore a change of fungicide should come in the near future. It is important that the chances of the moderately susceptible or moderately resistant cultivars will provide higher safety when sprayed with these new fungicides even they have susceptibility to rust. Novel products are developed also elsewhere, their test will also be necessary to identify other valuable products. This is necessary to change fungicides not allowing the selection of fungicide resistant strains in the fungal populations.

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Table 1. Summary of fungicide tests against FHB in wheat, 1998

Fungicide and		Traits		
rate L/ha	FHB	Yield loss	FDK	DON
	severity %	%	%	ppm
AMS 21619 250 EC 1.0	5.07	11.08	8.33	2.82
Folicur Top 1.0+Kolf.S 1.5	7.88	16.00	15.53	4.19
Fol. Solo 1.0	8.13	20.87	19.73	3.79
Falcon 0.8	9.85	20.57	28.08	6.24
Falcon 1.0	11.63	18.43	25.86	5.72
Fus. kontr.	41.55	50.36	58.56	11.37
Mean	8.41	13.73	15.61	3.41
LSD 5 %	0.71	2.89	3.33	2.07

Table 2. Fungicides against Fusarium head blight of wheat. Summary of general means for 1999.

Fungicide		Original data		
rate L/ha	FHB %	Yield loss %	Kernel inf. %	Leaf rust ACI
Falc.0.8+Kolf. 1.5	12.19	23.43	14.36	0.4
AMS 21619 250EC 0.8	13.19	26.00	15.86	31.2
Folicur Solo 1.0	13.42	27.14	22.37	1.6
AMS 21619 250EC 0.6	14.50	28.25	18.24	34.5
Falcon 0.8	14.99	28.61	20.47	1.8
Folicur Top	17.38	29.03	19.91	3.4
AMS 21619 250EC 0.4	19.00	37.05	26.13	42.1
Caramba 1.0	20.12	36.17	25.42	7.6
Falcon 0.6	20.68	39.69	37.86	7.9
Juwel 1.0	23.75	38.97	32.69	9.5
Granit 1.0	23.81	38.90	30.46	27.0
Alert 1.0	24.84	36.32	27.92	34.2
Kolfugo Super 1.5	25.13	39.93	31.31	58.2
Tango 0.8	26.75	39.96	28.44	4.6
Flamenco 1.0	33.58	48.79	43.40	14.2
Fusarium check	41.97	56.11	58.79	64.0
Mean	21.58	35.90	28.35	21.39
LSD 5 %	0.91	2.93	3.21	5.97

Table 3. Fungicides against FHB in wheat. Summary, 2000.

Fungicide		Parameters	
rate L/ha	FHB %	Yield loss %	Kernel inf.%
Folicur Solo 1.0	1.06	6.78	0.08
Falcon 0.8+Kolf. 1	1.45	8.74	0.45
AMS 21619 250EC 0.8	1.59	9.28	0.42
AMS 216191 125EC+HWG 125, 1.0	1.79	9.44	0.42
Falcon 1.0	1.93	9.70	0.86
Caramba, 1.2	2.54	8.53	0.68
Falcon 0.8	2.96	10.26	1.19
Juwel, 1.0	3.20	14.96	1.61
Kolfugo, 1.5	4.57	14.82	3.45
Fusarium check.	8.67	22.96	7.70
Flamenco, 1.5	9.10	24.06	10.24
Mean	2.43	8.72	1.69
LSD 5 %	0.50	1.06	1.10

HWG =tebuconazole

Table 4. Fungicide testsagainst Fusarium head blight in wheat, summary for 2001.

Treatment	Overall means			
	FHB %	FDK %	Yield loss %	Leaf rust
AMS 21619 125 EC + HWG 125EC 1.0	0.60	5.61	3.9	3.00
AMS 21619 250EC 0.8	0.92	6.59	3.5	32.52
AMS 21619 125 EC + HWG 125EC 0.8	0.99	7.44	1.1	2.56
Folicur Solo 1.0	1.14	9.08	4.8	1.74
Falcon 0.8+Kolf. S.1.5	1.39	13.80	6.5	3.59
Caramba 1.2	2.28	12.94	7.7	6.70
Falcon 0.8	2.91	14.91	12.3	5.37
Stratego 1.0	3.08	18.81	8.8	21.78
Sfera 1.0	3.40	16.41	16.2	6.63
Kolfugo S 1.5	5.71	22.56	17.0	58.15
Fusarium check.	12.02	38.54	17.2	74.07
Mean	2.65	14.69	100.00	17.66
LSD 5 %	0.49	2.05	2.97	3.49

HWG=tebuconazole

UNIFORM BARLEY FUNGICIDE AND BIOLOGICAL AGENT TRIALS, FARGO, ND, 2002

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OBJECTIVE

To evaluate registered and experimental fungicides and biological agents for control of Fusarium head blight (FHB) in spring barley at Fargo, ND.

INTRODUCTION

Uniform fungicide trials on spring barley in ND in recent years have shown inconsistent results in reduction of Fusarium head blight (FHB) field severity and DON levels (McMullen *et al*., 2000 and 2001). In 2000, fungicides tested reduced FHB field severity by 45 to 66.7%, but differences among treatments were not significant. In 2001, all fungicide treatments significantly reduced FHB field severity, with the experimental fungicide, AMS 21619, giving the greatest reduction (70.5%). DON levels, however, were not statistically reduced by treatments in either year. Biological agents were not consistently tested on barley across locations. An experiment in 2002 at Fargo, ND further tested experimental fungicides, applied alone or in combination, and evaluated biological agents, applied alone or in combination with a fungicide, for efficacy in controlling FHB in spring barley. Treatments were the same as those in the uniform trials for wheat.

MATERIALS AND METHODS

A uniform set of four fungicide treatments, two biological agent treatments, and a biological + fungicide treatment were evaluated on six row 'Robust' spring barley at Fargo, ND in 2002 (Table 1). Plots were planted on May 3, 2002 into wheat stubble that had been chiseled twice prior to planting. Plants emerged on May 16, but were frosted several times in late May. Two weeks before head emergence in early July, artificial inoculum in the form of inoculated corn grain was dispersed uniformly in the plots, approximately 100 g per 162 square foot plot. Natural rainfall was augmented by mist irrigation starting on July 3 and continuing until July 19.

All treatments were applied at early head emergence (Feekes 10.5) with a CO_2 backpack type sprayer, equipped with XR8001 nozzles mounted at a 60^0 angle forward and backward toward the grain heads. Spray was delivered in 18- 20 gpa at 40 psi. All treatments were applied between 6:00 and 8:00 am. Treatments were: Folicur (tebuconazole) fungicide; AMS 21619A (Bayer CropScience experimental fungicide); BAS 505 (BASF experimental fungicide); a yeast biological (*OH 182.9 - Cryptococcus nodaensis*) from Dr. Dave Schisler, USDA, Peoria; a bacterial biological agent (*TrigoCor 1448 - Bacillus subtilis*) from Dr. Gary Bergstrom, Cornell University; a combination treatment of TrigoCor and Folicur; and a combination treatment of AMS 21619 and Folicur (Table 1). FHB ratings and leaf disease ratings were taken at soft dough kernel stage. Plots were harvested with a small plot combine. DON (vomitoxin)

was determined by the NDSU Toxicology Lab using gas chromatography and electron capture. Plots were in a randomized complete block design and data were statistically analyzed across locations using ANOVA.

RESULTS AND DISCUSSION

All fungicide and biological treatments significantly reduced FHB head severity and field severity over the untreated check (Table 1). DON levels were significantly reduced by the AMS 21619A, BAS 505, the TrigoCor + Folicur and the AMS 21619A + Folicur treatments. Yields were significantly increased by most fungicide treatments, but not by the biological treatments. Test weights were significantly increased by only two treatments, the Folicur alone and the AMS 21619A + Folicur treatment. Although FHB levels were fairly high in this experiment, late season heat stress and low natural precipitation at this location may have resulted in poor grain fill, low yields and low test weights, and concomitant smaller differences among treatments.

ACKNOWLEDGEMENTS

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Table 1. Effect of fungicides and biological agents on Fusarium head blight (FHB), DON, yield and test weight in 'Robust' spring barley, Fargo, ND, 2002.

Treatment and rate/acre[1]		FHB I[2] %	FHB HS[2] %	FHB FS[2] %	DON ppm	Yield bu/a	Test wt lbs/bu
Untreated check		97	25.0	24	4.3	50	43.9
Folicur 3.6 F	4 fl oz	89	8.7	8	3.6	55	44.5
AMS 21619A 480 SC	5.7 fl oz	94	7.3	7	2.9	54	43.9
BAS 505 50 WG	6.4 oz	93	6.7	6	2.7	55	44.1
OH 182.9 (*Cryptococcus nodaensis*)		92	8.8	8	3.3	50	43.9
TrigoCor 1448 (*Bacillus subtilis*)		93	7.9	7	3.9	49	43.3
TrigoCor 1448 + Folicur	4 fl oz	94	6.9	6	2.9	52	43.8
AMS 21619A 3.6 fl oz + Folicur	4 fl oz	90	7.9	7	3.1	57	44.5
LSD P = 0.05		8	5.6	6	1.2	5	0.6

[1] All fungicide treatments had 0.125% Induce added; AMS 21619A an experimental fungicide from Bayer; BAS 505 an experimental fungicide from BASF; OH 182.9 an experimental yeast from the USDA, Peoria; and TrigoCor 1448 an experimental bacterium from Cornell University

[2] FHB I = Incidence (% tillers showing symptoms); FHB HS = % of kernels showing symptoms; FHB FS = Fusarium head blight field severity; field severity = incidence x head severity

EFFICACY OF FUNGICIDES AND BIOCONTROLS AGAINST FHB ON WHEAT IN ARKANSAS IN 2002

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INTRODUCTION

Identifying fungicides and biocontrols that reduce incidence and severity of Fusarium head blight (FHB) in the field and levels of damage and mycotoxins in the grain could have widespread benefits to growers and users of all market classes of wheat in the event of FHB epidemics. This test in Arkansas is part of the Uniform Fungicide and Biocontrol Trial that is coordinated by the Chemical and Biological Control Committee, and the objective is to hasten the integration of fungicides and biocontrols that are effective against FHB into cost-effective and environmentally-safe wheat disease management strategies.

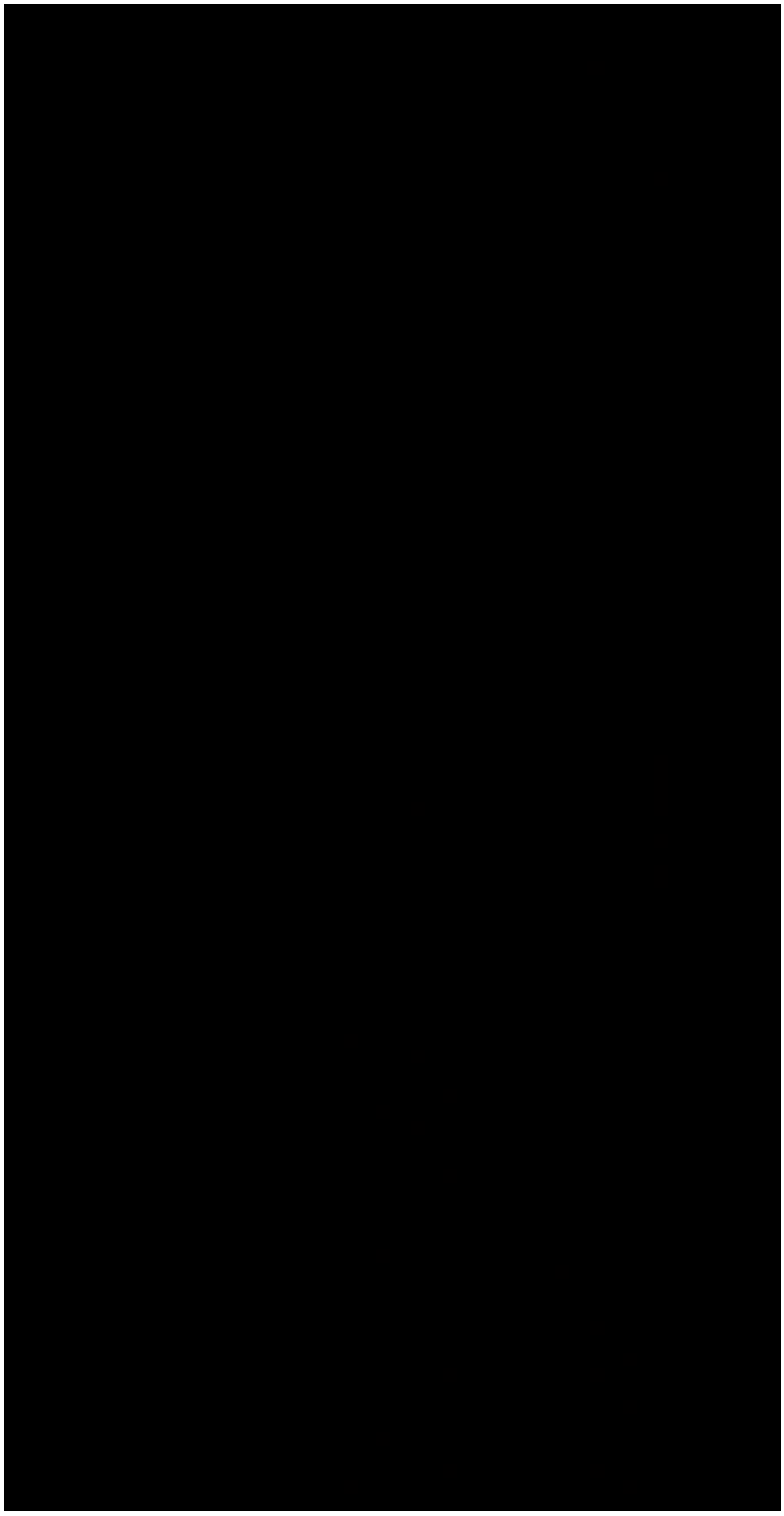
METHODS

The susceptible wheat cultivar 'Hazen' was planted at the University Farm at Fayetteville on 8 October 2001. Seed was treated with Dividend fungicide (1 fl oz / cwt) for loose smut and seedling diseases and Gaucho insecticide (3 fl oz / cwt) for aphids transmitting barley yellow dwarf. Individual plots were 7 rows by 13 ft. Plots were fertilized with 80 lb nitrogen from ammonium nitrate that was applied in equal splits on 28 February and 12 March. Ryegrass and broadleaf weeds were controlled with recommended herbicides. Infested corn kernel inoculum was applied to the plots on April 1 and 9 at a total rate of 12 kernels / sq ft. The mist system operated for eight 10-minute periods between midnight and 8:00 am for eight nights between 30 April and 8 May. TrigoCor 1448 was grown in broth culture and OH 182.9 was suspended from frozen paste according to directions supplied with the biologicals. To determine the concentration of viable cells of each biological agent, the suspension of each biological was assayed by dilution plating on TSA medium immediately before application to the plots. Fungicides and biocontrols were applied in a randomized complete block design with six replications in the late afternoon on 2 May when 50% of the main stems had begun to flower. Applications were at 20 gal / acre except for one AMS 21619A treatment that was applied at 10 gal / acre. On 23 May, 50 heads per plot were sampled randomly and evaluated for FHB incidence and head severity, and plot severity was calculated. Plots were harvested with a plot combine on 14 June, and grain was passed once through a seed cleaner before test weight and percentage of scabby grain were measured. Grain samples were sent to Pat Hart's laboratory for DON analysis.

RESULTS AND DISCUSSION

Except for low levels of barley yellow dwarf from spring infection in some plots, FHB was the only significant disease. Sixteen days of rain totaling 11.3 inches during April and May provided very favorable conditions for sporulation on the corn inoculum, infection, and FHB development. Fusarium head blight was severe by the end of the season, as indicated by the high

levels of scabby grain (Table 1). Compared to the non-treated check, all fungicides significantly reduced plot severity and increased test weight, but the two biologicals did not. However, there were no significant differences among the fungicides. Plots treated with fungicides had numerically greater yields that the non-treated check or plots treated with biologicals, but differences were not significant at the 5% level of confidence because of variability among plots of the same treatment. Poor performance of the biologicals did not appear to be due to low viability of cells in the suspension applied to the plots. AMS 21619A applied at 10 gal / acre appeared to have greater efficacy than at 20 gal / acre, but the differences were not statistically significant.



PRACTICAL ASPECTS OF GROUND APPLICATION OF FOLIAR FUNGICIDES

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ABSTRACT

While remaining at the forefront of intensive wheat management, Opti-Crop is also an industry leader in providing state-of-the-art consulting services to corn and soybean growers.

Presently, our staff of over 25 Opti-Crop consultants – most with CCA certification – manage over 200,000 acres of corn, soybeans and wheat in Kentucky as well as parts of Indiana, Illinois, Tennessee, Kansas, Oklahoma, South Dakota and North Dakota. Opti-Crop also has divisions that manage over 150,000 acres in Australia, plus consulting operations in Russia, Romania and Bolivia.

Ground application of foliar fungicides is a very important component of our intensive crop management program. Our company custom applies over 1,000,000 acres of chemicals and fertilizer annually, so logistics and timing are always a challenge. We strive to educate and train our personnel on the latest application technology by conducting field days and training sessions.

Selection of the appropriate fungicide, rates and specific adjuvants has a major impact on product effectiveness. Correct water volumes and product application timings are also crucial. We have 8 replicated research sites across the Midwest and Northern Plains, so we have the luxury of being able to apply different products at different rates and timings to determine the relative differences and economics of the individual treatments.

EFFICACY OF FUNGICIDES IN CONTROLLING BARLEY FUSARIM HEAD BLIGHT IN LINES WITH PARTIAL RESISTANCE

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ABSTRACT

Research to test the efficacy of fungicides in controlling Fusarium head blight (FHB) and deoxynivalenol (DON) levels in barley was previously conducted using cultivars (i.e. Robust, Foster, and Stander) that are susceptible to FHB. Results indicate that fungicides had little to no effect in reducing DON concentration to levels acceptable to the malting and brewing industry. Minimal information is available on the efficacy of fungicides in controlling FHB and DON levels on genotypes with partial FHB resistance. The objective of this study is to determine if the integrated use of fungicides and barley cultivars with partial resistance to FHB will control FHB severity and accumulation of DON. Experiments were conducted in the field in North Dakota since 2000 and included genotypes resistant, partially resistant, and susceptible to FHB. Fungicides used were Folicur in 2000, 2001, and 2002; and AMS21619 in 2001 and 2002. Folicur did not significantly reduce FHB severity or DON accumulation in resistant, moderately resistant, or susceptible genotypes. However, genotypes sprayed with Folicur generally had greater yield due to control of septoria speckled leaf blotch (SSLB), incited by *Septoria passerinii*. Yield gains due to control of SSLB tended to be sufficient to cover the cost of Folicur and its application on cultivars developed and released by upper Midwest barley breeding programs. Preliminary data indicates that efficacy of AMS21619 was slightly better than Folicur in reducing FHB and DON.

AUTOMATED CONTROL OF A WATERING SYSTEM FOR FUSARIUM HEAD BLIGHT RESEARCH

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OBJECTIVES

Use an automated water application control system to create a favorable growth environment for Fusarium head blight in the uniform fungicide trial plots. Evaluate the effectiveness of the watering system by 1) monitoring the microclimate in the plots and 2) measuring the FHB field severity levels in the watered control plots and surrounding dryland plots.

INTRODUCTION

To properly evaluate the effectiveness of fungicides, a favorable microclimate for the growth of FHB must be provided either by nature or artificially. Keeping the grain heads "wet" and/or maintaining a high humidity during the crucial FHB formation period is important for the evaluation of fungicides. Many researchers participating in the uniform fungicide trials use some type of watering system but some do not, relying on natural climatic conditions to provide the environment for the growth of FHB (McMullen, 2001).

A search of the literature reveals no set protocol for the operation of the watering systems during the FHB infection period. Most researchers haven't included a description of the watering system operation in their reports or research papers. Warnes (1995) used a misting system with a windbreak around the research plots. He ran the misting system for 20 minutes on even hours from 6 am to 6 p.m. and 10 minutes on even hours from 6 p.m. to midnight. The intended precipitation amount was 0.3 inches per day. Nelson (2000) ran his misting system for a half-hour at 7 p.m., 11 p.m. and 5 am. Neither researcher explained how they developed the watering protocol.

Research by Francl (2001) provided a guide for when and how often to operate a watering system. He is developing a model that uses weather data to predict when the weather conditions are right for FHB infection. He says, "Details of the interactions among environmental factors, infection, spore survival, etc. are not yet fully understood. *As a general guide, infection is indicated for wet periods longer than nine hours, but this may be substituted for by a high relative humidity and an average temperature above 60°F."* These guidelines could be used to operate the watering system using a feedback control system.

For statistical verification of the effectiveness of fungicides, the water application pattern should be uniform on all plots. The means the frequency, duration and amount of applied water should be equal for all plots. If too much water is applied, the fungicide could be washed off, loose its effectiveness and the fungus would overwhelm the plots. If too little water is applied, the fungus will not grow at an equal rate in all plots. A balance must be struck that mimics

natural conditions that favor the growth of FHB. The watering system must apply the amount of water that maintains the proper microclimate to grow the fungus without interfering with the effectiveness of the fungicide.

MICROSPRINKLER WATERING SYSTEM

During the 2000 growing season, a watering system which used microsprinklers was designed and installed in the FHB uniform fungicide trial plots (Scherer, *et al*., 2000). The same watering system was used during the 2001 and 2002 growing seasons. The research field covered about 1.8 acres. About 1.3 acres were planted to one variety of wheat and the remaining area planted to barley.

The watering system has three zones each 70 feet wide by 360 feet long. Within each zone, laterals are spaced 10 feet apart to match the plot width. The microsprinklers are spaced 15 feet apart along the laterals. Each lateral has 25 microsprinklers and the total for all three zones is 528 microsprinkler heads. Two zones had seven laterals and the other zone (a combination of wheat and barley) had eight laterals. Each zone has its own control valve and filter. The duration and frequency of the watering system was controlled by a programmed datalogger but could be operated manually.

AUTOMATED CONTROL AND REMOTE MONITORING SYSTEM

The automated control system comprised two sensor stations. One was located in a control plot in zone 1 and the other in a control plot in zone 2. They were installed on June 28 when the flag leaf was just starting to show. Each sensor station had a very accurate relative humidity/ temperature sensor and a leaf wetness sensor placed at the same elevation as the flag leaf on the wheat. The sensor stations were connected to the programmable datalogger that controlled the watering system and recorded the data. The critical infection period started on July 1. Relative humidity and temperature was read continuously from each sensor and an average value recorded every 10 minutes. The leaf wetness sensors were read continuously to record the “wetness duration” during the critical infection period. An automated recording rain gage was place in a watered plot and another was placed in an adjacent non-watered plot to record both watering and rainfall events.

In addition to the sprinkler control sensor system, remote microclimate monitoring stations were located in four watered control plots and two adjacent dryland plots. In the watered area, one station was located near the beginning of the sprinkler laterals, one near the end of the laterals and two were located halfway between. In the dryland area, stations were placed at one-third and two-thirds the lateral length. Each remote monitoring station had three self-contained dataloggers to measure relative humidity, wet bulb temperature and dry bulb temperature (HOBO Pro temperature/RH meters). The three dataloggers at each station were mounted on a single support pole at 15, 45 and 75 cm (6, 18 and 30 inches) above ground surface.

They were installed in the plots on June 24 when the wheat was approximately 20 cm (8 inches) tall. They were programmed to record data every 10 minutes. The data were downloaded once per week until July 24 when the wheat had passed the infection stage. A North

Dakota Agricultural Weather Network (NDAWN) weather station is located about 3000 feet from the research site and weather data for the area is recorded on an hourly basis. These data will be used to obtain stratified data of the climatic variables in and above the small grain canopy.

Control Algorithm

Based on recommendations from Dr. Francl and Dr. McMullen, the control system was programmed to begin watering at 5 p.m. each day if the relative humidity was below 92%. Each zone was watered for a total of 30 minutes. The first watering cycle ended at 6:30 pm. At 9 p.m., the relative humidity was checked and if it was below 92%, the watering system was activated and each zone was misted for 15 minutes. This was repeated every hour on the hour until 8 am in the morning. This assured at least 9 hours of wet conditions each day. The dry period during the day allowed the FHB spores to dry and move with the wind to ensure infection. The watering system was manually tested on June 28 when the wheat heads were just beginning to emerge. On July 1, the watering system was turned on and automatic control began. The watering system was under automatic control until July 19 when the system was shut off.

RESULTS AND DISCUSSION

Throughout the control period (July 1 to July 19), the watering system successfully maintained the relative humidity in the plots above 92% from 9 pm to 9 am except on July 5 and 6. On these two days, the wind speed stayed between 20 to 30 miles per hour and the air temperature between 79 to 93Ú F the entire time. Even under these conditions, the relative humidity was maintained at slightly over 80 percent.

The readings from the leaf wetness sensors show that the grain heads were wet about 73% of the time and dry about 27% of the time. By comparison, the wheat heads in the dryland plots were wet and dry 10% and 90% of the time, respectively. We did not have a leaf wetness sensor in the dryland plots, so these data were estimated using rainfall and relative humidity readings from the NDAWN station.

Remote Monitoring Sensors

The remote sensors measured the stratification of temperature and relative humidity in both the watered and dryland plots. One way to determine the wetness of the plots is to measure the amount of time the relative humidity was at a certain level during the critical infection pe-

Sensor Location	Percent time the RH was greater than 92% in the watered plots (average of 4 stations)	Percent of time the RH was greater than 92% in the dryland plots (average of 2 stations)
6 inches above ground	80%	47%
18 inches above ground	65%	42%
30 inches above ground	45%	30%

riod. The effectiveness of the watering protocol can be verified by examining the relative humidity data from the four remote monitors in the watered plots and compare that with the relative humidity data from the dryland plots. These results are shown in the following table.

The relative humidity was above 92% almost 80 percent of the time for the bottom sensors compared to 48% of the time for the dryland sensors. The difference decreased at the sensor stations higher in the canopy indicating there was a stratification effect induced by the watering schedule. It is interesting to note that the top sensor, which is at head height, is above 92% relative humidity about 50% of the time in the watered plots and 35% in the dryland plots.

FHB Infection Rates

The objective of this project was to make sure the all the plots had an equal chance for infection and that the microclimate was conducive to the growth of FHB. The level of infection in each plot was measured by taking 30 wheat heads and using a standardized scale to rate the severity of infection. The untreated checks in the watered plots had FHB field severity that ranged from 12 to 36 percent with an average of 30%. These levels provided a sufficient infection rate to evaluate fungicide treatments without an overwhelming amount of FHB. The field severity levels in inoculated dryland plots in adjacent research areas south of the watered plots (planted with the same variety of wheat) was about 2%.

DISCUSSION

Although the watering system and watering protocol successfully created the microclimate for the growth of FHB, limitations need to be addressed. The dryland plots, (part of the fungicide trials where two remote monitor stations were located) were not inoculated with FHB like the misted plots. We were not able to evaluate the growth of FHB in **inoculated** watered plots compared to **inoculated** dryland plots within the confines of this study. We did not have a leaf wetness sensor in the dryland plots and therefore had to infer the time of head wetness. We did not measure the amount of the time the sprinkler system was on and therefore could not pick out the periods when natural conditions were favorable for the growth of FHB.

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USDA-ARS, OHIO STATE UNIVERSITY COOPERATIVE RESEARCH ON BIOLOGICALLY CONTROLLING FUSARIUM HEAD BLIGHT 1: DISCOVERY AND SCALE-UP OF A FREEZE-DRYING PROTOCOL FOR BIOMASS OF ANTAGONIST*CRYPTOCOCCUS NODAENSIS* OH 182.9 (NRRL Y-30216)

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OBJECTIVES

To 1) identify cryoprotectant compounds and quantities of these that would enhance the shelf-life of freeze-dried biomass of OH 182.9 and 2) evaluate the propensity of a superior cryoprotectant compound to enhance shelf-life and maintain efficacy of OH 182.9 inoculum produced using precommercial, 100-L fermentor environments.

INTRODUCTION

Fusarium head blight (FHB), primarily incited by *Gibberella zeae*, can be a devastating disease of wheat and barley in humid and semi-humid regions of the world. In previous research, we have demonstrated the potential of several biological control agents to significantly reduce the severity of FHB in greenhouse and field environments (Schisler *et al*., 2002). A critical step in producing a commercially available biocontrol product is devising procedures for stabilizing biomass of the biological agent while maintaining product efficacy. A product comprised of frozen biomass of our yeast antagonist *Cryptococcus nodaensis* OH 182.9 was developed and tested at over 15 field sites as part of the U.S. Wheat and Barley Scab Initiative in the 2001 field season (Schisler *et al*., 2001, Milus *et al*, 2001). Though this product significantly reduced FHB, the development of a dried biocontrol product would have potential advantages of convenience, ease of handling, favorable economics, and consumer acceptance. However, dehydration of antagonist biomass can adversely affect its viability and efficacy.

MATERIALS AND METHODS

Eight cryoprotectant compounds (Fig. 1) were added separately at 25mM to semi-defined complete liquid medium (SDCL, Slininger *et al*., 1994), and shake-flask cultures of OH 182.9 initiated. Flasks were maintained at 250 rpm and 25°C for 96 h. Two milliliter aliquots of colonized broth were placed in 5 ml vials, freeze-dried for 48 h in a 6-L tray freeze-dryer, and stoppered under vacuum at a final temperature of 4°C. Colony forming units per milliliter (CFU/ml) were determined prior to freeze-drying and for rehydrated freeze-dried products stored at 24°C for 0, 8 and 37 days.

The effect of 1 mM to 100 mM concentrations of melezitose (a trisaccharide composed of two molecules of glucose and 1 molecule of fructose) on OH 182.9 survival and stability after

freeze-drying was studied by adding melezitose and/or 10% (w/v) skim milk to washed biomass from 48 h shake-flask cultures (Fig. 2). The CFU/ml were determined prior to freeze-drying and after product storage at 24°C for 0, 6, 13, and 21 days.

Yeast antagonist OH 182.9 was then produced in a B Braun D-100 fermentor charged with 80 L of SDCL medium. To initiate a production run, cells from a log-growth stage SDCL culture served as a 5% seed inoculum for the D-100 fermentor. Reactor medium pH, temperature, dissolved O_2, antifoam dose, and agitation rate were monitored and/or maintained to insure near identical production runs. After completion of biomass production at approximately 48 h, colonized reactor broth was concentrated into a paste using a Sharples 12-V tubular bowl centrifuge. The paste was resuspended using buffer containing 25 mM melezitose and 1% skim milk. The cell suspension was then freeze-dried in a 24-L tray freeze dryer for 48 h and vacuum sealed in mylarfoil bags. The CFU/ml were determined prior to freeze-drying and after product storage at 4°C for 0, 3, 10, 14, 21, 28, 35 and 42 days (Fig. 3). The effect of the freeze-dried product, freshly produced OH 182.9 cells, and cryoprotectants alone on FHB severity was determined in greenhouse bioassays after 0, 10 and 28 days storage (data not shown).

RESULTS AND DISCUSSION

Melezitose is characterized, for the first time, as an effective cryoprotectant (Fig. 1). Melezitose and turanose were the most effective in enhancing the survival of freeze-dried biomass of FHB antagonist *C. nodaensis* OH 182.9 compared to six other cryoprotectants found to be effective when drying biomass of other microorganisms.

Melezitose was effective in extending the shelf-life OH 182.9 at 100 mM and 50 mM concentrations but was not at concentrations of 10 mM and lower (Fig. 2). Amending biomass of OH 182.9 with 10% skim milk was effective in combination with melezitose or alone in extending OH 182.9 shelf-life.

The precommercial process of producing OH 182.9 biomass in a 100-L fermentor, separating cells from broth using a tubular bowl centrifuge, resuspending the biomass in a solution containing 25 mM melezitose and 1% skim milk, and freeze-drying the product in a 24-L tray freeze-drier produced a product that lost more than a log unit of CFU's during processing and freeze-drying but then maintained nearly constant CFU's over the next five weeks (Fig. 3).

Though cell survival of the precommercial product was satisfactory after freeze-drying (Fig. 3), the biocontrol efficacy of this product was less than that of similar concentrations of freshly produced of OH 182.9 cells in greenhouse bioassays with high disease pressure (data not shown). A portion of the failure of the freeze-dried product to control disease appears to be due to 25 mM melezitose and 1% skim milk enhancing disease (data not shown). Alternative drying methodologies such as air, fluidized bed or spray-drying may be required to produce a dried OH 182.9 biocontrol product that maintains biocontrol efficacy.

ACKNOWLEDGMENTS

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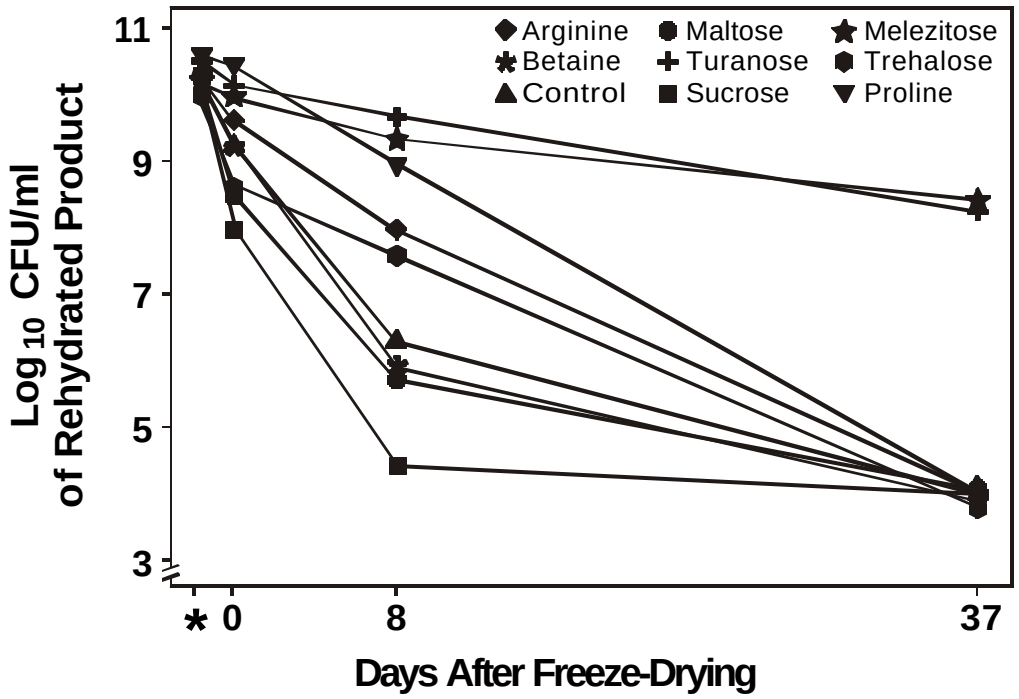
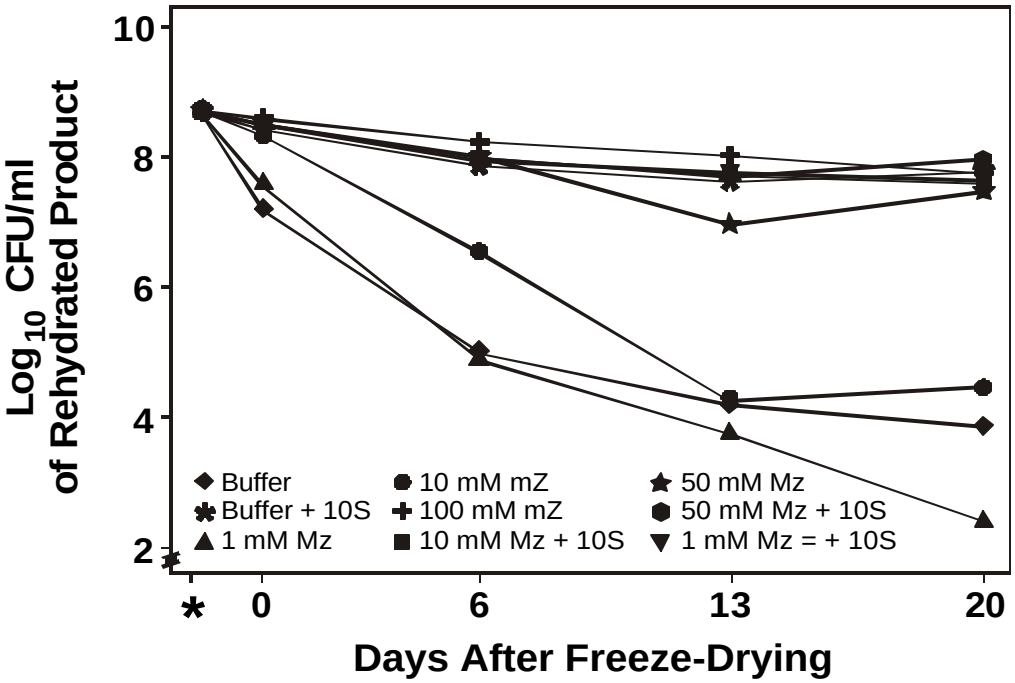


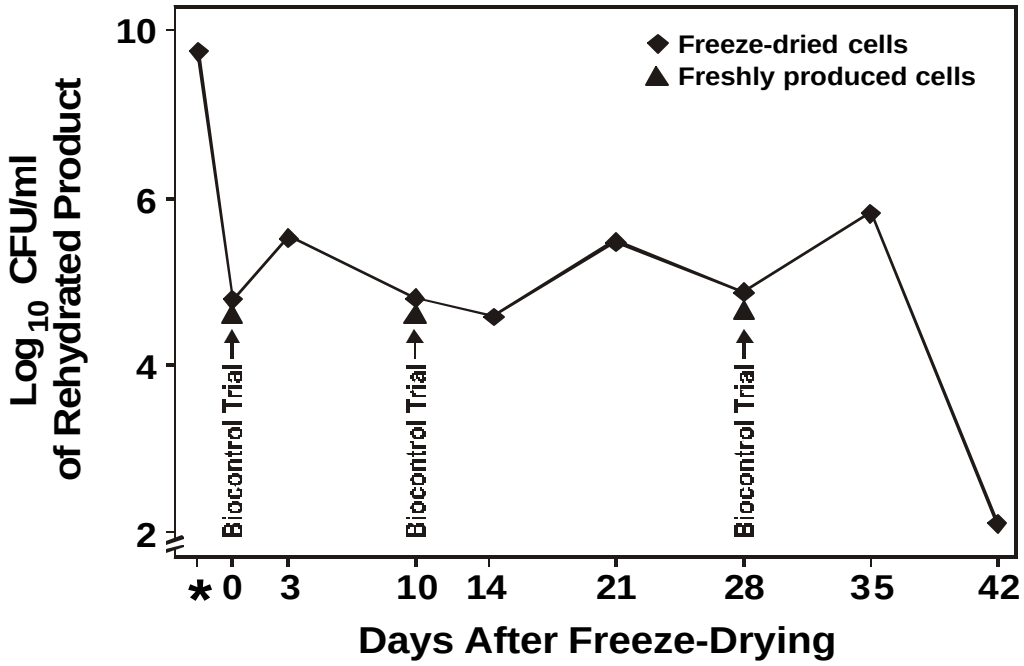
*Fresh CFU/ml count just prior to initiating a two-day freeze-drying process.

Figure 1. Influence of cryoprotectants added to liquid production medium in shake-flasks on the survival of freeze-dried biomass of FHB antagonist Cryptococcus nodaensis OH 182.9 stored at 24°C.



*Fresh CFU/ml count just prior to initiating a two-day freeze-drying process.

Figure 2. Influence of adding various concentrations of melezitose (Mz) and 10% skim milk (10S) to shake-flask-produced, washed biomass of OH 182.9 on the viability of freeze-dried cells stored at 24°C.



*Fresh CFU/ml count just prior to initiating a two-day freeze-drying process.

Figure 3. Survival of freeze-dried biomass of FHB antagonist Cryptococcus nodaensis OH 182.9 amended with 25 mM melezitose and 1% skim milk after production in a 100 L fermentor and storage at 4°C.

USDA-ARS, OHIO STATE UNIVERSITY COOPERATIVE RESEARCH ON BIOLOGICALLY CONTROLLING FUSARIUM HEAD BLIGHT 2: 2002 FIELD TESTS OF ANTAGONIST AND ANTAGONIST/ FUNGICIDE MIXTURES

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OBJECTIVE

Determine the effect of FHB antagonists, antagonist mixtures, and mixtures of antagonists and fungicides on FHB symptom development in field tests conducted in Illinois and Ohio on two cultivars of winter wheat.

INTRODUCTION

Fusarium head blight (FHB) is an important disease of wheat and barley in humid and semihumid regions of the world (McMullen *et al*., 1997). Research on optimizing methods for selectively isolating, mass producing and utilizing microbial antagonists effective against FHB was initiated in 1997 at the NCAUR in Peoria, IL, in conjunction with The Ohio State University. Several biological control agents remain under consideration for commercial development (Schisler *et al*., 2002). In addition to biological control, promising possibilities for reducing Fusarium head blight include fungicides and resistant cultivars. Combining these control measures may provide levels of control superior to that obtained when employing these control measures individually. Disease control measures utilized in various combinations in field tests conducted in Peoria, Illinois and Wooster, Ohio during the 2002 field season included biocontrol agents, a moderately resistant wheat cultivar, and fungicides.

MATERIALS AND METHODS

A naturally occurring fungicide-tolerant (FT) variant of superior yeast antagonist *Cryptococcus nodaensis* OH 182.9 (wild type (WT)) was selected from cultures grown in one-fifth strength Tryptic soy broth amended with 50 ppm of the fungicide BAS 505 50DF. Inoculum of OH 182.9 WT, OH 182.9 FT and *Bacillus subtilis* OH 131.1 was produced using a semidefined liquid culture medium (SDCL) with a carbon:nitrogen ratio of 11 and total carbon loading of 15 g carbon/liter (Schisler *et al*., 2002). The soft red winter wheat cultivars Pioneer 2545 (susceptible) and Freedom (moderately resistant) were used in both locations. Biomass was harvested from Fernbach shake flasks and applied at the beginning of wheat flowering (Schisler *et al*., 2002). Bacterial and yeast suspensions contained 50 % fully colonized broth (~$1x10^8$ CFU/ml and ~$5 x 10^7$ CFU/ml, respectively) and were applied at a rate of 20 gal/acre. The fungicides BAS 505 50DF and Folicur 3.6F were applied at recommended rates singly and in combination with microbial treatments (Tables 1 and 2). Controls were untreated plants

and plants treated with buffer/wetting agent only. Corn kernels colonized by *Gibberella zeae* (Schisler *et al*., 2002) were scattered through plots (~25-40 kernels/m^2) two weeks prior to wheat flowering and mist irrigation provided periodically for approximately one week after treatment application to promote FHB development. Heads were scored for disease incidence (presence or absence of disease symptoms) and severity using a 0-100% scale approximately three weeks after inoculation. Heads were then allowed to dry and threshed. Data for the deoxynivalenol content of grain and 100 kernel weight is being tabulated (ongoing). Randomized complete block designs were used in both trials (n=4 in Peoria; n=5 in Wooster).

RESULTS AND DISCUSSION

In Peoria, IL, most single and combination treatments reduced FHB symptoms versus at least one control on both susceptible cultivar Pioneer 2545 and moderately resistant cultivar Freedom (Table 1). A combination of yeast OH 182.9 FT and BAS 505 reduced disease severity by 70% compared to the untreated Freedom control. Combined biological control agent or biocontrol agent and fungicide treatments did not synergistically interact to reduce disease to a greater extent than the component parts of the combinations.

In Wooster, OH, on Pioneer 2545, most treatments reduced disease severity compared to the untreated control with the most effective treatments of BAS 505, OH182.9FT+BAS 505, OH182.9FT + Folicur and OH131.1+Folicur reducing disease severity by as much as 64% (Table 2). Treatments did not differ when tested on cultivar Freedom.

Across both locations, the lowest levels of FHB symptom development were found when two and sometimes three of the available control measures of antagonists, fungicides and the moderately resistant cultivar were combined. While methodologies for drying biomass require further development before fresh and dried preparations of OH 182.9 achieve equivalent efficacy, these results indicate that biocontrol products could play a key role in the integrated control of FHB.

ACKNOWLEDGMENTS

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Table 1. 2002 field trial results at Peoria, Illinois: Influence of *Cryptococcus nodaensis* OH 182.9, *Bacillus subtilis* OH 131.1, BAS 505 50DF, Folicur 3.6F and combinations thereof on FHB disease severity and incidence on two cultivars of winter wheat[1]

	Wheat Cultivar			
	Freedom		Pioneer 2545	
Treatment	% Disease Severity	% Incidence	% Disease Severity	% Incidence
Untreated control	4.1	19.6	1.6	7.5
Buffer/tween[2]	3.0	15.0	4.1	15.0
BAS 505[3]	1.4	7.1	1.3	3.8
Folicur[3]	1.6	9.6	3.5	12.1
OH182.9 WT[4,5]	1.7	9.2	2.5	9.2
OH182.9 FT[4]	3.0	14.6	0.8	4.2
OH182.9 WT + BAS 505	1.8	10.8	0.8	2.5
OH182.9 WT + Folicur	4.0	20.4	3.1	11.2
OH182.9 FT + BAS 505	1.2	6.2	1.0	3.8
OH182.9 FT + Folicur	2.2	11.2	2.8	8.3
OH131.1[5]	2.6	12.9	2.3	9.2
OH131.1 + BAS 505	1.8	9.6	1.0	3.3
OH131.1 + Folicur	3.3	16.7	2.5	7.9
OH182.9WT+OH131.1	2.4	12.9	2.8	11.2
OH182.9FT+OH131.1	2.2	11.2	2.7	10.8
OH182.9FT+OH131.1+BAS	3.2	13.8	1.0	3.8
OH182.9FT+OH131.1+Fol	3.7	17.9	3.8	12.9
$LSD_{(0.05)}$	1.3	6.0	1.5	4.8

[1]Within a column, the LSD value represents the critical value for separating treatment means at the P#0.05 level. Disease severity values are arc sine transformed.
[2]Weak PO4 buffer (Schisler et al., 2002) and 0.036% Tween 80.
[3]Applied at recommended label rates.
[4]WT= wild type of strain, FT= Fungicide tolerant natural variant of strain
[5]OH 182.9 WT and FT CFU/ml ~ 5×10^7, OH 131.1 CFU/ml ~ 1×10^8

Table 2. 2002 field trial results at Wooster, Ohio: Influence of *Cryptococcus nodaensis* OH 182.9, *Bacillus subtilis* OH 131.1, BAS 505 50DF, Folicur 3.6F and combinations thereof on FHB disease severity and incidence on two cultivars of winter wheat[1]

	Wheat Cultivar			
	Freedom		Pioneer 2545	
Treatment	% Disease Severity	% Incidence	% Disease Severity	% Incidence
Untreated control	2.6	25.0	20.4	63.8
Buffer/tween[2]	3.7	30.7	16.8	57.9
BAS 505[3]	3.0	25.0	7.4	32.1
Folicur[3]	2.5	25.3	12.9	48.3
OH182.9 WT[4,5]	2.5	23.7	21.4	65.4
OH182.9 FT[4]	2.8	28.0	12.1	46.7
OH182.9 WT + BAS 505	2.1	21.3	12.4	46.7
OH182.9 WT + Folicur	2.7	22.7	13.4	50.8
OH182.9 FT + BAS 505	2.2	23.0	8.6	30.4
OH182.9 FT + Folicur	2.0	18.7	9.7	39.2
OH131.1[5]	2.3	22.0	14.9	52.5
OH131.1 + BAS 505	3.3	23.3	12.7	46.7
OH131.1 + Folicur	2.5	22.7	9.5	42.5
OH182.9WT+OH131.1	3.4	26.0	13.2	51.2
OH182.9FT+OH131.1	2.3	23.0	15.4	55.0
OH182.9FT+OH131.1+BAS	2.5	22.0	11.3	42.1
OH182.9FT+OH131.1+Fol	2.4	22.3	13.1	52.9
$LSD_{(0.05)}$	NSD	NSD	2.8	8.8

[1]Within a column, the LSD value represents the critical value for separating treatment means at the P#0.05 level. Disease severity values are arc sine transformed.
[2]Weak PO4 buffer (Schisler et al., 2002) and 0.036% Tween 80.
[3]Applied at recommended label rates.
[4]WT= wild type of strain, FT= Fungicide tolerant natural variant of strain
[5]OH 182.9 WT and FT CFU/ml ~ 5×10^7, OH 131.1 CFU/ml ~ 1×10^8

EVALUATION OF FUNGICIDES FOR THE CONTROL OF FUSARIUM HEAD BLIGHT AND LEAF DISEASES ON 'ELKHART' AND 'PIONEER VARIETY 2540' WINTER WHEAT IN MISSOURI

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OBJECTIVES

To identify fungicides and biological control products that are effective in minimizing the damage from Fusarium head blight in winter wheat.

INTRODUCTION

The severity of Fusarium head blight epidemics in the United States has caused enormous yield and quality losses in wheat and barley (McMullen, *et al*., 1997). The development of this disease is dependent on host genetics, a range of favorable environmental conditions, the prevalence of the causal fungus and the survival and spread of the cause fungus (Sutton, 1982). Control of this disease has been difficult because of the complex nature of the host/pathogen interaction. In addition to the development of varieties with resistance to Fusarium head blight, research focusing on fungicide and biological treatments for the management of Fusarium head blight has been pursued.

In 1998, a Uniform Fungicide Trial was conducted across seven states (McMullen, 1998), which provided data on efficacy of five products or product combinations in reducing Fusarium head blight when applied at heading. This Uniform Fungicide Trial permitted evaluation of the performance of products across numerous states or sites, wheat classes and environments. Across the test sites that had substantial Fusarium head blight in 1998, an average of about fifty percent reduction in Fusarium head blight occurred, as well as a reduction in DON for most products, plus a substantial reduction in wheat leaf diseases. The Uniform Fungicide Trial has been continued since 1998 with additional test sites in more states and changes in products tested as new fungicides and biological control agents have become available. The Uniform Fungicide Trial continues to provide valuable information on efficacy and performance consistency of standard fungicides, new experimental fungicides and biological control agents. Missouri has participated in the Uniform Fungicide Trial since 1998 (Sweets, 2000). Results from the 2002 trial are presented in this report.

MATERIALS AND METHODS

Seven fungicide or biological control treatments and an untreated control were evaluated on 'Elkhart' and 'Pioneer variety 2540' soft red winter wheats at the Bradford Research Center, near Columbia, MO. 'Elkhart' and 'Pioneer variety 2540' were drilled directly into soybean stubble on 12 Oct 01. The soil type at the site was a Putnam silt loam. The planting rate was 100-lbs of seed/A. The experimental design for each variety was a randomized complete block with 6 replications. Individual plots were 4.5 ft (7 rows) by 30 ft in length. The entire plot

area was fertilized with 30-lbs/A nitrogen pre-plant followed by 90-lbs/A nitrogen topdressed in the spring. Treatments were applied with a CO_2 backpack sprayer with nozzles directed towards the heads. Treatments were applied in 400 ml of water. Applications were made at Feeke's Growth Stage (FGS) 10.51 on 14 May 02. Plots were rated for foliage diseases on 28 May 02. Ratings were done as estimates of the percentage of leaf area covered with Septoria leaf blotch or leaf rust on each of 10 flag leaves randomly collected from each plot. Fusarium head blight incidence and head severity measurements were taken 30 May 02. For harvest the plots were end trimmed and individual plot lengths measured. Plots were harvested on 25 June 02 with a Wintersteiger plot combine. Test weight and moisture were determined with a Dickey-John GAC 2000 Grain Analyzer. Samples were submitted to the Veterinary Diagnostic Services Department at North Dakota State University for DON analysis. Data was statistically analyzed using ANOVA.

RESULTS AND DISCUSSION

Plants emerged well and early stands were uniform. The 2002 season was warm and dry early; cool and wet as the wheat was flowering and heading; and then hot and dry as the crop matured. Septoria leaf spot and leaf rust did not begin to develop until late in the season. When foliage disease ratings were made, the level of leaf rust was very low across the trial so only Septoria leaf blotch ratings were recorded. Fusarium head blight was also in very low levels throughout the plot at the time Fusarium head blight incidence and severity ratings were made. However, the number of heads showing symptoms of Fusarium head blight seemed to increase as the crop matured. At harvest most plots had noticeable amounts of shriveled, lightweight kernels or tombstone kernels. Barley yellow dwarf was prevalent throughout the trial. Low temperatures in May caused head damage across the plot area. Hail on May 12 damaged plants and heads across the plot area.

The yield of the untreated control was significantly lower than the yields for the seven fungicide and biological control treatments on Pioneer variety 2540. There were no statistically significant differences in yield between the seven treatments and the untreated control on Elkhart. Septoria leaf blotch ratings were significantly higher for the untreated control than the seven fungicide and biological control treatments on both Pioneer variety 2540 and Elkhart. Septoria leaf blotch ratings were significantly lower with TrigoCor 1448 + Folicur 3.6F + Induce on Pioneer variety 2540 and with TrigoCor 1448 + Folicur 3.6F + Induce and Folicur 3.6F + Induce on Elkhart. Although there were no statistically significant differences between the untreated control and any of the seven treatments for percent of Fusarium head blight incidence, percent average head severity, percent field severity or percent of scabby kernels on Pioneer variety 2540, the untreated control was at the high end of the range for each of these. The AMS 21619A 480SC + Folicur 3.6F + Induce treatment tended to be at the low end of the range for percent Fusarium head blight incidence, percent average head severity and percent field severity. The two AMS 21619A treatments had significantly lower levels of DON than the untreated control and the other five treatments. On Elkhart there were statistically significant differences between treatments for percent Fusarium head blight incidence, percent average head severity, percent field severity, percent scabby kernels and DON levels. The two AMS 21619A treatments had consistently low ratings for all of these variables with the combination of AMS 21619A 480SC + Folicur 3.6F + Induce performing slightly better than the AMS 21619A 480SC + Induce. The OH189.2 biological control agent had the most variation in

results. The OH189 treatment had low percent of Fusarium head blight incidence, moderate percent of average head severity and percent of field severity but high percent of scabby kernels and DON levels compared to the other treatments. The untreated control for Elkhart had the highest percent of Fusarium head blight incidence, percent average head severity and percent of field severity and among the highest percent of scabby kernels and DON levels.

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Table 1. Elkhart

Treatment and Rate/A	Yield[1] bu/A	Test Wt. (lb/bu)	SLB Rating[2]	%FHB[3]	% Ave. Head Sev.[4]	% Field Sev.[5]	% Scab Kernels[6]	DON ppm
Untreated control	42.8	61.0	3.62	18.33	12.05	2.12	10.7	2.23
Folicur 3.6F 4.0 fl oz + Induce 0.125% v/v	42.3	61.6	0.17	8.33	5.08	0.68	7.9	1.68
AMS 21619A 480SC 5.7 fl oz + Induce 0.125% v/v	45.8	61.8	0.27	1.67	1.17	0.12	7.0	1.18
BAS 505F 50WG 6.4 oz + Induce 0.125% v/v	45.2	61.4	0.52	3.33	1.17	0.23	9.1	1.77
OH 182.9~5 x 10e8 cfu/ml	44.1	61.0	0.18	1.67	2.33	0.23	11.8	2.28
TrigoCor 1448~7.5 x 10^12^cfu/A	42.7	60.6	0.53	3.33	2.33	0.23	11.0	1.90
TrigoCor 1448~7.5 x 10^12^cfu/A + Folicur 3.6F 4.0 fl oz + Induce 0.125% v/v	44.4	60.4	0.17	8.33	6.83	0.68	9.6	1.53
AMS 21619A 480SC 3.6 fl oz + Folicur 3.6F 4.0 fl oz + Induce 0.125% v/v	45.0	62.1	0.23	0.00	0.00	0.00	7.8	1.10
LSD (P=0.05)[7]	NS	NS	0.86	6.81	4.35	0.62	2.9	0.36

[1]Yield based on 60-pound bushel weight adjusted to 13% moisture content

[2]SLB rating or Septoria leaf blotch rating based on the average % of flag leaf showing symptoms for 10 flag leaves.

[3]% FHB or percent of Fusarium head blight incidence based on % of heads showing symptoms for 50 heads.

[4]% ave. head sev or percent of average head severity based on % of head showing FHB symptoms for 50 heads.

[5]% field sev or percent field severity calculated using the formula (%FHB x % ave. head sev.)/100.

[6]%scab kernels or percent scabby kernels based on % scabby kernels in a 200 kernel sample.

[7]Data was analyzed by ANOVA with means separated by LSD at P=0.05.

Table 2. Pioneer variety 2540

Treatment and Rate/A	Yield[1] bu/A	Test Wt. (lb/bu)	SLB Rating[2]	%FHB[3]	% Ave. Head Sev.[4]	% Field Sev.[5]	% Scab Kernels[6]	DON ppm
Untreated control	51.8	60.2	4.40	10.00	4.88	0.84	12.7	2.17
Folicur 3.6F 4.0 fl oz + Induce 0.125% v/v	56.8	60.6	1.12	6.67	4.50	0.45	10.8	1.62
AMS 21619A 480SC 5.7 fl oz + Induce 0.125% v/v	59.4	61.0	1.07	5.00	7.00	0.70	11.5	1.08
BAS 505F 50WG 6.4 oz + Induce 0.125% v/v	60.9	61.1	0.97	6.67	3.60	0.88	9.5	1.72
OH 182.9~5 x 10e8 cfu/ml	54.1	60.5	1.25	3.33	2.33	0.23	10.4	1.72
TrigoCor 1448~7.5 x 10^12^cfu/A	53.5	60.4	1.33	5.00	1.55	0.46	11.9	2.05
TrigoCor 1448~7.5 x 10^12^cfu/A + Folicur 3.6F 4.0 fl oz + Induce 0.125% v/v	56.1	60.6	0.80	5.00	2.77	0.44	9.8	1.63
AMS 21619A 480SC 3.6 fl oz + Folicur 3.6F 4.0 fl oz + Induce 0.125% v/v	57.6	60.8	1.18	1.67	2.00	0.20	11.0	1.17
LSD (P=0.05)[7]	4.6	NS	0.67	NS	NS	NS	NS	0.26

[1]Yield based on 60-pound bushel weight adjusted to 13% moisture content

[2]SLB rating or Septoria leaf blotch rating based on the average % of flag leaf showing symptoms for 10 flag leaves.

[3]% FHB or percent of Fusarium head blight incidence based on % of heads showing symptoms for 50 heads.

[4]% ave. head sev or percent of average head severity based on % of head showing FHB symptoms for 50 heads.

[5]% field sev or percent field severity calculated using the formula (%FHB x % ave. head sev.)/100.

[6]%scab kernels or percent scabby kernels based on % scabby kernels in a 200 kernel sample.

[7]Data was analyzed by ANOVA with means separated by LSD at P=0.05.

REPORT ON INDUCED RESISTANCE AND FIELD BIOLOGICAL CONTROL OF FUSARIUM HEAD BLIGHT BY *LYSOBACTER ENZYMOGENES* STRAIN C3

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ABSTRACT

The bacterial biocontrol agent *Lysobacter enzymogenes* strain C3 was previously reported to be effective in field tests against a number of fungal pathogens in turfgrass and against rust in common bean. C3, when applied as a chitin broth culture, also inhibited leaf rust (*Puccinia triticina*), spot blotch (*Bipolaris sorokiniana*), and Fusarium head blight (FHB) (*Fusarium graminearum*) on wheat in laboratory and greenhouse experiments. Chitinolysis was one mechanism by which C3 suppressed a number of pathogens. Induced resistance involving a heat stable elicitor also is a mechanism in the control of *Bipolaris sorokiniana* by C3. One objective in this study was to determine if induced resistance could be involved in the control of FHB by C3. Another objective was to assess the potential for using C3 to control FHB under field conditions. Induced resistance was investigated in greenhouse experiments in which chitin broth culture of C3 was compared with a culture heated to 70°C for 20 minutes, and with a distilled water control. The heat treatment was intended to kill C3 cells and inactivate lytic enzymes excreted into the broth, but leave the elicitor intact. All treatments were sprayed onto wheat heads 1 day prior to inoculation with pathogen conidia. Both C3 treatments significantly reduced scab infection as compared to the distilled water check, suggesting that FHB inhibition could be due to induced resistance. A field test was conducted at South Dakota State University in collaboration with Yue Jin to evaluate the interaction of C3 and spring wheat genotypes in the control of FHB. Three treatments (C3 chitin broth culture, Folicur, and water) were applied at anthesis to four cultivars (Alsen, Ingot, Russ, and Norm) that differ in susceptibility to FHB. Plots were inoculated with suspensions of pathogen conidia and misted at night to favor development. Disease severity in three of the four cultivars was reduced by Folicur. C3 significantly reduced FHB severity in 'Russ' (39% infected spikelets) as compared to the control (48% infected spikelets), but had no effect on disease development in the other cultivars. The highest levels of FHB occurred in 'Russ', and thus, lack of C3 efficacy in the other cultivars could be explained in part by low disease development. Differential C3 activity on different cultivars also is a possible explanation. C3 colonized wheat heads and increased in numbers to the same extent on all of the cultivars. This suggests that C3-cultivar interactions may be related to induced resistance rather than antagonism.