CHEMICAL, CULTURAL AND BIOLIGICAL CONTROL

Chairperson: Marcia McMullen

EAR SPRAY TARGETING FOR IMPROVED EAR BLIGHT AND MYCOTOXIN CONTROL

Aldred, D.[1], Magan, N.[1*], Orson, J.[2], Parkin, S.[3] and Miller, P.[3]

[1]Applied Mycology Group, Cranfield University, Silsoe, Bedford MK45 4DT, United Kindgom; [2]Morley Research Centre, Wymondham, Norfolk NR18 9DB, United Kingdom; and [3]Silsoe Research Institute, Wrest Park, Silsoe, Bedford MK45 4HS, United Kingdom

[*]Corresponding Author: PH: 44 1525 863539; E-mail: n.magan@cranfield.ac.uk

OBJECTIVE

There has been interest in improving the targeting of fungicide applications to ripening ears during the crucial anthesis period to provide more effective control of Fusarium head blight development and prevention of mycotoxin contamination.

This study was conducted to examine different spray application techniques for more effective coverage of ripening ears.

INTRODUCTION

Fusarium infection is of concern because of impacts on crop yield and quality and the concomitant contamination with trichothecene mycotoxins, particularly deoxynivalenol (DON) which are produced under conducive environmental conditions during ripening of cereals. Suppression of FHB is partially achieved by the application of fungicides. However, detailed examination of the most effective spray systems for targeting of applications on the ear have not been examined in detailed. Thus this study examined a range of different spray systems for examining efficacy for better control of FHB in cereals in the UK.

MATERIAL AND METHODS

A series of experiments were done to examine deposits of fungicide and trace dyes on coverage of ears of ripening wheat plants in a wind tunnel. Conventional flat fan, 10o angled air induction nozzle, two conventional flat fan nozzles at 45°, one forward and one back (twin cap), wide angle hollow cone coarse spray, conventional flat fan nozzle 45° backword fine spray, conventional flat fan 45° medium spray, wide angle hollow cone fine spray, pre-orifice flat fan and 10° angled air induction nozzle were examined. All were used at 150 l/ha except the final treatment which was at 100 l/ha.

A field trial had been conducted for two years with 4 spray treatments (Conventional flat fan, 10° angled air induction nozzle, pre-orifice flat fan nozzle and a fine hollow cone nozzle. Three fungicides were used: 0.3 l Amistart + 0.3 l/ha folicur; 1.2 l/ha UK187; 0.6 l/ha UK 187. There were all applied at the beginning of anthesis. A full factorial experiment was carried out and the treatment plots were sprayed with a spore suspension of *F. culmorum* three days prior to fungicide application. 100 ears per plot were collected two weeks after spraying and immediately prior to harvest for analysis of DON and nivalenol (NIV). These were analysed using the method described by Ramirez et al. (2004).

RESULTS

The final grain yield was best in the full UK 187 application. There was a gradation of effect with this treatment being the best. There was a trend for the three test-application systems to be better than the conventional flat fan nozzle. There was a marked effect of fungicide treatment on FHB assessed two weeks after fungicide application. However, the effect was not directly related to type of spray system used. Analysis of DON and NIV using HPLC showed that most treatments had < 750 ng/g. In 2003 there was a significant natural contamination with *F. poae* and thus NIV levels were slightly higher than for DON concentrations found in the ear samples.

In 2004 the experiment showed that there was less FHB immediately after anthesis than in 2003. Thus FHB symptoms and DON/NIV levels were very low, with a high isolation of *F. graminearum* than *F. culmorum*. The efficacy of spray treatments are still being analysed.

DISCUSSION

This study is still in progress and the results obtained so far does not indicate that the four different types of spray systems employed have a significant effect on FHB or on mycotoxin levels. However, the droplet size impacting on the ears and the coverage may be critical parameters which will influence the level of control of FHB achieved.

REFERENCES

Ramirez, M.L., Chulze, S. & Magan, N. (2004). Impact of environmental factors on growth and deoxynivalenol production by *Fusarium graminearum* isolates from Argentinian wheat. ***Crop Protection*** 23, 117-125.

INTERACTIONS BETWEEN WHEAT APHIDS AND FUSARIUM HEAD BLIGHT AND THEIR INTEGRATED MANAGEMENT IN DURUM WHEAT IN INDIA

Paramjit S. Bagga* and Sweety Kaur

Punjab Agricultural University, Regional Research Station,Gurdaspur-143 521, Punjab, India
*Corresponding Author: PH: (91) 1874-221042; E-mail: psb_gsp@yahoo.com

OBJECTIVES

To investigate the role of wheat aphids in Fusarium Head Blight development and their integrated management in durum wheat.

INTRODUCTION

Fusarium Head Blight (FHB) in wheat (*F.graminearum, F. nivale*) has become a disease of serious concern, since the unusual epidemics in Punjab, North West India, in the early 1990s which had apparently resulted from the higher frequency of rains during flowering and the susceptible cultivars grown. Since the disease is of limited importance in India, resistance breeding is presently not conducted against FHB in the region. It has been observed that a large proportion of wheat heads affected by FHB were also heavily infested with aphids which suggests that the wheat aphids may have a role in FHB development. Wheat is affected by several species of aphids worldwide. In addition to direct feeding damage, many of the wheat aphids serve as vectors of serious virus diseases such as Barley Yellow Dwarf Virus (BYDV) (Wiese, 1977). Mites, thrips and aphids are reported as suspected vectors for *Fusarium poae* infection in Swedish cereals (Peterson and Ovlang,1997). Diehl and Fehrmann (1989) reported that mechanical injury or aphid attack led to a significant increase in the number of leaf lesions caused by *Gerlachia nivalis* in wheat. Our objective in this study was to find out the role of wheat aphids in FHB development, both in-vitro and field trials, and their integrated management through fungicides and insecticides.

MATERIALS AND METHODS

Reaction of wheat cultivars to aphids and FHB in the field - Reactions of seven commercial cultivars of wheat, four bread wheats (PBW 343, PBW 154, WH 542, HD 2687) and three durum wheats (PDW 274, PDW 233, PBW 34) to aphid infestation and FHB were studied under natural field infection. Four replicated plots (4.0*1.25 sq.m) of each cv. were sown in the field. The incidence of wheat aphids and FHB was sufficiently high to differentiate the reaction of different wheat cultivars. Observations on mean number of aphids /leaf and head and number of FHB infected heads /plot and number of infected spikelets/spike were recorded.

In-vitro* interactions between wheat aphids and *Fusarium - Spikes of durum wheat cv. PDW 274 (highly susceptible to FHB) were chosen at the boot stage, surface sterilized with sodium hypochlorite solution and placed on the surface of 0.5% water agar containing 10 mg l-1 benzimidazole as a senescence retarder in Petri plates (2 spikes/plate and four replications). There were six treatments viz; T1- Spikes infested with aphid alone, T2- Spikes inoculated with Fusarium sp. alone, T3- Simultaneous inoculation/infestation of Fusarium sp. and aphids, T4- Aphid infestation followed 72 h later by Fusarium sp. inoculation, T5- Inoculation of Fusarium sp. followed 72 h later by aphid infestation, T6-Control. Spikes were infested in the center with a mixture of 10 aphid nymphs /spike and a 5 mm mycelial disc of Fusarium sp. grown on PDA and incubated at 25ºC. Observations on % spike area bleached and % FHB infected spikelets /spike were recorded after 10-15 days.

Effect of Monocrotophos on aphid control and FHB- A field experiment was conducted with a durum wheat cv. PDW 274 (FHB susceptible), planted into rice stubble. Four replicated plots (4*1.25 sq.m) per treatment were sprayed at heading with Monocrotophos insecticide. There were two treatments viz; T1- Monocrotophos @ 0.1%- single spray, T2 –Monocrotophos @ 0.1%-two sprays. Data on aphid infestation /leaf and head and FHB were recorded at soft dough stage of grain development.

Integrated control of Aphids and FHB in the field- Field experiments were conducted with a durum wheat cv. PDW 274 (highly susceptible to FHB), under natural field infection in 2002-03. There were six treatments viz; T1- Propiconazole 0.1%, T2- Monocrotophos 0.1%, T3- Propiconazole 0.1% + Monocrotophos 0.1%, T4- Propiconazole 0.1% followed 72 h later by Monocrotophos 0.1%, T5- Monocrotophos 0.1% followed 72 h later by Propiconazole 0.1%, T6 – Control treatment. Four replicated plots (4.0*1.25 sq. m) per treatment were treated at Feekes growth stage 10.51(flowering). Both the aphid infestation and FHB development were sufficiently high which facilitated evaluation of these treatments. Data on mean number of aphids/leaf and head, number of FHB infected heads/plot and % infected spikelets/spike, grain yield (kg/plot) and thousand grain weight (TGW) were recorded. Data obtained in all the experiments were analyzed statistically and coefficient of correlation (r) between aphids and FHB were determined.

RESULTS AND DISCUSSION

Cultivar reaction- Both the bread wheats and the durum wheats were affected by aphids but aphid infestation was found to be more on heads than on leaves (Table 1). Among the bread wheats, the FHB susceptible cv. PBW 154 which had the highest aphid infestation on heads, also had the highest FHB infection where as the FHB moderately resistant cvs. PBW 343, WH 542 and HD 2687 had much lower aphid infestation and FHB infection. However in durum wheats, there was no apparent relationship between aphid infestation and FHB infection. Significant positive correlations (r = 0.97) were found between the mean number of aphids/head and the number of infected spikelets/spike in wheat cultivars.

In the Laboratory- In-vitro interactions between wheat aphids and FHB, conducted on water agar in Petri dishes(Table 2), showed that Fusarium sp. and aphids when inoculated /infested simultaneously, or when aphid infestation followed 72 h later by *Fusarium* species resulted in higher % infected spikelets/spike (11.0% and 6.2 %, respectively) and % spike area bleached, in comparison with *Fusarium spp*. inoculated alone (5.5%) or when *Fusarium spp.* inoculation followed 72 h later by aphids (4.0 %).

Effect of Monocrotophos on aphid control and FHB- Application of a single spray of Monocrotophos @ 0.1% at heading (Table 3) significantly reduced the mean number of aphids/head and simultaneously reduced the mean number of FHB infected spikes/plot (25.2%) and number of infected spikelets/spike (25.2%), resulting in significant increase in grain yield (20.0%) and thousand grain weight, in comparison with the control treatment, in a susceptible durum wheat cv. PDW 274. Significant positive correlation between aphids and number of infected spikes/plot (r = 0.99) and grain yield (r = 1.0) were found in this trial.

Integrated management- In another field trial on integrated management of wheat aphids and FHB (Table 4), application of Propiconazole and Monocrotophos alone @ 0.1% each, significantly reduced the mean number of infected spikes/plot by 60 % and 42 %, respectively whereas their combined application further reduced the number of infected spikes/plot by 66.7%, improved grain yield by 37 % and thousand grain weight. However, the treatment in which application of Propiconazole was followed 72 h later by Monocrotophos, was the most effective treatment and significantly reduced the number of infected spikes /plot by 76.9% and the number of infected spikelets/spike, resulting in significant increase in grain yield (32%) and thousand grain weight. Significant positive correlations were found between the number of aphids and % infected spikes/plot.

The results suggest that wheat aphids are important in FHB development and that controlling aphids in the field with Monocrotophos, can significantly reduce FHB disease and increase grain yields. Wheat cultivars that are poor hosts for aphids offer the most promise in reducing FHB.

REFERENCES

Diehl,T; and Fehrmann,H. 1989. Wheat fusarioses- influence of infection date,tissue injury and aphids on leaf and ear attack. Journal of Plant Diseases and Protection. 96:393-407.

Peterson, H ; and Ovlang , H.1997. Trichothecene production by *Fusarium poae* and its ecology. Sydowia - special issue, 217-218.

Wiese, M.V.1987. Compendium of wheat diseases. St.Paul: American Phytopathological Publication,112 pp.

Table 1. Reaction of wheat cultivars to Aphid infestation and Fusarium Head Blight under natural field infection, 2002-03.

Cultivar	Heading Date	FHB Reaction	Number of Aphids		FLB (%)	Fusarium Head Blight	
			Leaf	Head		No.infected spikes/plot	No.infected spikelets/spike
Bread wheat PBW 343	4/3	MR	0.85	3.27	15	5.2	1.97
PBW 154	25/2	S	1.50	8.75	25	51.0	3.23
WH 542	6/3	MR	2.12	5.12	05	9.5	2.40
HD 2687	6/3	MR	1.37	2.87	15	14.2	1.67
Durum wheat PDW 274	10/3	S	1.25	1.95	10	86.7	4.42
PDW 233	13/3	MR	1.57	2.90	05	17.2	3.54
PBW 34	10/3	S	1.22	4.57	05	36.2	3.50
CD at 5%			NS	1.99	1.78	6.41	0.88
Correlation coefficient (r) between number of aphids and FHB						- 0.03	0 .97**

Table 2. In-vitro interactions between Aphids and *Fusarium spp.* on water agar in Petri dishes.

Treatments	% Spike area bleached	% FHB infected spikelets/spike
T1- Aphid alone	27.50	-
T2- Fusarium sp. alone	39.27	5.5
T3- Aphid +Fusarium sp.	60.71	11.0
T4- Aphid followed 72h later by Fusarium sp.	35.00	6.2
T5- Fusarium sp.followed 72h later by Aphid.	25.00	4.0
T6- Control	0.0	0.0
CD 5%	22.0	1.93

Table 3. Effect of Monocrotophos on Aphids and FHB in durum wheat cv. PDW 274 under natural field infection, 2002-03.

Treatments (%)	No.of Aphids Leaf	Head	Fusarium Head Blight No.infected spikes/plot	No.infected spikelets/spike	Grain Yield (Kg/plot)	TGW (g)
T1- Monocrotophos,0.1 Single spray	0.30	0.60	95.75(25%)	4.12(25%)	3.55(20%)	45.93
T2- Monocrotophos,0.1 Two Sprays	0.07	0.02	96.50	4.15	3.78	46.10
Control	1.7	3.17	128.25	5.55	2.95	40.14
CD 5%	0.81	0.99	NS	NS	0.28	4.2
Correlation coefficient (r) between Aphid and FHB			0.99**	-0.275	1.0*	

Table 4. Integrated management of Aphids and FHB in durum wheat cv. PDW 274, under natural field infection, 2002-03.

Treatment (%)	No. of Aphids Leaf	Head	Fusarium Head Blight No. Infected Spikes/plot	% Infected Spikes	No.Infected Spikelets/spike	Grain Yield (Kg/plot)	TGW (g)
T1- Propiconazole,0.1	5.77	4.30	45.5 (60.0%)	1.98	3.64	3.350	45.47
T2- Monocrotophos,0.1	0.02	0.12	66.7 (42.0%)	2.91	4.57	4.087	48.76
T3- Propiconazole + Monocrotophos	0.07	0.10	38.2 (66.7%)	1.66	3.76	4.300	51.12
T4- Propiconazole followed 72h later by Monocrotophos	0.07	0.52	26.5 (76.9%)	1.15	2.77	4.137	50.92
T5- Monocrotophos followed 72h later by Propiconazole	0.20	0.15	34.7 (69.8%)	1.51	2.65	4.037	51.16
T6- Control	8.0	11.6	115.0	5.02	5.73	3.125	40.79
CD 5%	3.33	3.68	22.5	1.64	1.49	0.25	
Coefficient of correlation (r) between Aphids and FHB				0.68**	0.38	-0.09	

THE PROMISE AND CHALLENGE OF EMPLOYING BIOLOGICAL CONTROL IN THE INTEGRATED MANAGEMENT OF FUSARIUM HEAD BLIGHT

Gary C. Bergstrom

Department of Plant Pathology, Cornell University, Ithaca, NY, USA
Corresponding Author: PH: (607) 255-7849; E-mail: gcb3@cornell.edu

ABSTRACT

Since cultural measures, fungicides, and resistant cereal genotypes have provided only partial control of Fusarium head blight to date, biological control is being explored as an additional tool in the integrated management of this disease. Microbial antagonists or their metabolites are potentially useful in the disruption of spike infection, fungal spread within the spike, seedling blight development, saprophytic survival of the fungus in crop residues, and fungal sporulation on crop residues. Initial efforts have been focused on bioprospecting for microbial antagonists of *Gibberella zeae*. Bioprotectants have been selected primarily based on their antibiosis and competition abilities, though mycoparasitism, induced resistance, and metabolic inhibition of mycotoxin synthesis are also useful mechanisms of biological control. Numerous isolates of yeast, spore-forming bacteria, and other bacteria have been identified that reduced FHB and/or mycotoxin contamination in laboratory, greenhouse, or small-scale field tests, sometimes with a magnitude of control equivalent to fungicide applications. But a lack of consistency in FHB control, especially in variable field environments, has hampered the transition from the laboratory to meaningful field-testing of biological control agents. Almost nothing is known about the ecology, survival, and antimicrobial activity of biological control agents following their application to plant surfaces in field environments – a fundamental knowledge gap. Some research is underway and much more is needed to define controlled culture systems for producing biological control products of consistently high quality that could then be tested in uniform regional field tests against FHB. Product formulation and application technologies are as or more critical to biocontrol efficacy as they are to fungicide efficacy, yet little research has been conducted in the context of biological control agents. Bioprotectants, especially isolates of spore-forming bacteria, may be combined with foliar fungicides to further reduce FHB mycotoxin contamination in cereal cultivars with partial resistance to FHB. Antifungal metabolites of biological control agents should also be considered as direct tools in the integrated management of FHB. These substances might be applied as foliar sprays or the genes encoding their synthesis might be genetically engineered into cereal crops along with appropriate tissue-specific promoters. While there are significant challenges to overcome, biological control strategies hold considerable promise for contributing to the long-term management of FHB.

USE OF HPLC IN EXAMINING CULTURE SUPERNATANTS OF BACTERIA USED IN BIOLOGICAL CONTROL OF FHB FOR THE PRESENCE OF ITURIN

B.H. Bleakley[1,2*] and N.L. Baye[1]

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

ABSTRACT

Selected strains of bacteria in the genus *Bacillus* can antagonize *Fusarium graminearum* in laboratory, greenhouse, and field-plot studies. In some field plot studies where *Bacillus spp*. have been sprayed on to wheat or barley, symptoms of FHB have been reduced, and/or DON levels in grain have declined. The mechanism of the antagonism is not understood, but may depend in part on bacterial antibiotics, such as cyclic lipopeptides in the iturin family. We have cultured *Bacillus sp. s*train 1BA in a variety of defined (synthetic) and semi-defined broth media that lack glucose (which can suppress iturin production). The three broth media that were studied were: (1) a basal defined medium (BDM) containing mannitol, glutamic acid and inorganic salts; (2) a defined medium (DM) similar to BDM but containing increased amounts of mannitol and glutamic acid; and (3) a defined medium with the same composition as (2) but with increased concentrations of calcium and manganese, two elements which are known to be important in regulating different aspects of *Bacillus* metabolism. Broth cultures of *Bacillus* strain 1BA were grown for different time periods in these three media. At selected time intervals culture samples were aseptically removed for measurement of optical density at 600 nm, and for iturin analysis using HPLC, to see if different phases of bacterial growth resulted in differences in iturin production. Standard curves of iturin A (Sigma) were linear in a range from 50 ug/ml up to 250 ug/ml, with absorption maxima for iturin occurring at 214 nm and 275 nm for each iturin peak. In the BDM broth, maximum OD_{600} of 1.7 was reached after 5 to 6 days of growth, and maximum iturin production occurred at this time (about 720 ug/ml). After this time, iturin levels declined greatly. In the DM broth having increased levels of mannitol and glutamic acid, maximum OD_{600} of 2.5 was not reached until 14 days incubation. However, maximum iturin production was reached around 5 days of growth (OD_{600} of 1.3; iturin production of 400 ug/ml). After 5 to 6 days of growth, iturin production sharply declined in this DM broth. In broth medium (3) containing the same components as (2) but with increased levels of Ca and Mn, maximum OD_{600} of 3.6 was reached after 8 days of growth, giving the highest cell yield of any broth medium. Iturin production in this medium had a much different pattern than the other two, with greatest iturin levels found within the first 24-48 hours of growth (132 ug/ml)., and then declining sharply. Production of iturin in medium (3) was greatest during exponential growth, not stationary phase, and increased levels of Ca and Mn allowed iturin to be produced sooner, during early log to mid log phase of growth. Different growth media will result in different amounts of iturin; and the time of incubation will also affect iturin levels. This has implications for growing these bacteria for field application, in determining medium composition and incubation time.

MICROBIOLOGICAL AND CHEMICAL COMBINATION FOR PROTECTION AGAINST FUSARIUM HEAD BLIGHT OF WHEAT

W.C. da Luz*

Embrapa Trigo, Cx. P. 451, 99001-970 Passo Fundo, RS
*Corresponding Author: PH: 55 54 311 3444; E-mail: wilmar@cnpt.embrapa.br

ABSTRACT

Combinations of tactics for disease management offer a modern means for plant protection and may provide remarkable advantages over each method isolately, resulting in a series of benefits, including control efficacy, consistence, expansion of modes of action, and reduction of pesticide applications. The objetctive of this work was to determine the effect of the combination of bioprotectants with fungicide to control Fusarium Head Blight (FHB) of wheat, induced by *Fusarium graminearum*, under field conditions. Treatments and dosages of active ingredient per hectare were: Tebuconazole (Folicur 200 CE) (150 g); *Pantoea agglomerans* (Embr. 1494) (60 g); *P. agglomerans* (Embr. 1494) (60 g) + Tebuconazole (150 g); *Bacillus megaterium* (Embr. 9790) (60 g); *B. megaterium* (Embr. 9790) (60 g) + Tebuconazole (150 g); *Curtobacterium pusillum* (Embr. 9769) (60 g); *C. pusillum* (Embr. 9769) (60 g) + Tebuconazole (150 g); *Bacillus subtilis* (Trigocor 114) (60 g) and *B. subtilis* (Trigocor 114) (60 g) + Tebuconazole (150 g). A nontreated check was mantained as control. The experimental design was a randomized block with four replications. None of the biological or chemical treatments significantly controlled the disease intensity nor increased grain yield in 2002 and 2003. However the combinations of the biologicals with the chemical treatment significantly reduced the intensity of FHB and provided significant increase in grain yield over the nontreated control in both years of study. Combinations may have an important impact on disease management.

OBJECTIVE

To determine the effect of the interactions of bioprotectants with fungicide to control FHB under field conditions in Brazil.

INTRODUCTION

Fusarium head blight (FHB), induced by *Fusarium graminearum* is an economically significant disease in the south of Brazil. It has been controlled by fungicide treatement applied at the stage of complete anthesis. Biological control has been studied using several bioprotectants (Perondi et al., 1996; Luz 2000; Luz et al., 2003). This study included both biological and chemical products alone or in combination to control FHB.

MATERIAL AND METHODS

Treatments and dosages of active ingredient per hectare were: Tebuconazole (Folicur 200 CE) (150 g); *Pantoea agglomerans* (Embr. 1494) (60 g); *P. agglomerans* (Embr. 1494) (60 g) + Tebuconazole (150 g); *Bacillus megaterium* (Embr. 9790) (60 g); *B. megaterium* (Embr. 9790) (60 g) + Tebuconazole (150 g); *Curtobacterium pusillum* (Embr. 9769) (60 g); *C. pusillum* (Embr. 9769) (60 g) + Tebuconazole (150 g); *Bacillus subtilis* (Trigocor 114) (60 g) and *B. subtilis* (Trigocor 114) (60 g) + Tebuconazole (150 g).

The experiment, were carried out in the field in Passo Fundo, RS, Brazil in a randomized complete block design with four replications. The sowing date was

22nd of june, 2002 and on 20th at june 2003, respectively. Each plot consisted of 12 rows of 3m, spaced by 20cm apart. Treatments were applied at early anthesis. Each plot was rated for disease incidence and severity 21 days after applications scoring by the percent of heads showing disease symptoms. Mature grains were harvested and yield was recorded.

RESULTS

None of the biological or chemical treatments significantly controlled the disease intensity nor increased grain yield in 2002 and 2003 (Table 1). However the combinations of the biologicals with the chemical treatment significantly reduced the intensity of FHB and provided significant increase in grain yield over the nontreated control in both years of study. Combining fungicide and biological agents may have an important impact on disease management for wheat in Brazil.

REFERENCES

Luz, W. C. da. 2000. Biocontrol of Fusarium Head Blight in Brazil. Pages 77-81. Proceedings of the 2000. National Fusarium Head Blight Forum. Michigan State University Printing, East Lansing, MI.

Perondi, N. L., Luz, W. C. da. And Thomaz, R. 1996. Controle microbiológico da giberela do trigo. Fitopatologia Brasileira 21: 243-249.

Luz, W. C. da., Stockwell, C. A., and Bergstrom, G. C. 2003. Biological control of *Fusarium graminearum*. In: Leonard, K. J. & Bushnell, W. R. Fusarium Head Blight of wheat and Barley. P. 381-394. APS Press. 512pp.

Table 1. Microbiological and Chemical Protection of FHB of wheat in the field. Passo Fundo, Brazil. 2002 and 2003.

Treatment	Disease Intensity		Yield/Kg/ha	
	2002	2003	2002	2003
Testemunha	22 b *	23 b *	2788 b *	3012 b *
Tebuconazole	11 b	19 b	2969 b	3141 b
Pantoea agglomerans (Embr. 1494)	17 b	18 b	2883 b	3191 b
P. agglomerans + Tebuconazole	6 a	13 a	3199 a	3463 a
Bacillus megaterium (Embr. 9790)	15 b	17 b	2858 b	3179 b
B. megaterium + Tebuconazole	4 a	10 a	3196 a	3577 a
Curtobacterium pusillum (Embr. 9769)	18 b	19 b	2889 b	3112 b
C. pusillum + Tebuconazole	5 a	12 a	3188 a	3559 a
Bacillus subtilis (Trigocor 114)	16 b	19 b	2871 b	3113 b
B. subtilis + Tebuconazole	3 a	14 a	3189 a	3380 a
CV %	14.5	15.1	9.7	14.7

* Treatment means followed by different letters differ significantly at P= 0.05 according to Fisher's least significant difference (LSD) test.

CULTURAL CONTROL OPTIONS FOR THE MANAGEMENT OF FUSARIUM HEAD BLIGHT IN WHEAT AND BARLEY

R. Dill-Macky

University of Minnesota, Department of Plant Pathology, St. Paul, MN 55108.
Corresponding Author: PH 612-625-2227; E-mail: ruthdm@umn.edu

ABSTRACT

Fusarium head blight (FHB or scab) is a serious disease of wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.). Fusarium head blight reemerged in the Upper Midwest of the U.S. in 1993 and has caused numerous, widespread and severe epidemics throughout much of the U.S. small grains production area in subsequent years. Breeding for disease resistance is a long term solution that will reduce the risk of FHB in both wheat and barley. However, the lack of immunity to FHB in wheat and barley germplasm means that even cultivars with improved FHB resistance are likely to see some disease development, and incur yield losses and quality reductions, when inoculum pressure is high and environmental conditions favorable for FHB development. Chemical and biological control options may be able to reduce the development of the disease but may not reduce the pathogen population or lower the inoculum pressure. Fusarium head blight is caused by *Fusarium graminearum* (Shcwabe) [teleomorph: *Gibberella zeae* Schw. (Petch)], the principal pathogen in the U.S., and several other species in the genus *Fusarium*. The residues of host crops, such as wheat, barley and corn, are considered the principal reservoir of these fungi, providing the inoculum that generate FHB epidemics. Given the incomplete nature of available disease control options, it seems most likely that the successful long term management of FHB, especially in 'at risk' production areas, will rely on an integrated approach to disease management. Disease management employing cultural control options would be a key component in such a management strategy. Cultural control options for FHB management principally focus on crop residues. Crop rotations to avoid planting wheat and barley on *Fusarium*-infested residues has been suggested in the management of FHB since researchers first recognized residues as the principal source of inoculum. Planting wheat directly after wheat or corn should be avoided and where residue decomposition is slow rotations could be extended to allow greater residue decomposition between host crops. The inoculum in residues can be neutralized if buried, which both prevents perithecia formation and the release of spores into the air. Tillage practices can be used to bury residues and/or promote residue decomposition. Similarly fertilizer applications or green manures may increase residue decomposition or reduce the population of *Fusarium* by increasing microbial competition. The removal of residues from field (e.g. baling straw), the infield destruction of residues at the soil surface (e.g. burning) may also aid in reducing inoculum. Cultural control practices are likely to be most effectively used when integrated with disease forecasting models so that the benefit to a future crop can be weighed against the cost of implementing a control option. The success of cultural control practices will ultimately depend on the understanding of the biology of the pathogen, the development of effective practices and the adoption of these practices by wheat and barley producers.

2004 UNIFORM FUNGICIDE PERFORMANCE TRIALS FOR THE SUPPRESSION OF FUSARIUM HEAD BLIGHT IN SOUTH DAKOTA

M.A. Draper[1*], K.R. Ruden[1], K.D. Glover[1], S.M. Schilling[1], D.S. Wittmeier[1] and G. Lammers[1]

[1]Plant Science Department, South Dakota State University, Brookings, SD 57007, USA
[*]Corresponding Author: PH: (605) 688-5157; E-Mail: draper.martin@ces.sdstate.edu

ABSTRACT

Fusarium head blight (FHB – scab) has been a serious concern for wheat and barley producers in South Dakota for ten years. The objective of this study was to continue to evaluate the efficacy of various fungicides and fungicide combinations for the suppression of Fusarium head blight and other wheat diseases. Two hard red spring wheat cultivars, Oxen and Ingot, were planted at three South Dakota locations (Brookings, Groton, and South Shore/Watertown) and Robust barley was planted at Brookings. Data were collected from the barley trial and two of three spring wheat study sites, South Shore/Watertown and Brookings, SD. Little FHB developed at the third site and DON levels were similarly low. A winter wheat study site South Shore/Watertown, was lost due to poor stand associated with dry conditions at seeding. Trial treatments were from the Uniform Fungicide Trial treatments list for the suppression of FHB and included an untreated check, Folicur (tebuconazole) applied at 4.0 fl oz/A, Tilt (propiconazole) applied at 4.0 fl oz/A, JAU6476 (prothioconazole) applied at 5.0 fl oz/A, a premix of JAU6476 (2.85 fl oz/A) + Folicur (3.17 fl oz/A), and V-10116 applied at 4 or 6 fl oz/A. All treatments included Induce, a non-ionic surfactant, applied at 0.125% v/v. Trials were planted in a factorial randomized complete block design with six replications. Trial treatments were applied at anthesis. Plots were inoculated by spreading *Fusarium graminearum*(Fg4) inoculated corn (*Zea mays*) grain throughout the field and providing overhead mist irrigation on a 16 hr/8 hr on/off schedule (overnight mist) throughout anthesis at Brookings. Other sites had natural inoculum from corn stalk residue and natural moisture conditions. Twenty-one days following treatment, plots were evaluated for leaf diseases, FHB incidence, FHB head severity, and FHB field severity. Samples were collected for Fusarium damaged kernels (FDK), deoxynivalenol (DON), grain yield, and test weight. Under dryland conditions at South Shore/Watertown FHB was not severe, with only 4.3% total disease on the untreated. Only Folicur and the V-10116 (6 fl oz) reduced FHB incidence. The same treatments as well as JAU 6476 + Folicur and the low rate of V-10116 significantly reduced total FHB. All treatments but the low rate of V-10116 significantly increased yield while only Tilt increased test weight. Either rate of V-10116 or the JAU 6476 + Folicur mix significantly decreased FDK. All products significantly reduced DON, but none were decreased to levels acceptable to the market. At the mist irrigated site at Brookings, FHB plot severity was greater than 30% on the untreated. All products except Tilt significantly reduced head severity of FHB while plot severity was reduced by JAU 6476, JAU 6476 + Folicur, or either rate of V-10116. While numeric reductions in disease and DON were observed on 'Robust' barley, neither disease nor DON was significantly reduced under mist irrigation conditions.

2004 UNIFORM TRIALS FOR THE PERFORMANCE OF BIOLOGICAL CONTROL AGENTS IN THE SUPPRESSION OF FUSARIUM HEAD BLIGHT IN SOUTH DAKOTA

M.A. Draper[1*], B. Bleakley[1], K.R. Ruden[1], K.D. Glover[1], S.M. Schilling[1], D.S. Wittmeier[1] and G. Lammers[1]

[1]Plant Science Department, South Dakota State University, Brookings, SD 57007, USA
[*]Corresponding Author: PH: (605) 688-5157; E-Mail: draper.martin@ces.sdstate.edu

ABSTRACT

Fusarium head blight (FHB – scab) has been a serious concern for wheat and barley producers in South Dakota for ten years. The objective of this study was to continue to evaluate the efficacy of various fungicides and fungicide combinations for the suppression of Fusarium head blight and other wheat diseases. Ingot hard red spring wheat and Robust barley were planted at Brookings, South Dakota. Trial treatments included an untreated check; Folicur (tebuconazole) applied at 4.0 fl oz/A; TrigoCor 1448 (*Bacillus* sp.) from Cornell University, Ithaca, NY; AS 54.6 (gram positive bacterium) from USDA-ARS, Peoria, IL; C3R5 (*Lysobacter enzymogenes*) from University of Nebraska, Lincoln, NE, and; 1BC (*Bacillus subtilus*) from South Dakota State University, Brookings, SD. Treatments were grown on site according to specifications from their originating labs. Trial treatments were applied at anthesis. Plots were inoculated by spreading *Fusarium graminearum*(Fg4) inoculated corn (*Zea mays*) grain throughout the field at least ten days prior to flowering (wheat) or head emergence (barley) and providing overhead mist irrigation on a 16 hr/8 hr on/off schedule (overnight mist) throughout anthesis at Brookings. Twenty-one days following treatment, plots were evaluated for FHB incidence, FHB head severity, and FHB field severity. Samples were collected for Fusarium damaged kernels (FDK) and deoxynivalenol (DON). Yields were not measured in the barley trial due to significant depredation by birds. Under the mist augmented environment of 2004, FHB was severe at this location. FHB incidence was as high as 60% on wheat and 100% on barley. FHB plot severity ranged from about 14-21% in spring wheat and 15 to 24% in barley. No significant improvements on the untreated were observed among the biological treatments. Also, the Folicur treatment did not provide the level of disease and DON suppression expected from past experiences. Beyond the uniform trial treatments, 1BA (*Bacillus* sp., SDSU, Brookings, SD) was also included in the trial as well as a combined application of 1BC + C3R5. The combined treatment gave no greater response that each component separately. 1BC and 1BA were also grown in a defined medium supplemented with casamino acids. These two isolates responded differently to the casamino acids. 1BA performed numerically better that the same isolate in a standard undefined culture medium, while 1BC performed numerically worse than when grown in a standard medium. Strikingly, the only significant differences recorded in the trial were between 1BA and 1BC grown in the casamino acid culture. 1BA was significantly superior to 1BC from that medium as measured by FDK reduction.

EFFECTIVENESS OF CHEMICAL SEED TREATMENTS IN LIMITING THE SPREAD OF *FUSARIUM GRAMINEARUM* THROUGH INFECTED SPRING WHEAT SEED

M.R. Fernandez[1*] and W. May[2]

[1]Semiarid Prairie Agricultural Research Centre, Agriculture and Agri-Food Canada, P.O. Box 1030, Swift Current, Saskatchewan, S9H 3X2, Canada; and [2] Indian Head Research Farm, Agriculture and Agri-Food Canada, Indian Head, Saskatchewan, S0G 2K0, Canada
[*]Corresponding Author: PH: (306) 778-7255; E-mail: fernandezm@agr.gc.ca

ABSTRACT

The potential spread of Fusarium head blight (FHB) to western regions of the Canadian Prairies is of major concern to wheat and barley growers. Planting *Fusarium*-infected seed may introduce *F. graminearum* into areas that for the most part are still free of FHB. It is therefore of interest to determine the effectiveness of seed treatments in preventing the spread of this pathogen which could result from planting an infected seed lot. In 2003 and 2004, *F. graminearum*-infected seed of common and durum wheat treated with fungicides currently registered in Canada, or untreated, were planted in replicated trials at two locations in eastern Saskatchewan. At stem elongation, 50-75 plants from one row in each plot were removed, and subcrown internodes collected and rated for incidence and severity of discoloration. Pieces of discolored tissue were then surface-disinfested and plated on nutrient agar for fungal identification. In some cases, there was a lower severity of subcrown internode discoloration in the seed-treated than in the untreated control; however, these differences were not consistent and no seed treatment resulted in a lower level of subcrown internode discoloration at both locations and years. *Fusarium graminearum* was recovered from discolored subcrown internodes in all treatments. In addition, percent isolation of *F. graminearum*, and other *Fusarium* spp., from discoloured subcrown internodes in seed-treated plots was in general not significantly different from the untreated control. Based on the observation that none of the products tested appeared to prevent or consistently reduce the growth of *F. graminearum* from infected seed into underground plant tissue, we conclude that treating infected seed with currently registered fungicides will not likely prevent the spread of this pathogen to areas that are still relatively free of this pathogen.

ALTERNATIVE AGENTS AND TARGETS FOR BIOLOGICAL CONTROL OF *FUSARIUM GRAMINEARUM/GIBBERELLA ZEAE*

J. Gilbert[1*], S. Inch[1], W.G.D. Fernando[2], S. Nakkeeran[2], Y. Chen[2] and A. Tekauz[1]

[1]Cereal Research Centre, Agriculture and Agri-Food Canada, Winnipeg, Manitoba; and
[2]Department of Plant Science, University of Manitoba, Winnipeg Manitoba
[*]Corresponding Author: PH: (204) 983-0891; E-mail: jgilbert@agr.gc.ca

ABSTRACT

Studies are underway investigating biological control of *Fusarium graminearum* Schwabe (teleomorph = *Gibberella zeae* (Schwein.) Petch). Several potential fungal and bacterial biocontrol agents are being assessed *in vitro* and under field conditions. The long term objective of all three projects will be to identify the active compounds and mechanisms of control. The first study is examining the biocontrol potential of *Cochliobolus sativus* (Ito & Kuribayashi) Drechs. ex Dastur. *Fusarium graminearum* and *C. sativus* were applied to spikes of CWRS wheat cv. 'McKenzie, during anthesis. FHB severity (FHB Index), levels of *Fusarium* spp. on harvested seed, and plot yields were determined. Substantial reduction of FHB severity and an increase in yield was observed on spikes treated first with *C. sativus* at mid-anthesis followed by *F. graminearum* 2-3 days later. Percent FDK, TKW, Hectoliter weights and DON will be determined for all treatments. The role of antifungal compounds produced by *C. sativus* in the suppression of FHB will be investigated. In a second study, bacterial antagonists, *Pseudomonas chlororaphis* (PA23), *P. chlororaphis* (63), *P. chlororaphis* (314), *Bacillus amyloliquefaciens* (BS6) and *B. subtilis* (H-08-02) were evaluated *in vitro* for their antagonistic action against *F. graminearum*. All antagonists except isolate 314 inhibited pathogen growth. Isolate H-08-02 inhibited mycelial growth of *F. graminearum* by 50.59%. Isolates PA23, BS6 and 63 inhibited the mycelial growth of *F. graminearum* up to 47.36, 43.71 and 36.43% respectively. Culture filtrate of antagonists H-08-02, PA23, BS6 and 63 reduced the germination of macroconidia of *F. graminearum*. Antifungal compounds produced by the antagonists might be responsible for the suppression of pathogen *in vitro*. Evaluation of the efficacy of these isolates to manage FHB under controlled conditions is in progress. A third project is investigating the biocontrol potential of *Trichoderma harzianum* (Rifai). Eleven *T. harzianum* isolates were evaluated by confrontation plate assays. *Trichoderma harzianum* isolates were paired with *F. graminearum* in Petri plates containing PDA. All but one isolate showed some ability to overgrow *F. graminearum*. Isolates T83, T51, T30, and T183 overgrew *F. graminearum* by 20 mm or more. To determine the effect of *T. harzianum* on the production of perithecia and ascospores of *G. zeae* on wheat residue, spore suspensions, or cell-free filtrates of *T. harzianum* isolates, were applied to wheat residues either 24 h before, co-inoculated, or 24 h after, inoculation with *G. zeae*. Plates containing the treated residues were placed under UV light in a randomized complete block design with 4 replicates per treatment. On residues that were inoculated with either spore suspensions or cell-free filtrates of *T. harzianum,* 24 h before *G. zeae*, perithecia and ascospore development were substantially reduced. Residues that were co-inoculated showed moderate reduction. No control was achieved when the residues were inoculated first with *G. zeae*. The effect of spore concentration and mechanisms of control are currently being investigated.

AERIAL FUNGICIDE APPLICATION TECHNOLOGY TO ENHANCE FOLICUR EFFICACY FOR FUSARIUM HEAD BLIGHT (FHB)

S. Halley[1*], V. Hofman[2], S. Panigrahi[2] and H. Gu[2]

[1]Langdon Research Extension Center, North Dakota State University, Langdon, ND 58249,USA; and
[2]Dept. of Agricultural Engineering, North Dakota State University, Fargo, ND 58105, USA
[*]Corresponding Author: PH: (701) 256-2582; E-mail: shalley@ndsuext.nodak.edu

OBJECTIVES

To evaluate the aerial application technology parameters drop size and travel direction to improve efficacy of fungicide for control of Fusarium head blight through improved hard red spring wheat spike coverage.

INTRODUCTION

The purpose of spray application technology research is to enhance fungicide efficacy for control of Fusarium head blight (FHB). Research efforts to control FHB have been accelerated with the initiation of the United States Wheat and Barley Scab Initiative funding program and the severe epidemics that devastated the northern Great Plains region of the United States and Canada in the early 90s. Much of the early trials with fungicide application technology to date have focused on ground application equipment. The reasons for this focus are aerial application technology research is complicated by the cost of the equipment, the necessary skills to operate the equipment, the large area needed to conduct the research, and the limited practical range of adjustment parameters available to aircraft currently being utilized for spray applications. However, aerial spray units currently spray approximately 50% of the acreage treated with fungicides for FHB control in North Dakota. Research to identify efficient aerial spray application technology to enhance fungicide needs to be addressed.

MATERIAL AND METHODS

Trials were conducted with randomized complete block design arranged as a 2 x 2 (drop sizes x spray directions) factorial with four replicates at Hunter and five replicates at St. Thomas in 2003. Hunter is located in east central North Dakota and St. Thomas in northeast North Dakota. An untreated plot was included in trial but not included in statistical analysis. Prior to trial initiation the spray planes were pattern tested with the use of the WRK pattern test system to determine the appropriate orifices and speed needed to obtain the required spray volumes. The pattern test system determines the uniformity of the spray pattern across the swath width which was adjusted to produce the optimum spray pattern for the spray width. The pattern test is useful to identify uneven pattern deposition. A preferred spray pattern should slope out on the edges with the center of the pattern as horizontal or uniform as possible. Adjustments to the pattern can be made by adding or moving nozzles and identifying equipment leaks and taking corrective action. The pattern is adjusted by moving the nozzles and orifices along the boom. Additional orifices can be added or closed to increase or decrease spray volume. The planes used CP nozzles. The drop sizes are adjusted by changing the angle of deflection relative to the travel direction and speed. A straight back delivery has larger drops than deliveries at angles oriented downward. Increased speed decreases drop size. Drop diameters were measured using the WRK DropletScan system. The DropletScan system uses water sensitive paper to determine the drop sizes produced by the spray nozzles. This paper has calculated spread factors which are used to determine drop sizes. The measured values are shown in Table 3.

Both locations were selected for their field uniformity, the skill of the associated cooperator, and the proximity to the aerial applicators that participated in this effort. Collaborators for the trials were farmers Mark Richtsmeier and Pete Carson from Hunter and St. Thomas, respectively and aerial applicators Tim McPherson and Don Hutson from Page, and Grafton, respectively. Two spray planes were used in this study.

The spray planes and application parameters are listed in Table 1.

Water sensitive cards were placed on three stakes at grain head height in the sprayed strips. On each stake, four cards were mounted vertical back to back, two cards oriented parallel with flying direction and 2 cards placed perpendicular to flying direction. An additional card was placed horizontal face up. The results are shown in Table 3. The column titled "area" is an estimate of the area of the paper covered with spray drops. The number is a relative value to compare the vertical front against the vertical back side and the horizontal card. The column titled "VMD" is the volume median diameter of the spray drops deposited on the cards. The column titled "GPA" is the estimated gallons per acre applied as determined from the spray drops deposited on the water sensitive cards. The value is only relative as the GPA applied to the field is determined by the spray applicator and the calibration of the sprayer.

Spike coverage was determined by placing a food grade fluorescent dye (Day Glo) in the airplane spray tank with the fungicide and adjuvant. The dye was added to a tank mix of Folicur fungicide (4 oz/ acre) + Induce adjuvant (0.125% v/v) at 1.75% v/v at St. Thomas and 3% v/v at Hunter. The St. Thomas rate was reduced after consultation with the system developer, Suranjan Panigrahi, North Dakota State University. After the plots were sprayed, grain head samples, 5 per plot, were collected. The samples were placed under an incandescent light followed by an ultraviolet light and photographed. The ultraviolet light delineates the area covered by the fluorescent dye. By subtracting the total area of the spike, determined by the photograph under incandescent light, from the area determined by the fluorescent dye photograph, spike coverage can be computed. Coverage was measured on both sides of the spike to compute mean percent spray coverage of the spike.

A strip, representing one airplane boom width was sprayed for each treatment area. An untreated area between each plot was not treated to minimize drift to the adjacent treatment areas. Treatment areas were 120 ft. on center at Hunter and 90 ft on center at St. Thomas which allowed for five treatments and the subsequent replicates at each location. The field headlands were excluded from all data collection. Large colored flags were placed centrally in each plot at each end of the plot to designate data collection areas after the crop had emerged and all non fungicide pesticide applications had been completed. General hard red spring wheat crop production practices recommended by NDSU Extension were followed by the respective cooperators.

The treatments at both locations included spray solution applications at 2.5 and 5 GPA obtained by making either one or two spray passes. Spray applications were made from east to west for one application treatment and both directions for two application treatments. Twenty grain spikes were evaluated determine incidence and field severity of Fusarium head blight and leaf disease from each of two transects across the treatment areas, one near each end of the respective strip. A grain sub sample from each replicate was retained after combining from the weigh wagon to determine deoxynivalenol concentration, percent protein, and test weight. Data was analyzed with the general linear model (GLM) in SAS. Least significant differences were used to compare means at the 5% probability level.

The Hunter location was previously cropped soybean. The trial was located on the east half of the quarter directly south of a field previously cropped corn. Winds in North Dakota blow predominately from the NW enhancing the potential for Fusarium head blight. The cultivar 'Walworth' hard red spring wheat, susceptible to Fusarium head blight, was planted in early May. Treated plots were 1000 feet long lying in an east-west direction. Fungicide applications were made on 8 July from at 10:00 to 11:00 a.m. about three days after Feekes growth stage 10.51, the optimum time for fungicide application. Fusarium head blight incidence and field severity counts were taken on 21 July. The plots

were harvested on 13 August by threshing the center 30 feet of the spray area with a John Deere model 9600 combine and measuring the sample in a weigh wagon provided by Pioneer and operated by David Strand.

The St. Thomas location was previously cropped sugarbeet. The cultivar 'Oxen' hard red spring wheat, also susceptible to Fusarium head blight, was planted on May 7. Treated plots were 850 feet long lying in an east-west direction. Fungicide applications were made on 7 July from at 9:00 to 11:00 a.m. at Feekes growth stage 10.51 Fusarium head blight incidence and field severity counts were taken on 26 July. The plots were harvested on 18 August by threshing the center 25 feet of the spray area with an AGCO Gleaner model R65 combine and measuring the samples in a weigh wagon.

RESULTS AND DISCUSSION

Levels of FHB disease were small at both locations. No significant differences in FHB incidence or field severity, foliar disease, yield, test weight, and protein were measured at the St. Thomas site. Deoxynivalenol (DON) was not present. No differences in spike coverage were determined between treatments at St. Thomas. Average FHB incidence was less when large drop treatments were compared to small drop treatments at Hunter, 21.3% to 16.9% respectively Table 2. Two spray applications with small drops had smaller yields than two applications with large drops and one application with small drops. The yield data did not correlate with the spike coverage data. The coverage data indicated significantly less backside coverage on the two greater yielding treatments and significantly greater front coverage on the one pass large drop treatment compared to the greater yielding treatments. This seems to infer that the yield increase was not a result of increased fungicide coverage. The data from the water sensitive cards (Table 3) showed almost no coverage on the backside of the papers with one spray application and a 5 to 10 fold increase in backside coverage with a second spray application from the opposite direction. This increase was likely not a significant amount of area covered and enough spray volume deposition compared to front side or to the horizontal card coverage to affect yield. The volume median diameter (VMD) deposition data did contrast drop size between the front and backside of the cards, small drop range 235-299 VMD and large drop range of 340-439 VMD on front side and small drop range 162-182 VMD and large drop range 109-165 VMD on backside. The cards also showed that only relatively small drops deposit on the backside regardless of travel direction indicating the wind likely was a contributing factor to deposition side. The volume medium diameter range, 235-439, also indicates a comparatively large drop selection range can be achieved by aerial spray units with minor adjustments.

ACKNOWLEDGEMENT

This material is based upon work supported by the U.S. Department of Agriculture, under Agreement No. 59-0790-3-079. This is a cooperative project with the U.S. Wheat & Barley Scab Initiative. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture. The authors wish to acknowledge the collaborators Mark Richtsmeier and Pete Carson, producers, and Tim McPherson of Tall Towers Aviation and Don Hutson of Dakota Aviation, aerial applicators. We also wish to express thanks to Pioneer and Bayer CropScience for the use of the weigh wagons and to Bayer CropScience for providing Folicur fungicide and Induce adjuvant to conduct the trial.

Table 1. Aerial application equipment type and spray application technology parameters by location, 2003.

Equipment or Parameter Description	Treatment Parameter	St. Thomas	Hunter
Aircraft Type		**Airtractor**	**502Agtruck**
Nozzle Type & Orifice Size	Small Drops	CP 0.078	CP 0.078
	Large Drops	CP 0.125	CP 0.125
Nozzle Deflection Angle from Horizontal in Degrees	Small Drops	90	30
	Large Drops	0	0
Nozzle Number		34	44
Operating Pressure		30	35
Spray Volume (gpa)	One Pass	5	5
	Two Passes	2.5	2.5
Swath Width (ft.)		50	64
Flying Speed (mph)		118	125
Flying Height (ft. above canopy)		8	8

Table 2. FHB incidence and field severity, leaf disease, yield, test weight, percent protein, DON, and spike coverage by number of spray applications and droplet size at Hunter and St. Thomas, 2003.

# of Spray Applications	Droplet Size	FHB Incidence	FHB Severity	Leaf Disease	Yield	Test Weight	Protein	*DON[a]	**Spike Coverage[b] Back	Front	Mean
		%	%	%	bu/ac	lb/bu	%	Ppm	%	%	%
Hunter											
Untreated	na	22.5	0.9	8.0	68.1	60.6	13.8	0.9	0.1	0.3	0.2
One	large	21.3	1.3	4.1	66.7	miss.	13.7	0.9	1.1	8.4	4.7
Two	large	21.3	1.4	3.4	68.6	61.0	13.6	0.6	0.7	3.5	2.1
One	small	14.4	0.6	2.2	69.0	60.9	13.6	0.7	0.6	2.0	1.3
Two	small	19.4	0.7	7.0	65.8	60.6	13.9	0.9	1.5	5.7	3.6
Applications[c]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Droplet Size		4.0*	NS	NS	NS	NS	NS	NS	NS	NS	NS
Appl.*Drop.		NS	NS	NS	**2.8****	**NS**	NS	0.3*	**0.3***	**4.6****	**2.7****
% CV		19	78	69	3	1	5	23	53	59	57
St. Thomas											
Untreated	na	25.0	1.3	31.5	78.7	61.2	14.0	<0.05	0.82	2.20	1.51
One		19.5	0.7	19.1	82.5	61.4	14.1		0.5	3.3	1.9
Two		19.8	0.8	23.4	81.7	61.4	14.0		0.3	1.5	0.9
	large	19.3	0.7	18.0	82.0	61.3	14.0		0.4	3.0	1.7
	small	20.0	0.8	24.6	82.2	61.5	14.1		0.4	1.9	1.1
Applications		NS	NS	NS	NS	NS	NS		NS	NS	NS
Droplet Size		NS	NS	NS	NS	NS	NS		NS	NS	NS
Appl.*Drop.		NS	NS	NS	NS	NS	NS		NS	NS	NS
% CV		41	45	49	2	1	1		56	87	79

[a] Deoxynivalenol

[b] Hunter dye rate 3.0 % v/v, St. Thomas dye rate 1.75% v/v

[c] *,**, significant at 0.1 and .05 % level, respectively.

Table 3. Coverage Area, VMD, and GPA by Front and Backside of Water and Oil Sensitive Paper on Cards Oriented Vertically and Horizontally by Spray Applications and Droplet Size at Hunter and St. Thomas, 2003.

Spray Applications	Droplet Size	Water and Oil Sensitive Paper								
		Vertical Cards						Horizontal Cards		
		Front side Mean			Backside Mean					
		Area	VMD	GPA	Area	VMD	GPA	Area	VMD	GPA
Hunter										
Untreated [a]		0.1	153	0.04				0.2	138	0.1
Two Sprays	large	6.1	340	2.40	0.07	165	0.04	7.1	373	2.8
One Spray [b]	large									
One Spray	small	7.3	299	2.90	0.12	181	0.04	7.3	292	2.9
Two Sprays	small	4.1	235	1.50	0.64	203	0.20	8.0	240	3.0
St. Thomas										
Untreated [a]		0.1	172	0.04				0.5	170	0.2
Two Sprays	large	10.5	439	3.60	0.02	109	<0.01	[c]	[c]	[c]
One Spray	large	6.7	340	2.50	[c]	[c]	[c]	[c]	[c]	[c]
One Spray	small	2.6	267	1.00	0.03	177	0.01	2.1	214	0.8
Two Sprays	small	[c]	[c]	[c]	0.16	162	0.49	[c]	[c]	[c]

[a]Mean coverage of both sides.
[b]No data due to spray error.
[c]Excessive moisture damaged the cards so no data was included.

EFFECT OF APPLICATION TECHNOLOGY PARAMETERS SPRAY VOLUME AND DROP SIZE ON FUNGICIDE EFFICACY FOR CONTROL OF FUSARIUM HEAD BLIGHT

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

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

OBJECTIVES

The study had two principle objectives: 1) Determine if increasing spray volume can improve fungicide performance for control of Fusarium head blight (FHB). 2) Determine the effects of drop size on fungicide efficacy for control of FHB.

INTRODUCTION

Fungicide applications to small grains for control of FHB have often give results that are inconsistent. Studies have been completed that define application timing parameters that improve on previous results. Studies on application volume and pressure in greenhouse and field environments have show improved coverage of spikes with increasing application volume but still having inconsistent fungicide efficacy. Droplet size is different with changes in volume and this interaction. Possible effects on fungicide efficacy have not been thoroughly examined. This report is a summary of 2004 field application studies completed at Langdon.

MATERIALS AND METHODS

A series of studies using ground application equipment were initiated in 2004 to determine if spray solution volume and drop size can improve the performance of fungicide for the control of Fusarium head blight (FHB). An interdisciplinary team involving agriculture engineering and plant pathology researchers was used to address the application problems. Four trials were established at the Langdon Research Extension Center in spring 2004. Barley, durum and hard red spring wheat (HRSW) were planted to evaluate spray solution volume for improved efficacy of fungicide for FHB control. A fourth study was established on HRSW to measure differences among drop sizes in the category fine, fine, and medium.

The durum and barley spray volume studies were established on an area previously cropped with small grains. The HRSW spray volume and spray drop size studies were established on an area previously cropped soybean. The trials were designed as randomized complete blocks with five replicates on the barley and durum trials and six replicates on the HRSW trials. The soil type was a Barnes-Svea complex. Approximately three weeks prior to heading all trials received an inoculum of 330 grams of barley grains colonized by *F. graminearum*. The inoculum was hand broadcast on individual plots to increase chances of FHB infection. The durum study also received a spray application of *F. graminearum* macroconidia. The macroconidia, 250,000 spores/ml, were applied by CO_2 backpack sprayer in 18.4 GPA water. Five oz/acre of the Bayer experimental fungicide (prothioconazole), JAU 6476 with 0.125% v/v Induce surfactant, was applied to the barley at growth stage Feekes 10.3, and wheat at Feekes 10.51. The spray volumes, 5, 10 or 20 gpa/acre, were applied by CO_2 pressurized tractor sprayer through Spraying Systems XR8001 nozzles on either one or two parallel boom configurations depending on desired volume for the three spray volume studies. The nozzles were mounted on a double swivel and angled 30 degrees downward from horizontal and oriented to spray forward and backward or forward to maximize spike coverage. The spray boom was configured with 5 sets of nozzles on 20-inch nozzle spacing. For the drop

size study Spraying Systems XR8001, XR8002, and XR8003 nozzles were used to attain the fine, fine, and medium drop sizes and applied at 10 gallons water/ acre. The pressure was 40 psi for all the treatments except for the XR8003 nozzles which was 20 psi. The tractor traveled at 6 mph for the studies. North Dakota State University Extension recommended crop production practices for Northeast North Dakota were followed.

Differences between treatments were measured by using water sensitive cards and spike photography. Water sensitive cards were placed back to back on stands and oriented vertically both in the direction of travel and perpendicular to the direction of travel and horizontally. The WRK DropletScan system was used to determine the drop size from deposits on the water sensitive paper. Day-Glo orange dye, mixed with water at 1.75% v/v and Induce adjuvant at 0.125%v/v, was sprayed on additional plots to characterize spike coverage. Grain heads were removed and imaged with a low light CCD camera under incandescent lighting and under ultraviolet lighting to determine total spike area and spray coverage on both the front and back sides of the spike. Twenty-one spikes were photographed from each treatment. Additionally, from the barley spray volume study and the HRSW spray volume and drop size studies, approximately 200 grams of heads were sampled from each of four plots and combined to form two replicates of treatments. The samples were immediately frozen and shipped to Bayer Crop Science to determine fungicide and metabolite residue (Data not reported in this paper). A visual disease estimation was made from 20 samples per plot 20 to 30 days after fungicide application to estimate the FHB incidence (number of spikes infected) and FHB field severity (number of FHB infected kernels per head divided by total kernels per individual spike) of each plot. Each plot was harvested with a Hege plot combine and the grain sample cleaned and processed for yield, protein, and test weight determination and plump on barley. A sub sample was ground and analyzed for the toxin deoxynivalenol (DON) by North Dakota State University. Data was analyzed with the general linear model (GLM) in SAS. Least significant differences (LSD) were used to compare means at the 5% probability level.

RESULTS AND DISCUSSION

The Langdon area mean summer temperatures were colder than the previous low by over 1.5 degrees making this the coldest summer in over 100 years. The amount of disease development in the studies was small and was a reflection of the summer growing environment. Additionally, the fungicides were required to provide protection for much longer periods of time than the normal 20-30 days it takes for the plants to mature in this region. Disease development on the barley study was minimal so only the untreated plots were rated for disease levels. The fungicide treatments with nozzles oriented forward and backward and the five gallon treatment increased the % plump significantly over the untreated (Data not included). No differences were measured in yield or test weight. In the HRSW spray volume study the 5 gpa treatment had the same yield as the untreated (Data not included). The 10 gpa nozzles forward had less yield than the either the untreated or the 5 gpa treatment as did the 10 gpa F+B and the 20 gpa treatments. No differences were measured in test weight or percent protein. The durum spray volume study's disease level was influenced by the crop's susceptibility to FHB, the planting date, and the application of additional inoculum and had the greatest FHB of the studies. Although there were no differences in yield and test weights, all the fungicide treatments reduced FHB incidence and field severity and deoxynivalenol levels significantly (Table 1).

In the drop size study all the fungicide treatments decreased FHB incidence and field severity over the untreated (Table 2). No differences in yield, test weight, and protein were determined. Spray coverage (Table 3) generally was linear by spray volume increasing as gpa increased. The backside of the spike had up to 1/ 5 less coverage than the front side. Forward orientations had less coverage than forward and back orientations. Straight down orientation front on barley were less at 10 gpa than F + B and not different at 5 and 20 gpa. Forward orientation was not different from F + B orientation on barley at 5 or 10 gpa but much less on HRSW at 10 gpa. The durum data was excluded because the fluorescing flowers on tip of the kernels cannot be removed physically or by means of filtering

without affecting the actual spray droplets. Because these flowers occupied relatively larger areas than spray droplets, we can not make conclusions on spray coverage for durum in this case.

From the data on the water sensitive cards several conclusions can be drawn (Table 4). At spray volumes greater than 5 gpa, drop sizes are the same due to sequential deposition on areas previously receiving spray deposits. Smallest drop sizes are associated with cards with very few total deposits. Most of these were on the card side opposite the direction of the prevailing wind gust during application. The cards with the most coverage reflected the direction of the prevailing wind or wind gusts. Fewer spray deposits were found on cards in barley compared to the less dense HRSW canopy. Mean coverage was greater on forward oriented nozzles at 5 gpa than straight down oriented nozzles. F + B nozzle orientation at 20 gpa had greater coverage than all other spray volumes and most orientations. Any benefits of small drop size diminished with spray volumes greater than 5 gpa. There were no differences in coverage by nozzle type.

ACKNOWLEDGEMENT

The study group wished to acknowledge the contributions and support of Bayer CropScience, Marcia Van Ee, Grace Bredeson, and Kristin Karsky. This material is based upon work supported by the U.S. Department of Agriculture, under Agreement Nos. 59-0790-3-079 and 59-0790-9-072. This is a cooperative project with the U.S. Wheat & Barley Scab Initiative. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

Table 1. FHB incidence, field severity, yield, test weight, and DON in durum by spray volume, Langdon 2004.

Spray volume (gallons/acre)	Boom number and nozzle orientation	Fusarium head blight Incidence (%)	Field severity (%)	Yield (bu/ac)	Test weight (lb/bu)	DON[1] (ppm)
untreated		46	4.6	72.7	60.7	3.5
5	1 F	19	1.1	79.0	60.2	0.8
10	2 F	15	0.9	70.7	60.3	0.7
10	1 F+B	16	0.7	80.8	60.5	0.7
20	2 F+B	17	1.3	80.8	60.0	0.9
LSD[2]		19	1.6	NS	NS	1.1
% C.V.		61	68	12	2	59

[1] Deoxynivalenol

[2] Significant at 0.05 probability level for mean comparison

Table 2. FHB incidence, field severity, yield, test weight, and protein in HRSW by spray drop size, Langdon 2004.

Nozzle (gallons/acre)	Drop size category	Fusarium Head Blight Incidence (%)	Field severity (%)	Yield (bu/ac)	Test weight (lb/bu)	Protein (%)
Untreated		60.8	3.1	54.0	56.9	12.7
XR8001	Fine	26.7	0.9	52.0	56.3	12.8
XR8002	Fine	33.3	1.4	54.0	57.0	12.6
XR8003	Medium	25.8	0.9	57.9	56.7	12.6
LSD[1]		18.5	1.3	NS	NS	NS
% C.V.		41	65	20	2	3

[1]Significant at 0.05 probability level for mean comparison.

Table 3. Spike spray coverage by crop, spray volume and nozzle orientation, Langdon 2004.

Crop or spray volume	Nozzle orientation	Area of spray deposition Back (%)	Front (%)	Mean (%)
Barley				
Untreated		0.06	0.04	0.06
5	Straight Down	0.48	2.36	1.42
5	Forward	0.47	1.20	0.83
10	Straight Down	0.15	0.87	0.51
10	Forward	1.66	3.16	2.41
10	F + B[1]	1.31	5.00	3.15
20	Straight Down	1.22	6.83	4.02
20	F + B	1.83	9.50	5.66
LSD		0.8	3.01	1.87
% C.V.		51	48	47
HRSW				
5	Forward	1.1	2.6	1.8
10	Forward	6.1	10.4	8.2
10	F + B	9.2	23.1	16.2
20	F + B	14.9	26.2	20.6
LSD[2]		4.7	8.7	5.5
% C.V.		30	28	23

[1] Nozzle orientation forward and backward
[2] Significant at 0.05 probability level for mean comparison

Table 4. Drop Size and coverage from water and oil sensitive cards, Langdon 2004.

Spray Volume	Nozzle or Orientation[2]	Drop Size $VMD_{0.5}$[1] Hori.	Front	Back	Left	Right	% Coverage Hori.	Front	Back	Left	Right	Mean
Barley												
5	SD	342	247	244	348	297	12.1	2.4	6.1	4.8	1.3	3.6
5	Forward	450	331	298	388	370	28.5	23.1	15.5	11.3	9.5	14.8
10	SD	611	351	387	518	461	48.9	13.2	23.8	12.3	16.1	16.1
10	Forward	559	*	357	460	390	49.4	69.2	1.2	15.1	9.5	23.7
10	F + B	489	343	546	399	408	28.5	6.9	39.7	10.4	20.1	19.3
20	Forward	513	256	474	379	*	53.2	2.4	35.6	7.0	70.2	28.8
20	F + B	545	469	*	484	568	51.5	22.3	66.7	20.3	41.1	37.6
HRSW												
5	Forward	273	341	369	333	298	5.3	1.3	20.4	1.1	9.2	8.0
10	Forward	495	*	122	652	256	26.1	77.5	5.0	63.1	7.5	38.3
10	F + B	510	401	*	653	395	30.9	14.3	66.5	63.7	16.7	40.3
20	F + B	649	552	*	561	918	59.2	30.9	87.5	34.7	75.4	57.2
untreated		243	156	20	15	112	0.1	0.1	0	0	0	0
10	XR8001	607	*	101	574	453	43.1	69.8	0.1	35.5	15.9	30.3
10	XR8002	550	*	142	557	367	39.4	70.9	1.2	25.8	3.5	25.3
10	XR8003	693	770	84	517	369	33.0	66.1	8.0	17.7	15.1	26.7
LSD[3]												9.8
% C.V.												20

[1] Volume median diameter, * represents missing data due to card overload.
[2] SD=straight down, F + B=forward and backward.
[3] Significant at 0.05 probability level for mean comparison.

EFFECT OF APPLICATION OF A SUBLETHAL DOSAGE OF GLYPHOSATE ON FHB SEVERITY IN SPRING WHEAT AND DURUM

Jana M. Hansen[1], Robert W. Stack[1*], Elias Elias[2] and Mohamed Mergoum[2]

[1]Dept. of Plant Pathology; and [2]Dept. of Plant Sci., North Dakota State University, Fargo, ND 58105, USA
[*]Corresponding Author: PH: (701)231-8362; E-mail: robert.stack@ndsu.nodak.edu

OBJECTIVES

To determine whether glyphosate drift onto growing spring wheat and durum plants at a sublethal dosage affects their subsequent susceptibility to FHB.

INTRODUCTION

The 2004 Monsanto decision to withdraw development of "Roundup Ready" wheat for the foreseeable future has somewhat lessened urgency of concern over effects of glyphosate on FHB. Despite that, there have been recent reports that wheat grown on land where glyphosate had been used on a previous crop might have a greater risk of FHB (Fernandez et al., 2004); and reports of tests showing that low levels of glyphosate stimulated growth of *Fusarium* in culture (Hanson and Fernandez, 2003). In wheat country, the use of herbicide resistant cultivars in crops such as soybean and canola has grown dramatically in the past decade. In North Dakota, for example, 74% of the 1.4 million ha of soybean grown were herbicide resistant cultivars as were about 80% of the 0.5 million ha of canola. Together that acreage is equivalent to about one-third of the area planted to spring wheat and durum, making it very likely that a field with a herbicide resistant row crop may be adjacent to a wheat field or in a rotation with a wheat crop.

MATERIALS AND METHODS

In North Dakota, the spring wheat and durum breeding programs maintain nurseries on a university farm at Prosper, ND, some 40 km northwest of Fargo. One of those nurseries is the FHB testing nursery, equipped with overhead mist irrigation and inoculated with *Fusarium graminearum*-infested corn kernels spread on the ground thoughout the nursery. The trials in this nursery use hill plots planted at a spacing of 30 x 45 cm; each hill is one genotype. In replicated trials the hill plots are grouped into blocks based on configuration of the planter but each replicate is in a different block.

In 2003 a plot of "Roundup-Ready" soybeans was located immediately adjacent to the wheat and durum breeding nurseries. The spring wheat and durum FHB nursery was located along the border with the soybean plot. The soybean plot was sprayed with glyphosate during a period when the wind was blowing directly from the soybean plot toward the wheat nursery. The wheat was in the late tillering stage at this time. The wheat border strips (ca. 3 m wide) were killed outright or severely stunted and never recovered. Within the FHB nursery several trials were planted in a randomized complete block design. Four of these replicated trials were located in such a way that some blocks were on the side of the nursery closest to the misapplication and others were on the side farthest away. The closest plots were approx. 3 to 10 m downwind from the directly sprayed area; presumably they were subject to highest exposure and showed visible height reduction at time of flowering. Plants in plots on the side of the nursery farthest away (approx. 40 m) from the spray drift area showed no visual symptoms and grain harvested from these plants appeared normal. Within the exposed plots some individual genotypes appeared to be more affected than others by the drift but all showed some symptoms. The distance from the spray drift source and the most distant blocks was beyond the range considered appropriate for buffer zones for protection of very sensitive vegetation from glyphosate drift (Yates et al., 1978).

FHB scores were taken visually at 3.5 weeks post anthesis. At least 20 individual spikes from each genotype and replicate were scored for FHB symptoms (Stack and McMullen, 1995). Hills were marked individually at anthesis so that FHB scoring was done at the same number of days post anthesis, regardless of the flowering date for the genotype. FHB severity scores were taken on plants in all replicate plots.

In durum, replicate blocks of the Uniform Regional Durum Nursery (URDN) and the Elite Durum Nursery (EDA) were distributed throughout the nursery site. While each trial had different sets of lines, we were able to identify ten genotypes that were present in every replicate block of both of these trials. Two replicate blocks containing those ten lines were adjacent to the glyphosate drift, two most distant, and two were in between.

In spring wheat there were four replicated trials available; these were the Uniform Regional Nursery (URN), the Variety and Advanced Lines Trial (VAL), the Advanced Yield Trial lines (AYT) and the Uniform Regional Scab Nursery (URSN). Because each trial had replicates distributed across the positions in the nursery, we did not attempt to identify a common set of lines but report the means for the entire sets of genotypes in each trial: URN 39 entries; VAL 41 entries; AYT 71 entries; URSN 39 entries.

RESULTS AND DISCUSSION

The FHB severity was significantly lower in the glyphosate affected plants in both spring wheat and in durum. There was no observed relationship between the amount each genotype was visually affected by the glyphosate exposure and its FHB susceptibility.

In durum (Table 1.) the mean FHB severity of the 10 selected lines in the plots closest to the glyphosate drift was 62%, significantly lower than that in the plots midway or most distant from the drift which did not differ from each other (74.9%, 73.7%, respectively).

In spring wheat (Table 2) entire replicates of 39 to 71 genotypes were present in positions adjacent to or distant from the glyphosate source. In each of the four trials represented, the FHB scores of the lines in the blocks closest to the glyphosate were lower than those in the more distant blocks. Differences in location were statistically significant in each of the four trials present.

Given the number of genotypes and number of hill plots involved and the large number of individually scored spikes (over 7,000 in spring wheat, 1,200 in durum), it seems unlikely that the observed systematic differences are simply due to random variation among plots.

Some reports have implied that glyphosate may increase FHB in wheat. Such reports have been seized upon by anti-GMO activists who have interpreted far more into them than the authors themselves. The reports published so far, however, have been based on crops growing on land treated the previous season (Fernandez et al., 2004), or on culture studies with the fungi (Hanson and Fernandez, 2003) - - both are indirect evidence at best. The results we present here are based on crops exposed to glyphosate during the growing season as any possible "Roundup-Ready" wheat would have been. This is quite a different situation than that reported by Fernandez et al.

The opportunity for this study was fortuitous; the misapplication and subsequent spray drift was not planned. The layout of the nurseries with replicate blocks on opposite sides of the nursery was also fortuitous; had the drift come from east or west instead of south to north, it would not have been possible to match up exposed and non-exposed groups of the same genotypes.

The dosage of glyphosate to these plants was not determined but was likely very low since wheat is very sensitive and most plants survived. In a dosage response study of simulated glyphosate drift on wheat, a height reduction of the order seen here was associated with exposure levels in the range of about 3% to 10% of the normal field application rate (Deeds et al., 2005).

Correlations do not prove causation. We examined possible factors which might have resulted in such a pattern of disease. Malfunction of the mist irrigation

or improper distribution of inoculum in this nursery were not found. The soil on which the nursery was located was uniform and had a uniform cropping history over the previous several years.

To guide FHB scoring, every hill in each replicate block was individually marked at flowering time o that each could be scored at the same number of days post anthesis. If the crop were retarded or advanced by the glyphosate exposure, that effect would have been compensated for by the marking procedure and any differences in flowering time in the glyphosate exposed plots were, therefore, unlikely to account for the observed FHB difference. Other factors not investigated might be found to account for these observations although every effort was made to examine such.

The results of Fernandez et al. (2004) are also only correlations, although over several years and locations. In controlled field and greenhouse studies in North Dakota where low doses of glyphosate were applied to wheat, no consistent effect of those treatments to either increase or decrease FHB was found (G. Bresnahan and S. Neate, 2004, Personal communication). Controlled studies under different environmental conditions using proper experimental design are needed to sort out these effects or the lack thereof.

REFERENCES

Deeds, Z.A., D.E. Peterson and K. Al-Khatib. (2005). Wheat response to simulated drift rates of glyphosate and imazamox applied at two growth stages. Weed Technology (submitted).

Fernandez, M.R., F. Selles, D. Gehl, R.M. DePauw and R.P Zentzer. 2004. Identification of crop production factors with the development of fusarium head blight in spring wheat in southeast Saskatchewan. Can. J. Plant Pathol. 25:212 (abstr).

Hanson, K.G. and M.R. Fernandez. 2003. Glyphosate herbicides affect plant pathogenic fungi. Can. J. Plant Pathol. 25:120 (abstr).

Stack, R.W. and M.P. McMullen. 1995. A Visual Scale to Estimate Severity of Fusarium head blight in wheat. NDSU Ext Circ. PP1095. 2p.

Yates, W.E., N.B. Akesson and D.E. Bayer. 1978. Drift of glyphosate sprays applied with aerial and ground equipment. Weed Sci. 26:597-604.

Table 1. Comparison of FHB severity in ten durum wheat lines present in plots adjacent to or distant from a sublethal glyphosate spray drift occurring at late tillering stage.

	FHB Severity (%) *		
	Location §		
Line†	Distant from drift	Midway	Adjacent to drift
D901155	50	65	41
D91103	55	61	48
RUGBY	58	62	52
BELZER	56	67	75
PIERCE	88	77	52
LEBSOCK	91	77	55
RENVILLE	82	70	76
D87450	80	93	73
MAIER	88	86	76
D88541	89	91	72
Average	73.7 a	74.9 a	62.0 b

* FHB severity scored on minimum of 20 spikes per replicate.
§ Location: Distant plots were 25 - 40 m from spray application; Adjacent plots were 3 - 10 m from sprayed area.
† Lines are listed in order of overall mean FHB severity. D901155 and D91103 are MR checks, D87450 and D88541 are susceptible checks.
a, b: Means followed by different letters are significantly different at p=0.05.

Table 2. Comparison of FHB severity in spring wheat in plots adjacent to or distant from a sublethal glyphosate spray drift occurring at late tillering stage.

% FHB Severity *				
	Trial § (Number of lines)			
Position of plots †	URN (39)	VAR (41)	AYT (71)	URSN (39)
Distant from drift	47.0 b	49.8 b	39.7 b	45.5 b
Adjacent to drift.	27.8 a	18.2 a	17.9 a	19.6 a

* FHB Severity value is mean of all entries. (Twenty spikes of each genotype in each block were individually scored for FHB).
§ Trials (all had 4 replicate blocks): URN = Uniform Regional Nursery for Spring Wheat; VAR = Varieties and Elite Lines Test; AYT = Advanced Yield Trial lines; URSN = Uniform Regional Scab Nursery for Spring Wheat.
† Location: Distant plots were 25 - 40 m from spray application; Adjacent plots were 3 - 10 m from sprayed area.
a, b: comparisons within columns only; values followed by different letters are significantly different at p=0.05.

GUSHING AND "FUSARIUM HEAD BLIGHT"(FHB)

Pavla Havlová[1*], Michaela Nevrklová[2], Katerina Lancová[2], Marie Vanová[3] and Jana Hajšlová[2]

[1]Research Institute of Brewing and Malting, Malting Institute Brno, Mostecka 7, CZ-614 000 Brno, Czech Republic; [2] Institute of Chemical Technology Prague, Department of Chemistry and Food Analysis, Technicka 5, CZ-166 28 Prague6 – Dejvice, Czech Republic; and [3]Agricultural Research Institute Kromeriz, Ltd., Havlickova 2787, CZ-76701 Kromeriz, Czech Republic

[*]Corresponding Author: PH: 420 545214110/37; E-mail: havlova@brno.beerresearch.cz

ABSTRACT

The quality of barley and consequently of malt is of basic importance for attaining the good beer quality. Gushing of beer is a very negative phenomenon so far not completely investigated.

The term gushing is common both in the English and in German literature and it usually indicates spontaneous over-foaming of beer from a bottle or tin. It expresses itself mainly in beer but it can occur in non-alcoholic beverages as well. Basically, immediate release of carbon dioxide (CO_2) upon bottle opening, is regarded here [1].

Causes for gushing creation can be various. So called "primary gushing" is probably associated with formation of compounds produced in barley after it is attacked by *Fusarium* spp. The above mentioned fungal disease occurs most often in wheat and barley and it is called "Fusarium head blight"(FHB) altogether

The presence of FHB in a barley caryopsis and malt is also connected with other side effects influencing the beer quality such as off-flavor or premature flocculation of yeasts leading to precocious termination of fermentation [2].

Occurrence of so called primary gushing is connected with a barley caryopsis attack by microscopic fibrous fungi not only by *Fusarium* spp. but also by e.g. *Aspergillus*, *Rhizopus, Penicillium*, and *Nigrospora.* The actual compounds that cause gushing are unknown. These compounds are probably a product of a plant - pathogen interaction, result of a preceding stress of an organism.

We followed the occurrence of *Fusarium* spp. and amount of over-foamed beer – gushing in the selected spring barley varieties that were grown after different forecrops, i.e. sugar beet, maize, rape and cereal.

REFERENCES

Pellaud J.: "Gushing: State of the Art", *Cerevisia* 27 (4), 2002, 189-205.

Axcell B., Van Nierop S., Vundla W.: Malt Induced Premature Yeast Flocculation, *Tech. Q. Master Brew. Assoc. Am.* 37, 2000, pp.501-504.

EFFECT OF PREVIOUS CROP RESIDUES AND TILLAGE ON FUSARIUM HEAD BLIGHT OF WINTER WHEAT

W. Hermann[1*], E. Kübler[2] and W. Claupein[2]

[1]University of Hohenheim, Experimental Station Ihinger Hof, D-71272 Renningen, Germany; and [2]University of Hohenheim, Institute of Crop Production and Grassland Research, D-70593 Stuttgart, Germany
[*]Corresponding Author: PH: 0049-7159-926422; E-mail: hermannw@uni-hohenheim.de

ABSTRACT

Fusarium head blight (FHB) is a major disease in all European wheat producing regions. The principle pathogen associated with FHB in Europe is *Fusarium graminearum* and its teleomorph *Gibberella zeae*, but also other species occur. Monitoring results in Europe indicate that FHB epidemics occur preferably in maize-wheat rotations. These results were confirmed by a 10-year monitoring of natural FHB incidence in Bavaria with annually 400-700 samples. Maize as a pre-crop is especially worse in combination with conservation tillage systems, which are favoured for economic reasons and by governmental support over the last years (Beck & Lepschy, 2000). Important factors determining infection of FHB are: quantity, inoculum potential, incorporation and decomposition of pre-crop residues interacting with climate conditions and wheat cultivar resistance. The present study was conducted in order to evaluate the influence of maize residues differing in Gibberella stalk rot infection and residue management practices on FHB incidence of winter wheat. In a 2-y (2003, 2004) factorial field trial at two locations (Ihinger Hof 480 m a. s. l., 8°C, 690 mm; Oberer Lindenhof 700 m a. s. l., 7°C, 930 mm) maize residues collected of cv. Arsenal (stalk rot infested) and cv. Helix (non-infested) were spread onto winter wheat plots (cv. Darwin – susceptible to FHB, cv. Petrus – rather resistant to FHB) to simulate no-till winter wheat after maize. In another experiment different tillage practices were simulated by dispersal of maize residues on winter wheat plots (cv. Darwin). Experimental factors were: (a) simulated mulch tillage (maize residues incorporated with rotary tiller), (b) simulated no-till (application of maize residues after sowing without incorporation), (c) chopped maize residues (5-10 mm length, application after sowing), (d) application of compensating fertilization (30 kg N ha^{-1}) on maize residues after sowing. To avoid plot-to-plot dispersal of ascospores, test plots were spaced 14 m apart with winter wheat crops in between. FHB incidence was substantially affected by the interaction of year and stalk rot infection of maize residues. Significant effects of different maize residues were observed in the susceptible winter wheat cv. Darwin in 2004, when wet weather conditions favoured FHB infection. Stalk rot infested maize residues (cv. Arsenal) caused on average a higher disease incidence in following wheat (cv. Darwin) than non-infested maize residues (cv. Helix). FHB incidence was mainly affected by winter wheat cultivar, whereas FHB incidence of the rather resistant cv. Petrus was 96% less than that of the susceptible cv. Darwin. Incorporation and partial burial of maize residues did not significantly affect FHB disease incidence. When maize residues were chopped fine, FHB incidence was lower than in corresponding plots with residues cut to pieces of 250-300 mm. In contrast, application of nitrogen to enhance decomposition of maize residues did not affect FHB incidence. The results indicated that small amounts of infested residue can provide sufficient inoculum for FHB epidemics in susceptible wheat varieties under favourable conditions for infection. Cultural practices in conjunction with Gibberella stalk rot resistance of the previous crop maize can help to reduce inoculum potential and subsequent FHB infection in epidemic years. Additionally, high resistance of wheat varieties to FHB is a precondition to meet existing guidelines on mycotoxin levels at high risk for FHB infection.

REFERENCE

Beck, R., Lepschy, J. (2000): Results from Fusarium-Monitoring 1988-1999 – the influence of the agronomical factors crop rotation and soil cultivation. Bodenkultur und Pflanzenbau 4(3), 39-47.

ANALYSIS OF 2004 UNIFORM WHEAT FUNGICIDE TRIALS ACROSS LOCATIONS AND WHEAT CLASSES

D. Hershman[1*] and M. Draper[2]

[1]Dept. of Plant Pathology, University of Kentucky, Princeton, KY 42445, USA; and
[2]Dept. of Plant Pathology, South Dakota State University, Brookings, SD 57007, USA
[*]Corresponding Author: PH: (270) 365-7541 x 215; E-mail: dhershma@uky.edu

OBJECTIVES

To evaluate a common set of foliar fungicide treatments, across a range of environments and wheat classes, for effectiveness in managing Fusarium head blight (FHB) symptoms and deoxynivalenol (DON) accumulation in wheat.

INTRODUCTION

FHB is a potentially devastating disease that can result in serious economic losses for wheat producers, millers, and end-users of wheat products. Grain contaminated with DON, a mycotoxin usually associated with FHB, can cause health problems in both humans and livestock. As a result, grain exceeding 2 ppm DON is often discounted at sale and grain with higher DON accumulation may be rejected by the buyer. Thus, identifying fungicides that significantly reduce FHB symptoms in the field, and DON accumulation in harvested grain, would have widespread benefits to growers and end-users of all market classes of wheat. The Uniform FHB Fungicide Trials were established in 1998 as a means of evaluating promising, manufacturer-supported, fungicides that may be useful in FHB management programs nationwide.

MATERIALS AND METHODS

Uniform Test - Scientists from 12 states conducted 27 trials across a range of environments and wheat classes in 2004 (Table 1). Six fungicide treatments and a non-treated check where evaluated in each trial. Disease pressure was enhanced in about one-half of the trials by inoculating with *Fusarium graminearum* and mist-irrigating. Twelve of 27 trials were conducted in fields with 20% or greater surface residue (barley, corn, or wheat). Fungicides were applied at early flowering (Feeke's stage 10.51) using a CO^2-pressurized sprayer, equipped with Twinjet XR8001 nozzles mounted at a 60^o angle backward and forward. The experimental design was a randomized complete block. Plot size, crop husbandry, spray volume and pressure, sprayer type, and number of treatment replications varied by location. Consult individual state trial reports for details. For all trials, percent FHB incidence, severity, index (i.e., plot severity), and *Fusarium*-damaged kernels (FDK) were measured as previously described (McMullen, et al., 1999). DON accumulation was measured at one of the two USWBSI-funded DON Testing Laboratories.

Summarization of Results - In several instances, more than one wheat class or variety was grown at the same location. These were treated as separate experiments for the purposes of this summary. Data were grouped and statistically analyzed according to whether they involved spring or winter wheat. The experimental design was a randomized complete block using locations as blocks. Data were subjected to analysis of variance (ANOVA). Percentage data were arcsine-transformed prior to being statistically analyzed. When ANOVA results indicated a significant (P= 0.05) treatment effect, means were subjected to a means separation test (Student-Newman-Keuls, P=0.05). Percent control by each treatment (an industry standard measure of fungicide efficacy) was calculated to give the reader an additional means of comparing treatment efficacy. Tests with very low disease incidence or severity (<10%) and low DON (<2ppm) were not included in statistical analyses.

RESULTS AND DISCUSSION

Winter Wheat - Data from winter wheat trials are summarized in Table 2. FHB pressure was heavy in most trials. All treatments except Folicur and Tilt significantly reduced FHB incidence compared to the check. FHB severity, index, and FDK were significantly reduced by all treatments. Both treatments involving JAU6476 and the high rate of V-10116 significantly reduced DON compared to the check. Treatments involving Folicur, Tilt, and the low rate of V-10116 (4 fl oz/A) had DON levels comparable to the check. FHB and DON suppression associated with treatments were within the ranges previously reported for fungicides in the United States (Hershman and Milus, 2003a, 2003b). No treatment provided better than average control of FHB or DON. Generally, the high rate of JAU6476 (5 fl oz/A) was the best performing treatment, followed by JAU6476 (2.85 fl oz/A) + Folicur (3.17 fl oz/A) and both rates of V-10116 (4 or 6 fl oz/A).

Spring Wheat - Data from spring wheat trials are summarized in Table 3. FHB pressure was highly variable across locations. All treatments except Tilt significantly reduced FHB incidence, while all treatments significantly lowered FHB severity and index compared to the check. FDK and DON were significantly reduced by all treatments except Folicur and Tilt. As in the winter wheat trials, no treatment provided better than average control of FHB or DON. In contrast to winter wheat trials, there was little difference between treatments involving JAU6476 or V-10116.

Spring and Winter Wheat Comparison- When data were averaged across fungicide treatments, fungicide efficacy (expressed as percent control) was statistically similar for winter and spring wheat (**Table 4**). This is in contrast to 2003 Trials where spring wheat had an overall greater response to fungicides than winter wheat (Hershman and Milus, 2003b)

REFERENCES

McMullen, M., Milus, G., and Prom, L. 1999. 1999 Uniform fungicide trials to identify products effective against Fusarium head blight in wheat. Pages 64-68 in: Proc. Of the 1999 National Fusarium Head Blight Forum, Sioux Falls, SD, Dec. 5-7, 1999. Michigan State Univ.

Hershman, D. E. and Milus, E. A. 2003a. Analysis of 2003 Uniform wheat fungicide trials across locations and wheat classes. Pages 76-80 in: Proc. of the 2003 National Fusarium Head Blight Forum, Bloomington, MN, Dec 13-15, 2003. Michigan State Univ.

Hershman, D. E. and Milus, E. A. 2003b. Performance of Folicur in Fusarium head blight uniform fungicide trials, 1998-2003. Pages 81-82 in: Proc. of the 2003 National Fusarium Head Blight Forum, Bloomington, MN, Dec 13-15, 2003. Michigan State Univ.

Table 1. 2004 Uniform Wheat Fungicide Trials.

State and Principal investigator	Test and location	Wheat class	Test ID	Inoculated	Water applied?	20% or more barley, corn, or wheat residue?
AR / Milus	Fayetteville	SRWW	AR	Yes	Yes	No
IN / Shaner	West Lafayette	SRWW	IN1	No	Yes	Yes
	North Vernon	SRWW	IN2	No	No	Yes
IL / Malvick	Urbana	SRWW	IL1	No	No	Yes
/ Adee	Monmouth	SRWW	IL2	No	No	Yes
/ Adee	Carbondale	SRWW	IL3	No	No	Yes
LA / Padgett	Baton Rouge	SRWW	LA1	Yes	Yes	No
	Winnsboro	SRWW	LA2	Yes	Yes	No
MD / Grybauskas	Queenstown	SRWW	MD1	Yes	Yes	No
MI / Hart	East Lansing 1	SRWW	MI1	Yes	Yes	No
	East Lansing 2	SRWW	MI2	Yes	Yes	No
MO / Sweets	Columbia 1	SRWW	MO1	No	No	No
	Columbia 2	SRWW	MO2	No	No	No
MN / Hollingsworth	Crookston	HRSW	MN	No	No	Yes
ND / McMullen	Carrington	HRSW	ND1	No	Yes	No
	Fargo	HRSW	ND2	Yes	Yes	Yes
	Langdon 1	Duram	ND3	Yes	Yes	No
	Langdon 2	HRSW	ND4	Yes	Yes	No
	Minot	HRSW	ND5	No	No	No
OH / Lipps	Wooster	SRWW	OH	Yes	Yes	No
SD / Draper	Brookings 1	HRSW	SD1	Yes	Yes	Yes
	Brookings 2	HRSW	SD2	Yes	Yes	Yes
	Watertown 1	HRSW	SD3	No	No	Yes
	Watertown 2	HRSW	SD4	No	No	Yes
	Groton 1	HRSW	SD5	No	No	No
	Groton 2	HRSW	SD6	No	No	No
VA / Stromberg	Warsaw	SRWW	VA	No	No	Yes
12 States	27 Tests	15 SRRW 11 HRWW 1 Durum		12 yes 15 no	14 yes 13 no	12 yes 15 no

Table 2. Winter wheat results: FHB incidence, head severity, index (plot severity), Fusarium damaged kernels(FDK) and deoxynivalenol (DON) accumulation in harvested grain.

	Incidence		Severity		Index		FDK		DON	
Treatment and rate/A	(%)	% Ctrl[1]	(%)	% Ctrl	(%)	% Ctrl	(%)	% Ctrl	(ppm)	% Ctrl
1. Non-treated	56.3a[2]		36.9a		21.8a		22.2a		7.4a	
2. Folicur 432SC 4.0 fl oz + 0.125% Induce	50.9ab	9.6	29.0b	21.4	16.8b	22.9	15.9b	28.4	6.0ab	18.9
3. Tilt 3.6EC 4.0 fl oz/A	50.2ab	10.8	29.0b	21.4	16.8b	22.9	15.9b	28.4	7.6a	0.0
4. JAU6476 480SC 5.0 fl oz + 0.125% induce	38.0c	32.5	26.3b	28.7	11.4c	47.7	11.2b	49.6	4.3b	41.9
5. JAU6476 480SC 2.85 fl oz + Folicur 432SC 3.17 fl oz + 0.125% Induce	42.4bc	24.7	27.4b	25.7	13.4bc	38.5	13.7b	38.3	4.4b	40.5
6. V-10116 1.81FL 6.0 fl oz + 0.125% Induce	46.4bc	17.6	27.1b	26.6	14.0bc	35.8	13.3b	40.1	4.9b	33.8
7. V-10116 1.81FL 4 fl oz + 0.125% Induce	45.5bc	19.2	26.9b	27.1	13.5bc	38.1	15.0b	32.4	5.9ab	20.3
[1] % control relative to check CV	14.2%		12.2%		17.3%		15.0%		29.4%	
[2]Student-Newman-Keuls, P=0.05 N	12		13		12		10		9	

Table 3. Spring wheat results: FHB incidence, head severity, index (plot severity), *Fusarium* damaged kernels(FDK) and deoxynivalenol (DON) accumulation in harvested grain.

	Incidence		Severity		Index		FDK		DON	
Treatment and rate/A	(%)	% Ctrl[1]	(%)	% Ctrl	(%)	% Ctrl	(%)	% Ctrl	(ppm)	% Ctrl
1. Non-treated	56.5a[1]		26.4a		17.8a	-	13.5a	-	11.4a	
2. Folicur 432SC 4.0 fl oz + 0.125% Induce	47.4bc	16.1	19.7b	25.4	12.3bc	30.9	11.8ab	12.6	10.3ab	9.6
3. Tilt 3.6EC 4.0 fl oz/A	51.5ab	8.8	20.9b	20.8	14.0b	21.3	12.9a	4.4	10.8ab	5.3
4. JAU6476 480SC 5.0 fl oz + 0.125% induce	43.3c	23.4	18.5bc	29.9	9.9cd	44.4	8.4b	37.8	8.0bc	29.8
5. JAU6476 480SC 2.85 fl oz + Folicur 432SC 3.17 fl oz + 0.125% Induce	41.7c	26.2	15.7d	40.5	9.6cd	46.1	8.6b	36.3	7.2c	36.8
6. V-10116 1.81FL 6.0 fl oz + 0.125% Induce	41.6c	26.4	16.3cd	38.3	9.0d	49.4	8.5b	37.0	6.7c	41.2
7. V-10116 1.81FL 4 fl oz + 0.125% Induce	45.6bc	19.3	19.0bc	28.0	11.6b-d	34.8	9.3b	31.1	8.0bc	29.8
[1] % control relative to check CV	10.4%		17.6%		7.6%		12.1%		19.6%	
[2]Student-Newman-Keuls, P=0.05 N	9		8		8		7		8	

Table 4. Winter versus spring wheat comparison; % FHB/DON control across all fungicide treatments in relation to the control.

	% Control				
Wheat class	**Incidence**	**Severity**	**Index**	**FDK**	**DON**
Spring Wheat	20.0	30.5	37.8	26.5	25.4
Winter Wheat	19.1	25.2	34.4	36.2	25.9
Difference	0.9%	5.3%	3.4%	9.7%	0.5%
$P>F$	0.79	0.12	0.38	0.17	0.92

PLANT NUTRIENT SUPPLEMENT WITH BIOSTIMULANTS REDUCED DEVELOPMENT OF FUSARIUM HEAD BLIGHT IN WINTER WHEAT

Hofgaard, I.S.[1], Henriksen, B.[1], Ergon, Å.[1,2], Skinnes, H.[2], Kolstad, H.[1], Tarkegne, Y.[2] and Tronsmo, A.M.[1,2*]

[1]The Norwegian Crop Research Institute, Plant Protection Centre, Høgskoleveien 7, 1432 Ås, Norway; and [2] Agricultural University of Norway, Dept. of Plant and Environmental Sciences, P.O.Box 5003, 1432 Ås.
[*]Corresponding Author: PH: 47 64965004; E-mail: anne-marte.tronsmo@nlh.no

ABSTRACT

We are studying resistance to Fusarium head blight (FHB) in winter wheat plants pre-treated with chemical defense activators. Several potential defense-inducing compounds including chitosans, acibenzolar-S-methyl, DL-3-aminobutyric acid, Milsana, Trehalose, Resistim have been pre-screened for their defense inducing capacity by using a detached leaves test (Browne and Cooke 2004). Promising candidates were further tested for their FHB-resistance inducing capacity on mature winter wheat plants in a controlled environment and in a field experiment during the summer of 2004.

Symptom development in heads of winter wheat after *Fusarium culmorum* inoculation was reduced in plants pre-treated with Resistim one week prior to inoculation. The reduced disease development in Resistim treated compared to water-treated winter wheat plants, was found after both point inoculation and spray inoculation of the heads with *F. culmorum* in greenhouse and field studies, respectively. Further studies on the percentage infected kernels and mycotoxin content will be performed on grains from the different treatments in the field experiment.

REFERENCE

Browne, R.A. and Cooke, B.M. 2004. Development and evaluation of an *in vitro* detached leaf assay for pre-screening resistance to Fusarium head blight in wheat. European Journal of Plant Pathology 110: 91-102.

UNIFORM FUNGICIDE TRIAL ON FHB OF HARD RED SPRING WHEAT IN MINNESOTA

C.R. Hollingsworth* and C.D. Motteberg

Univ. of Minnesota Northwest Research and Outreach Center, Crookston, MN 56716
*Corresponding Author: PH: (218) 281-8627, E-mail: holli030@umn.edu

OBJECTIVE

Evaluate and compare the fusarium head blight (FHB) control efficacy of experimental chemical products when applied to hard red spring wheat in Minnesota. Cooperatively, the multi-state uniform fungicide trial effort will indicate which fungicide compounds are most effective in reducing disease severity on wheat across diverse environments and under various disease pressures.

INTRODUCTION

Fusarium head blight was originally described more than a century ago (Stack, 2000). Since that time the disease has caused severe and repeated epidemics on small grain crops (Sutton, 1982; McMullen et al., 1997; Steffenson, 1998; Windels, 2000) resulting in billions of dollars in crop losses (McMullen et al., 1997; Wood, 2002). More specifically, Nganje et al. (2004) estimated the recent 1993-2001 FHB epidemics caused economic losses of greater than $5.2 billion in Minnesota and North Dakota alone. The disease remains a constant threat to the economic stability of small grain growers in production areas with rain, humidity, or heavy dews during critical fungal infection periods (McMullen, 1997).

Successful infection of *Fusaria* pathogens is largely dependent on environmental conditions prior to, and during the period when the crop is in a susceptible growth stage. Cultural disease management strategies (i.e.: crop rotation, tillage, and field sanitation) have offered producers partial suppression. Likewise, moderate disease suppression has also been achieved from application of select fungicide products at Feekes 10.51 (early flowering stage). Ongoing research on disease control efficacy of experimental fungicides is needed to preserve small grain yield and quality losses in regions most at risk for catastrophic crop losses.

MATERIALS AND METHODS

Hard red spring wheat cultivar 'Oxen' was planted 4 May 2004 into wheat stubble at 1.25 million live seed/acre in a randomized complete block design with four replicates. Each plot was inoculated with 112 kg ha^{-1} of *Fusarium graminearum* infested corn grain five weeks after planting. Night-cycle mist irrigation was initiated after inoculation and continued until 3 August; growth stage Feekes 11.2 (soft dough stage). Misting was discontinued temporarily during the growing season when weather events caused standing water at the testing site. Puma, Harmony GT, MCPA, and Tilt were applied to the test site on 8 June to control weeds and early season leaf disease. Afterward, weeds were managed by hand as needed.

Ten weeks after planting (14 July), fungicide treatments were applied to wheat in the Feekes 10.51 growth stage (early flowering). Treatment applications were made with a CO_2 backpack-type sprayer adjusted to 40 psi at 18-20 gpa with forward and backward positioned 'XR' Teejet flat fan 8001 VS nozzles. On 26 July, leaf spotting disease severities were recorded. The same day spikes were collected and frozen until FHB symptoms could be rated. The test was harvested 17 weeks after planting on 31 August.

Fusarium head blight severities were estimated according to the visual scale published by Stack and McMullen (1995), while percent visually scabby kernels (VSK) was estimated using a set of grain standards provided by R. Jones and based on Jones and Mirocha (1999). Percent leaf disease was estimated using James (1971). Grain sample deoxynivalenol (DON) levels were determined by the University of Minnesota Toxi-

cology Lab in St. Paul utilizing the gas chromatography/mass spectrometry (GC/MS) method. ANOVAs were performed with SAS using PROC GLM. Fisher's protected least significant difference (LSD) mean comparisons were used to identify statistically different treatments.

RESULTS AND DISCUSSION

The nontreated control had significantly more severe disease than the fungicide treatment with the best disease control (Table 1). The mixed-product treatment ('JAU6476' + 'Folicur') significantly reduced FHB and leaf disease symptoms, preserving crop yield and grain quality across all categories tested. The 'JAU-6476' (5 fl oz) treatment significantly controlled fusarium head blight incidence and visually scabby kernels, while increasing yield. DON levels, as well as fusarium head blight and leaf disease severities were controlled with the 'V-10116' (6 fl oz.) treatment while test weights were improved over the nontreated control. Application of 'Tilt' resulted in the least disease control of all products with results in five of eight categories not significantly different from the nontreated control (e.g.: FHB incidence, visually scabby kernels, DON, leaf disease severity, and kernel test weight). 'Folicur' offered the greatest level of disease control of those products commercially available to small grain producers. Compared with the nontreated control, it produced significantly better results in six of eight categories. While not significantly different from the nontreated control, 'Quadris' caused an increase in grain DON levels over the control. This phenomenon has been noted in the past resulting from head applications of strobilurin-based fungicides.

ACKNOWLEDGEMENTS

The authors would like to thank the U.S. Wheat and Barley Scab Initiative and the Northwest Research and Outreach Center for supporting this research, BASF Corp., Bayer CropScience, Syngenta Crop Protection, and Valent U.S.A. for supplying fungicide materials, and the University of Minnesota Mycotoxin lab for providing DON results.

REFERENCES

James, C. 1971. A manual of assessment keys for plant diseases. Can. Dept. Agric. Publ. 1458. American Phytopathological Society. St. Paul, MN.

Jones, R.K. and C.J. Mirocha. 1999. Quality parameters in small grains from Minnesota affected by Fusarium head blight. Plant Disease 83:506-511.

McMullen, M., R. Jones and D. Gallenberg. 1997. Scab of wheat and barley: A re-emerging disease of devastating impact. Pl. Dis. 81:1340-1348.

Nganje, W.E., S.Kaitibie, W.W. Wilson, F.L. Leistritz, and D.A. Bangsund. 2004. Economic impacts of fusarium head blight in wheat and barley: 1993-2001. NDSU AES Report No. 538.

Stack, R.W. 2000. Return of an old problem: Fusarium head blight of small grains. Pl. Health Progress Online. 0622-01-RV.

Stack R.W. and M.P. McMullen. 1995. A visual scale to estimate severity of Fusarium head blight in wheat. NDSU Ext. Bulletin 1095. Fargo, North Dakota.

Steffenson, B.J. 1998. Fusarium head blight of barley: Epidemics, impact, and breeding for resistance. Technical Quarterly 35: 177-184.

Sutton, J.C. 1982. Epidemiology of wheat head blight and maize ear rot caused by *Fusarium graminearum.* Can. J. Pl. Path. 4:195-209.

Windels, C.E. 2000. Economic and social impacts of Fusarium head blight: Changing farms and rural communities in the Northern Great Plains. Phytopathology 90: 17-21.

Wood, M. 2002. Gene jockeys fight Fusarium head blight. August issue. United States Dept. of Agriculture, Agricultural Research Service, Beltsville, MD.

Table 1. Fusarium head blight and leaf spot disease responses from 'Oxen' hard red spring wheat in Crookston, Minnesota during 2004.

	Fusarium Head Blight							
Treatment[1]	*HS (%)*	*I (%)*	*FS (%)*	*VSK (%)*	*DON (ppm)*	*LD*[2] *(%)*	*Test Wt. (lb/bu)*	*Yield (bu/A)*
1. Nontreated control.....	41.9a	98.5a	41.2a	27.5a	15.2a	7.2a	51.8a	33.3a
2. Folicur 432SC 4 fl oz	32.7bc	86.0bcd	28.1bc	22.5ab	12.9a	4.2bc	53.9bc	42.7b
3. Tilt 3.6EC 4 fl oz	34.8b	92.5ab	32.2b	27.5a	12.2ab	6.9a	52.4ab	41.3b
4. JAU6476 480SC 5 fl oz ..	26.3de	78.5d	20.6cd	10.3d	7.4bc	4.8bc	57.2d	55.6d
5. JAU6476 480SC 2.85 fl oz + Folicur 3.17 fl oz	22.9e	81.5d	18.7d	9.8d	4.9c	4.1bc	57.2d	56.6d
6. V-10116 1.81FL 6 fl oz ..	24.1e	84.0cd	20.3cd	12.8cd	5.0c	3.4c	56.5d	50.9cd
7. V-10116 1.81FL 4 fl oz ..	31.1bc	90.7bc	28.2bc	14.5bcd	7.5bc	4.2bc	53.7bc	51.5cd
8. Quadris 2.08F 9 fl oz	29.7cd	86.0bcd	25.6bcd	20.8abc	16.0a	5.6ab	52.6ab	39.6b
9. Headline 2.09EC 9 fl oz ..	32.2bc	93.0ab	29.9b	20.0abc	11.9ab	3.2c	54.7c	48.9c
$LSD_{0.05}$	3.90	7.81	8.81	9.26	5.19	2.09	1.82	5.94
CV	60.0	6.1	22.2	34.5	34.4	98.2	2.3	8.7

[1]Each fungicide treatment included 0.125% Induce. Treatment abbreviations are HS, head severity; I, incidence; FS, field severity (field index); VSK, visually scabby kernels; LDS, leaf disease severity.
[2]Fungal foliar diseases consisted of Septoria/Stagonospora blotch complex (*Septoria tritici* and *Stagonospora nodorum*) and tan spot (*Pyrenophora tritici-repentis*).

UNIFORM FUNGICIDE TRIAL ON FHB OF SPRING BARLEY IN MINNESOTA

C.R. Hollingsworth* and C.D. Motteberg

Univ. of Minnesota Northwest Research and Outreach Center, Crookston, MN 56716
*Corresponding Author: PH: (218) 281-8627; E-mail: holli030@umn.edu

OBJECTIVE

Evaluate and compare fusarium head blight (FHB) suppression resulting from application of fungicide products on spring barley in northwest Minnesota. Cooperatively, the multi-state uniform fungicide trial effort will indicate which fungicide compounds are most effective in reducing disease severity on barley across diverse environments and under various disease pressures.

INTRODUCTION

Fusarium head blight was originally described more than a century ago (Stack, 2000). Since that time the disease has caused severe and repeated epidemics on small grain crops (Sutton, 1982; McMullen et al., 1997; Steffenson, 1998; Windels, 2000) resulting in billions of dollars in crop losses (McMullen et al., 1997; Wood, 2002). More specifically, Nganje et al. (2004) estimated the recent 1993-2001 FHB epidemics on small grains resulting in economic losses of greater than $5.2 billion in Minnesota and North Dakota alone. The disease remains a constant threat to the economic stability of small grain producers in areas with rain, humidity, or heavy dews during critical fungal infection periods (McMullen, 1997).

Successful infection of *Fusaria* pathogens is largely dependent on environmental conditions prior to, and during periods when crops are susceptible. Cultural disease management strategies (i.e.: crop rotation, tillage, and field sanitation) have offered barley producers partial suppression, and barley varieties with resistance to FHB are not yet available. Disease suppression has been achieved from application of select fungicide products at Feekes 10.50 (early-heading stage). Ongoing research on disease control efficacy of experimental fungicides is needed to preserve malting quality barley grain in areas where the crop has been grown historically.

MATERIALS AND METHODS

Spring barley cultivar 'Robust was planted 4 May 2004 into wheat stubble at 1.375 million live seed/acre in a randomized complete block design with four replicates. Each plot was inoculated with 112 kg ha^{-1} of *Fusarium graminearum* infested corn grain five weeks after planting. Night-cycle mist irrigation was initiated after inoculation and continued until 3 August; growth stage Feekes 11.2 (soft dough stage). Misting was discontinued temporarily during the growing season when weather events caused standing water at the testing site. Puma, Harmony GT, MCPA and Tilt were applied to the test site on 8 June to control weeds and early season leaf disease. Afterward, weeds were managed by hand as needed.

Nine weeks after planting (7 July), fungicide treatments were applied to barley in the Feekes 10.5 growth stage (early-heading). Treatment applications were made with a CO_2 backpack-type sprayer adjusted to 40 psi at 18-20 gpa with forward and backward positioned 'XR' Teejet flat fan 8001 VS nozzles. On 26 July, leaf spotting disease severities were recorded. On 28 July, spikes were collected and frozen until FHB symptoms could be rated. The test was harvested 15 weeks after planting on 17 August.

Fusarium head blight severities were determined by counting the number of symptomatic glumes on each head and dividing diseased glumes by the total glumes per head. Percent leaf disease was estimated using James (1971). Grain sample deoxynivalenol (DON) levels were determined by the University of Minnesota Toxicology Lab in St. Paul utilizing the gas chromatography/mass spectrometry (GC/MS) method.

ANOVAs were performed with SAS using PROC GLM. Fisher's protected least significant difference (LSD) mean comparisons were used to identify statistically different treatments.

RESULTS AND DISCUSSION

The cool growing season provided an optimum environment for barley production in the Red River Valley while frequent rainfall increased disease pressures. Four of eight disease response categories (FHB incidence, FHB field severity, DON, and yield) did not have significantly different results (Table 1). Of the categories with significantly different results, the nontreated control had the largest ratings for FHB head severity, visually scabby kernels, and leaf disease severity, but was not different from 'Folicur' (4 fl oz/A) for most reduced 1000-kernel weights. 'Headline' resulted in significant control of FHB head and leaf disease severities and fewer visually scabby kernels were noted. Two treatments ('JAU6476' 5 fl oz and 'JAU6476' + 'Folicur') resulted in increased 1000-kernel weights.

ACKNOWLEDGEMENTS

The authors would like to thank the U.S. Wheat and Barley Scab Initiative and the Northwest Research and Outreach Center for supporting this research, BASF Corp., Bayer CropScience, Syngenta Crop Protection, and Valent U.S.A. for supplying fungicide materials, and the University of Minnesota Mycotoxin lab for providing DON results.

REFERENCES

James, C. 1971. A manual of assessment keys for plant diseases. Can. Dept. Agric. Publ. 1458. American Phytopathological Society. St. Paul, MN.

McMullen, M., R. Jones and D. Gallenberg. 1997. Scab of wheat and barley: A re-emerging disease of devastating impact. Pl. Dis. 81:1340-1348.

Nganje, W.E., S. Kaitibie, W.W. Wilson, F.L. Leistritz, and D.A. Bangsund. 2004. Economic impacts of fusarium head blight in wheat and barley: 1993-2001. NDSU AES Report No. 538.

Stack, R.W. 2000. Return of an old problem: Fusarium head blight of small grains. Pl. Health Progress Online. 0622-01-RV.

Steffenson, B.J. 1998. Fusarium head blight of barley: Epidemics, impact, and breeding for resistance. Technical Quarterly 35: 177-184.

Sutton, J.C. 1982. Epidemiology of wheat head blight and maize ear rot caused by *Fusarium graminearum.* Can. J. Pl. Path. 4:195-209.

Windels, C.E. 2000. Economic and social impacts of Fusarium head blight: Changing farms and rural communities in the Northern Great Plains. Phytopathology 90: 17-21.

Wood, M. 2002. Gene jockeys fight Fusarium head blight. August issue. United States Dept. of Agriculture, Agricultural Research Service, Beltsville, MD.

Table 1. Fusarium head blight and leaf spot disease responses from 'Robust' spring barley in Crookston, Minnesota during 2004.

	Fusarium Head Blight							
Treatment[1]	*HS (%)*	*I (%)*	*FS (%)*	*VSK (%)*	*DON (ppm)*	*LD*[2] *(%)*	*1000 Kernel*	*Yield (bu/ac)*
1. Nontreated control.....	37.9a	98.5	37.4	73.8a	18.6	0.93a	34.1a	88.2
2. Folicur 432SC 4 fl oz	29.4bcd	99.5	29.4	42.5bc	13.8	0.50bcd	34.1a	93.0
3. Tilt 3.6EC 4 fl oz	31.8b	99.3	31.6	56.3ab	15.0	0.73ab	35.8bc	99.1
4. JAU6476 480SC 5 fl oz ..	24.2ef	94.5	22.9	26.3c	11.6	0.25d	36.8c	96.6
5. JAU6476 480SC 2.85 fl oz + Folicur 3.17 fl oz	30.2bc	97.0	29.3	43.8bc	11.1	0.33cd	36.7c	92.9
6. V-10116 1.81FL 6 fl oz ..	25.8def	99.0	25.5	43.8bc	9.9	0.60bc	36.0bc	99.2
7. V-10116 1.81FL 4 fl oz ..	27.7def	99.0	27.4	55.0ab	11.6	0.55bc	34.9ab	99.4
8. Quadris 2.08F 9 fl oz	32.4b	99.5	32.2	31.3bc	14.8	0.33cd	36.4bc	104.3
9. Headline 2.09EC 9 fl oz ..	23.5f	97.0	22.8	20.0c	15.8	0.23d	35.8bc	94.4
$LSD_{0.05}$	*3.94*	*NS*	*NS*	*27.8*	*NS*	*0.30*	*1.56*	*NS*
CV	*67.0*	*33.0*	*24.1*	*43.6*	*30.5*	*41.8*	*3.0*	*9.8*

[1]Each fungicide treatment included 0.125% Induce. Treatment abbreviations are as follows: HS, fusarium head severity; I, FHB incidence; FS, field severity (field index); VSK, visually scabby kernels; LD, leaf disease severity.
[2]Foliar diseases consisted of Speckled leaf blotch (*Septoria passerinii* and *Stagonospora avenae* f. sp. *triticea*), net blotch (*Pyrenophora teres*) and spot blotch (*Cochliobolus sativus*).

EFFECTIVE APPLICATION OF FUNGICIDES ON WHEAT HEADS: WHAT'S THE BEST?

D.C. Hooker[1*], H. Spieser[2] and A.W. Schaafsma[1]

Department of Plant Agriculture[1], Ontario Ministry of Agriculture and Food (OMAF)[2], Ridgetown College, University of Guelph, Ridgetown, Ontario, N0P 2C0, Canada
[*]Corresponding Author: PH: (519) 644-2036; E-mail: dhooker@skynet.ca

ABSTRACT

Uniform coverage of Folicur® (tebuconazole) on wheat heads is critical for overall protection from Fusarium head blight. Spray coverage on wheat heads using a conventional sprayer with single-spaced nozzles on a boom has not been satisfactory. Wheat producers and custom chemical applicators need more options to achieve the highest possible effectiveness of the fungicide (total and uniform coverage), simple and inexpensive spray-boom configurations, and the ability to spray at high travel speeds. This has led to an investigation of various spray delivery systems and nozzle configurations for overall coverage — and uniformity of coverage — of spray solution on wheat heads. In 2001, UV dye in various sprayers showed coverage on wheat heads from various spray configurations. In 2002, 2003, and 2004, water sensitive papers (Spraying Systems Co., Wheaton, IL) were used to evaluate spray coverage, which were transformed into cylinders to mimic wheat heads before spraying. After each spray treatment, the papers were unfolded, scanned, and analyzed for coverage on each "side" of the "heads" using SigmaScan Pro Version 5.0 software. In addition to the spray coverage data, copper was used in the spray solution in all years, except 2001, to assess the amount of chemical applied on each "side" of the paper cylinders. The ground sprayer nozzle configurations included the use of Turbo TeeJet® nozzles in a forward-back configuration, TwinJet® nozzles, air induction nozzles, Turbo FloodJet® (single nozzles alternating forward and backward along the boom), FullJet nozzles, and the use of Twin Caps; all nozzle configurations on ground sprayers were compared at forward speeds of 10 and 19 kph (6 and 12 mph) and sprayed at the same water volumes. Ground sprayer configurations were compared with the airplane and helicopter in 2002. The backward-forward nozzle configuration and the FloodJet configuration produced the highest coverage and apparent distribution of chemical on the simulated wheat heads when compared to all other spray applicators. In these two sprayer configurations, a forward speed of 19 kph was equal in total coverage and uniformity of coverage compared to 10 kph at the same water volumes. All other spray nozzle configurations, however, had either lower total coverage, higher variability, or both, when spraying at 19 kph compared to 10 kph. TwinJet nozzles at 9 kph produced half the coverage of the backward-forward nozzles, but coverage was relatively uniform compared to the Twin Cap and flat fan configurations. Although the spray coverage from the airplane and helicopter was relatively low (<3%), the amount of chemical that reached the "heads" was comparable to most of the other ground applicator systems, but less than the backward-forward and FloodJet configurations. These data will be presented, along with a ranking of sprayer systems for effective application of fungicides for controlling Fusarium head blight.

THE EVALUATION OF *TRICHODERMA HARZIANUM* AS A BIOLOGICAL CONTROL AGENT OF *GIBBERELLA ZEAE*

S. Inch[1*] and J. Gilbert[1]

[1]Cereal Research Centre, Agriculture and Agri-Food Canada, Winnipeg, Manitoba, Canada
[*]Corresponding Author: PH: (204) 984-0223; E-mail: sinch@agr.gc.ca

ABSTRACT

Fusarium head blight (FHB) is currently the most important disease of wheat and other small grains in Canada. In Manitoba, the principal pathogen associated with FHB is *Gibberella zeae* (Schwein.) (anamorph = *Fusarium graminearum* Schwabe). Perithecia and ascospores of *G. zeae* develop on residue in the spring and are the primary source of inoculum. Presently, there are no registered resistant wheat varieties, and no reliable chemicals or biological agents to control FHB. The objectives of this study were to investigate the biocontrol potential of *Trichoderma harzianum* (Rifai) and to determine the mechanisms in which control of the disease is achieved. Eleven *T. harzianum* isolates were evaluated by confrontation plate assays for their antagonistic action against *F. graminearum*. *Trichoderma harzianum* isolates were paired with *F. graminearum* in Petri plates containing potato dextrose agar (PDA). All but one isolate showed some ability to overgrow *F. graminearum*. Isolates T83, T51, T30, and T183 overgrew *F. graminearum* by 20 mm or more. Isolates of *T. harzianum*, which reduced mycelial growth of *F. graminearum,* were further tested to determine their effects on the production of perithecia and ascospores of *G. zeae* on wheat residue. Spore suspensions, or cell-free filtrates of *T. harzianum* isolates, were applied to wheat residues either 24 h before, co-inoculated, or 24 h after, inoculation with *G. zeae*. Plates containing the treated residues were placed under UV light in a randomized complete block design with 4 replicates per treatment. On residues that were inoculated with either spore suspensions or cell-free filtrates of *T. harzianum*, 24 h before *G. zeae*, perithecia and ascospore development were substantially reduced. Residues that were co-inoculated showed moderate reduction. No control was achieved when the residues were inoculated first with *G. zeae*. The effect of spore concentration and mechanisms of control are currently being investigated.

EFFECT OF FUNGICIDE TIMING AND APPLICATION RATE ON CONTROL OF FUSARIUM HEAD BLIGHT

Philip Jennings[1*], Paul Nicholson[2] and Judith A Turner[1]

[1]Central Science Laboratory, Sand Hutton, York, YO41 1LZ, UK; and [2]John Innes Centre, Norwich Research Park, Colney Lane, Norwich, NR4 7UH, UK
*Corresponding Author: PH: 44 1904-462233; E-mail: p.jennings@csl.gov.uk

ABSTRACT

In the UK, Fusarium head blight (FHB) is generally associated with a complex of five different pathogens: *Fusarium culmorum*, *F. avenaceum*, *F. poae*, *Microdochium nivale* and more recently *F. graminearum*. The increase in *F. graminearum* combined with the imminent introduction of EU legislation, setting limits for mycotoxin contamination of grain, means that the effective control of FHB is becoming increasingly important in the UK.

There are several approaches to the control of FHB infection these include use of resistant cultivars, fungicides, biological control and cultural practices. The use of resistant cultivars is potentially the most effective approach to FHB control; however, in the absence of effective resistant cultivars, the main approach for FHB control is likely to remain the use of fungicide. The effectiveness of fungicides against FHB in the field has been questioned due to inconsistent results, in many instances the inconsistency may be attributed to incorrect fungicide application, especially through wrong product choice or miss-timing of application. However, even when applied optimally the best products currently available are still likely to be only 60-70 % effective.

To achieve optimal control of FHB pathogens and their associated mycotoxins there are several areas where choices have to be made, these include the product used, application rate and application timing. In the UK it is not uncommon to find several FHB pathogens infecting the ear at the same time. This can complicate disease control, particularly as different products can be differentially active against the different pathogens involved in the disease complex e.g. triazole fungicides such as tebuconazole have consistently shown good efficacy against *Fusarium* species but not *M. nivale*, whereas the reverse is true for strobilurin fungicides such as azoxystrobin. It has also been shown that depending on the species present on the ear, product choice can adversely influence the levels of mycotoxin found in grain. The optimum time for FHB infection is during crop flowering. Fungicides currently on the market are most effective when applied as fusarium spores arrive at the ear. The efficacy of all fungicides reduce as the timing between fungicide application and inoculum arrival increases, until eventually all efficacy is lost. In general, this occurs when the difference between spore arrival and fungicide application is greater than five days. The level of control achieved by a fungicide can also be greatly affected by the rate at which it is applied with, not surprisingly, a higher rate of application giving greater control. This paper will focus on how timing and rate of fungicide application affect the control of FHB pathogens and associated mycotoxins.

THE LONGEVITY OF FUNGICIDES CONTROLLING FHB IN WHEAT

Kászonyi, G., Mesterházy, A.*, Bartók, T., Varga, M and Tóth, B.

Cereal Research non-profit Co., 6726 Szeged, P.O.Box 391, Hungary
*Corresponding Author: PH: 36 30 415 9730, E-mail: akos.mesterhazy@gk-szeged.hu

OBJECTIVES

Longevityor duration of fungicide activity is an importantfeature of practical fungicide technology. Several fungicides were tested with artificial inoculation up to 28 day inoculation following spraying at flowering

INTRODUCTION

The durability of the fungicides is a long issue in plant protection. For the leaf diseases it is relative easy to do as spraying technology is good or excellent and the natural infection is normally enough to secure infection severity. The extinction of the fungicide effect can be seen by the newly developing symptoms, so in this respect it was never a hard to gain data. For FHB the situation is more problematic. In many years no or sporadic natural infection is present, the spraying technology is not good to cover heads and artificial inoculation has also the problem of not complete coverage of heads. For this reason the information is less reliable. Our microplot method (Mesterházy et al. 2003) corrects most of these setbacks of the methodology and with the precise timing of the spraying and inoculation the problem can be tested much better than by any earlier methods.

MATERIALS AND METHODS

The tests were made in 1999, 2000 and 2001. Three cultivars with differing resistance were used (Zugoly, Samson, Bence), three plot replicates (5 m^2) for a cultivar were used for a fungicide treatment. Within each plot four isolates of *Fusarium* were used in three replicates as head of groups consisting of 15-20 heads (Mesterházy et al. 2003). Spraying terming: full flowering. Inoculation: 1, 5, 10 and 15 days after fungicide treatments in 1999, 1, 7, 14, and 21 days in 2000, and 1, 14, 21 and 28 days in 2002 by gradually expanding the duration test. Evaluation: FHB, FDK, yield loss and DON contamination. Fungicides: Kolfugo S 1.5 l/ha, 20 % carbendazime, Caramba 1.0 (2000) and 1.2 L/ha (2001), metconazole 60 g/L, Falcon 250 g spiroxamine, 167 g tebuconazole and 43 g triadimenole in one liter. In 2001 AMS 21619 and Prosaro (125 g prothioconazole and 125 g tebuconazole/L) were additionally tested.

RESULTS AND DISCUSSION

Table 1 shows the FDK values for 1999. The Fusarium control data show that later inoculation leads to reduced infection severity. Two weeks after flowering only 10 % infection severity remained as mean across all cultivars and isolates. When data are expressed as a % of the Fusarium check, we see that efficacy for Falcon 0.6 L/ha increased from 79 % to 37 % in two weeks. For Falcon 0.8 no change was observed, Kolfugo and Caramba remained nearly unchanged. The DON data (Fig. 1) show a somewhat different picture. The Falcon 0.6 L/ha had decreasing efficacy, the Falcon 0.8 had only slight worsening during the two week... Kolfugo was stable for 10 days, thereafter rapid decrease of efficacy followed.

Of the 2000 tests only the DON data will be shown (Fig. 2.).Up to two weeks the data correspond to the results in 1999. Up to the 21st day all lost efficacy, but Falcon 1.0 L/ha had the smallest decrease. Caramba showed the least stability. Kolfugo performed well two weeks, thereafter lost rapidly efficacy.

The 2001 results agreed so far with the previous results than up to 14 days an acceptable stability was found. Thereafter Caramba and Kolfugo lost all efficacies, Falcon 0.8 proved better than the two fungicides mentioned. The best performance was registered at AMS2619 and Prosaro having after one month only 20 % of the check value.

CONCLUSIONS

The three years study showed that durability of the fungicide protection differs strongly between fungicides. Earlier we tested a number a fungicides (Mesterházy 2003, Mesterházy et al. 2003), in this tests only the bests were tested, Kolfugo was kept only as less effective check. It seems that tebuconazole and prothioconazole are the most durable products among the tested fungicides. Metconazole was also often mentioned as powerful fungicide, but in these tests it ranked only third after prothipoconazole and tebuconazole.

The best fungicides have now about one month protective time. In warmer traditional wheat production areas this secures a good control up to the ripening. In the northern regions where vegetation period is 2-3 weeks longer than in Hungary or Fargo, another spraying can be necessary to combat late infection.

We found that the susceptible phase of wheat is not only the flowering, but may take at least about 10-12 days. In 1992 we made a similar test, repeated the inoculation 10 days later and there was no difference between the infection severity of the first and second inoculation. The reason was that after the second inoculation we received 50 mm rain and this humidity could enhance a significant infection.

ACKNOWLEDGEMENTS

Authors are indebted for financial support from Bayer AG, OTKA projects TS040887 and D38486, as well as FVM project 38194/2003 for technology development.

REFERENCES

Mesterházy, Á. 2003. Control of *Fusarium* head blight of wheat by fungicides. In: Leonard, K. and Bushnell, W. (Eds.): *Fusarium* head blight of wheat and barley. APS Press, St. Paul. 363-380.

Mesterházy Á., T. BARTÓK and Cs. Lamper. 2003. Influence of cultivar resistance, epidemic severity, and *Fusarium* species on the efficacy of fungicide control of *Fusarium* head blight in wheat and deoxynivalenol (DON) contamination of grain. Plant Disease, 87:1107-1115.

Table 1. Fungicide durable effect on FHB in wheat, grain infection data (%), 1999.

Inoculation days after fungicide application	Fungicides				
	Kolfugo S 1.5	Falcon 0.6	Falcon 0.8	Caramba 1.0	Fus.contr.
1	42.78	49.72	28.69	33.42	62.17
5	17.11	19.64	8.19	12.67	29.67
10	14.83	16.83	13.53	13.42	30.61
15	5.28	3.47	4.47	3.81	9.22
Mean	20.00	22.42	13.72	15.83	32.92

Data expressed as % of the Fusarium check

	Fus.contr.	Falcon 0.6	Kolfugo S 1.5	Caramba 1.0	Falcon 0.8
1	100.00	79.98	68.81	53.75	46.15
5	100.00	66.19	57.67	42.69	27.62
10	100.00	55.54	48.94	44.26	44.63
15	100.00	37.66	57.24	41.28	48.51
Mean	100.00	59.84	58.17	45.50	41.73

Figure 1.

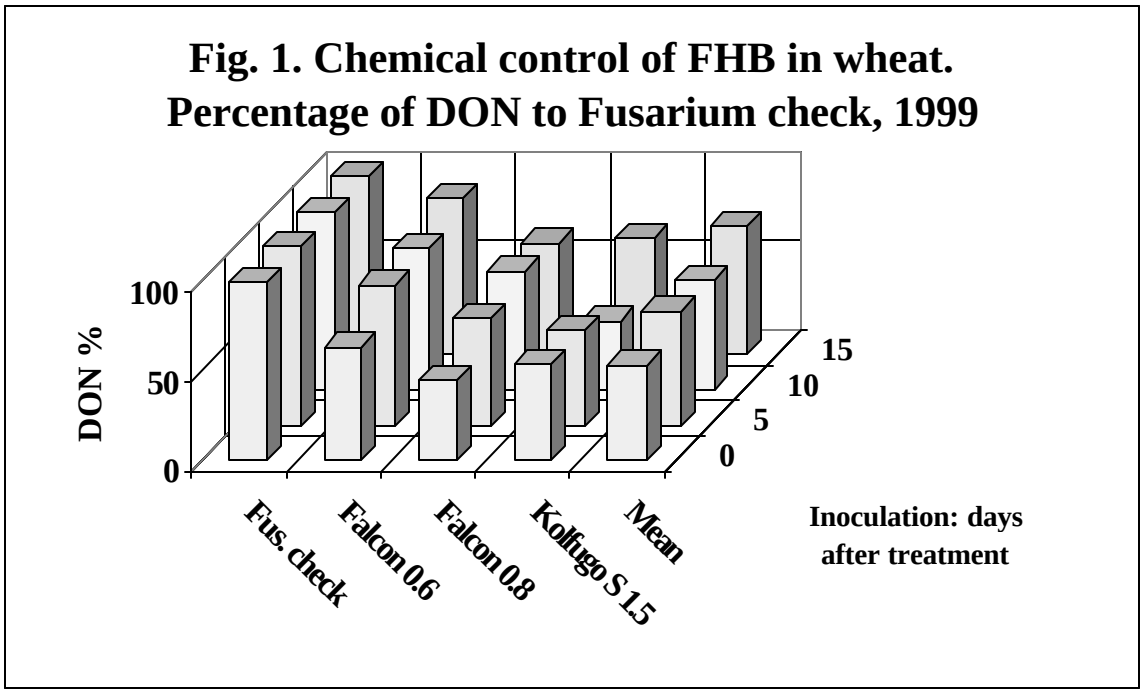


Figure 2.

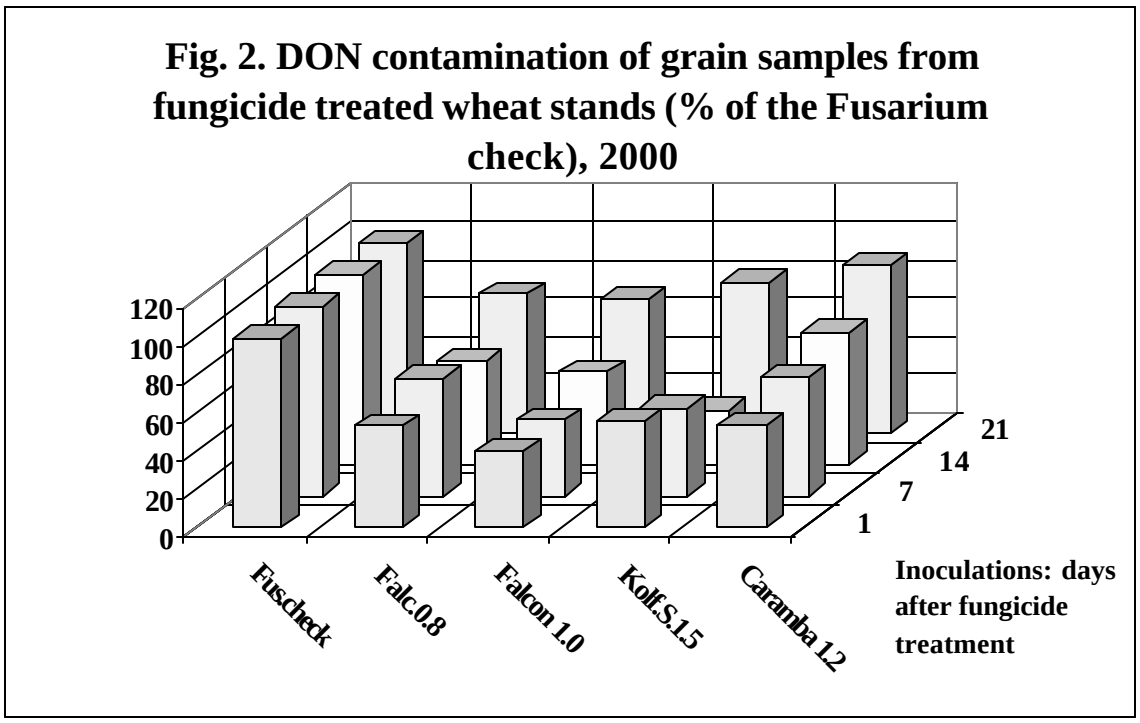
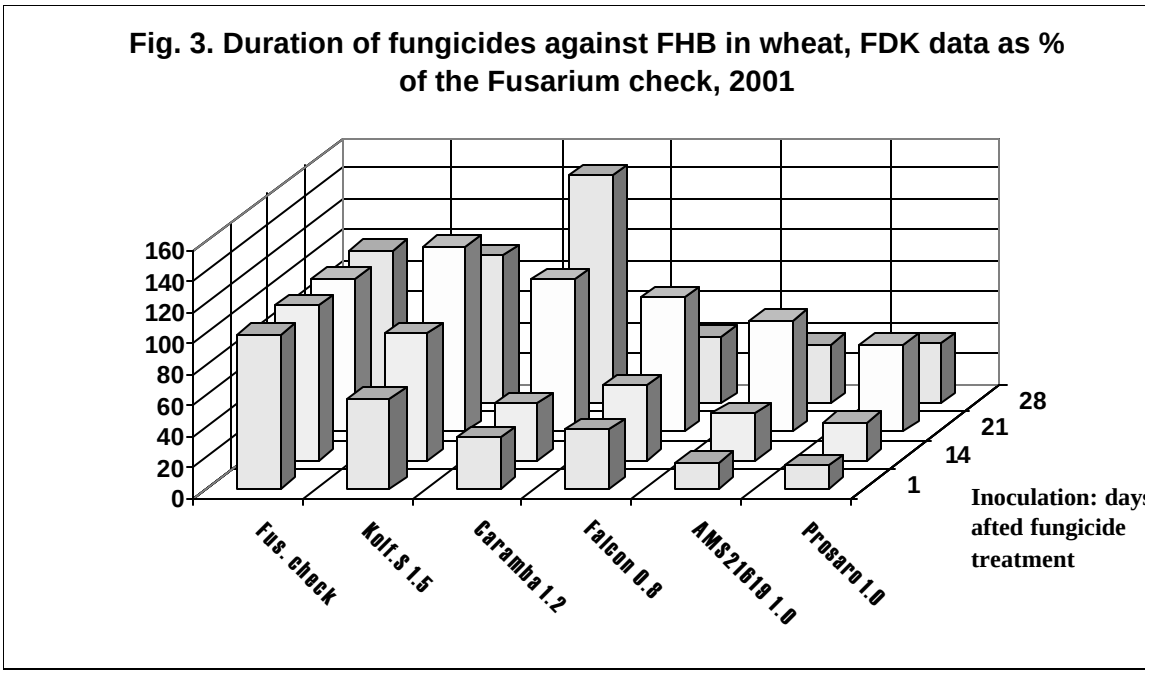


Figure 3.



EXPERIENCE WITH DMI FUNGICIDES FOR THE CONTROL OF FHB - EFFICIENT USE OF EFFICIENT TOOLS

Friedrich Kerz-Möhlendick*, Isolde Häuser-Hahn, Stefan Dutzmann and Anne Suty-Heinze

Bayer CropScience AG, Alfred-Nobel-Str. 50, D-40789 Monheim, Germany
*Corresponding Author: E-Mail: Friedrich.Kerz-Moehlendick@BayerCropScience.com.

OBJECTIVES

To describe experience with DMI (demethylation inhibitors)-fungicides for the control of Fusarium Head Blight (FHB).

INTRODUCTION

DMI-fungicides are the largest and most important class of fungicides applied in cereals over the last thirty years. The different generations of azole fungicides have contributed to suppress more and more disease in wheat and barley. Nevertheless Fusarium Head Blight remained the main challenge, cereal growers have to face. Tackling this disease is very difficult because of the presence of several pathogens with different epidemiology. With the introduction of tebuconazole Bayer CropScience offered a tool for the chemical control of FHB. The development of prothioconazole amongst all fungicides sets new standards of *Fusarium* control. It presents an unsurpassed performance against FHB and all major associated mycotoxins, thus contributing to the production of high quality yield. This paper presents an overview on factors influencing FHB infection and its impact on quality wheat production. The possibility of an effective use of tebuconazole and prothioconazole against FHB are extensively discussed.

MATERIAL AND METHODS

Field trial - Field trials were carried out under natural infection conditions in different areas of Western-Europe (Germany, France, UK, The Netherlands) in compliance with approved guidelines from 1997 to 2002 to characterise the efficacy of products containing tebuconazole and prothioconazole in comparison to commercial standards. Treatments were carried out during the flowering growth stage, preferably at the beginning of anthesis (EC 61) one or two days after rain. The level of infection was evaluated on the basis of "percentage of infected spikelets" at EC 85 (wax-ripe stage). At growth stage EC 99, grains from each experimental treatment were harvested for further investigations.

Mycotoxin analysis - Grains sampled from field trials were ground and analysed at IFA Tulln (Austria). Detection was performed on GC with electron-capture detection (Weingärtner, 1997). All samples were analysed in the µg/kg range for contamination with deoxynivalenol. Furthermore, samples were partly analysed for other B-trichothecenes (3 Ac-deoxynivalenol (3 Ac-DON), 15 Ac-deoxynivalenol (15 Ac-DON) and nivalenol (NIV)) and/or zearalenone (ZEA).

Cytological studies - Cytological studies were performed under controlled conditions by Buchenauer at the University of Hohenheim. As described by Kang & Buchenauer (1999, 2000), the wheat plants were sprayed with prothioconazole 1 day before and 1 day after inoculation. *Fusarium graminearum* was inoculated at mid anthesis (EC 65) with a conidia suspension. The conidia suspension was pipetted into the cavity between the lemma and palea of a spikelet in the middle of a spike. One or three days after inoculation the inoculated and uninoculated wheat spikes were analysed by electron microscopy.

RESULTS AND DISCUSSION

Integrated approach to the reduction of Fusarium Head Blight - Tackling Fusarium Head

Blight in wheat is a complicated problem as the degree of severity of infection is a function of the occurrence of various factors favourable to the development of the disease. In addition , epidemiological studies have demonstrated the complex biology of *Fusarium* species and the difficulty of forecasting the disease (Suty & Mauler-Machnik, 1996). Plants are particularly susceptible to Fusarium Head Blight at the flowering growth stage. Nevertheless, depending on the climatic conditions, dominating species may differ from year to year. Moreover, tillage operations or choice of variety are definitely involved in disease severity. As the *Fusarium* fungus is spread by residual plant matter, reduced tillage in form of direct sowing or minimal tillage dramatically increases disease incidence and consequently mycotoxin contamination. The presence of higher inoculum density is encouraged by monocotyledonous previous crop like maize or wheat. Especially maize as previous crop represents a high risk for an increased infection by Fusarium Head Blight and high mycotoxin content. At last, even if no resistant varieties are available, differences in sensitivity to Fusarium Head Blight may also influence the mycotoxin contamination of harvested grains (Obst et al., 2000).

Chemical control - Generally, all applications of *Fusarium* active compounds at the different plant growth stages contribute to maintain the crop healthy and reduce the risk of ear infection (Mauler-Machnik & Zahn, 1994).

In the last 10 years (Suty et al., 1996), tebuconazole containing products applied at flowering proved to clearly reduce the disease severity of Fusarium Head Blight and consequently decrease mycotoxin contamination and increase technological quality of cereal grains (baking and cooking performance, seed quality). Similar results were obtained either after inoculation or under natural infection conditions as described by different authors (Homdork et al., 2000, Matthies & Buchenauer, 2000, Schaffsma et al., 2001).

Depending on application timing and technique variation in efficacy level of tebuconazole containing products have been observed. Studies have shown that tebuconazole should be applied +/- 5 days around infection date. The best results have been obtained when tebuconazole containing products were applied at the beginning of anthesis one or two days after rain. Also the quality of fungicide application plays an important role in efficacy level. Reaching the ear is due to its verticalness a critical issue. Field studies showed that standard application techniques using normal spraying machinery cover only one face of the ear. As only a partial redistribution of the fungicidal compound takes place, particular attention should be paid on the use of appropriate spraying nozzles. For example, the use of double fan nozzles, one spraying forward and the other one backward, improved the efficacy of tebuconazole significantly against Fusarium Head Blight (Courbon, 1995).

Prothioconazole – a new standard to control FHB

Mode of action

Prothioconazole, as a sterol biosynthesis inhibitor, shows no effect on spore germination but inhibits development of germ tubes at very low concentration.

Results of studies using scanning electron microscopy show that prothioconazole, applied in a protective way (1 day before inoculation [I-1d]), inhibits germ tube extension and causes severe morphological alterations of the fungus. In comparison to untreated fungi the germ tubes are swollen and show multiple buds one day after inoculation. The hyphal tip is often extremely swollen and appears in spherical shape (Fig. 1). Consequently, no hyphal network can be formed and no penetration of hyphae in any tissues of the wheat spikes can take place.

Three days after inoculation, *F. graminearum* forms a dense hyphal network in untreated control. After curative application of prothioconazole (1 day after inoculation [I+1d]), one day after inoculation, newly formed hyphae become irregularly swollen and distorted (Fig. 2), whereas hyphae that have been developed before fungicide treatment, show no morphological alteration. The whole hyphal development is less dense compared to the hyphae observed in the control. Furthermore, no hyphal growth can be detected in the rachis.

Efficacy of prothioconazole against *Fusarium* species and yield response

Results on field efficacy of prothioconazole against *Fusarium roseum* (*F. graminearum and F. culmorum*) and *Microdochium nivale* are presented in table 1 in comparison to tebuconazole, the commercial standard for Fusarium Head Blight control to date.

The relatively low amount of results available for *M. nivale* is due to the low incidence of this pathogen the last 5 years. Globally, results show that prothioconazole has a high activity potential against both *F. graminearum* and *M. nivale*. Efficacy level obtained with this molecule is significant higher than that of tebuconazole. Increased efficacy of prothioconazole is also correlated with yield response, in fact yield is improved much more when prothioconazole is applied at anthesis.

Reduction of mycotoxins by application of tebuconazole and prothioconazole

Incidence of prothioconazole on formation of the three main *Fusarium* mycotoxins, deoxynivalenol (DON), nivalenol (NIV) and zearalenone (ZEAS) in wheat grains, has been investigated in comparison to tebuconazole (Fig. 3).

Results demonstrate that independent of the mycotoxin considered, prothioconazole reduces more significantly the level of mycotoxin in grain than all other commercial standards.

ACKNOWLEDGMENTS

The authors would like to thank all colleagues who contributed to the know-how presented in this paper and the teams behind tebuconazole and prothioconazole.

REFERENCES

Courbon, R. (1995): Epiaison et qualité – L'enjeu de la protection fongicide. Colloque Fusarioses des céréales, Bayer S.A. Paris, Kolloquiumbericht.

Dutzmann, S., Mauler-Machnik, A., Häuser-Hahn, I. & Suty-Heinze, A. (2003): Prothioconazole and Fluoxastrobin – two novel fungicides for innovative solutions in cereals. AFPP – seventh international conference on plant diseases, Tours, France, *in press*

Homdork, S., Fehrmann, H. & Beck, R. (2000): Effects of Field Application of Tebuconazole on Yield, Yield Components and the Mycotoxin Content of *Fusarium*-infected Wheat Grain. J. Phytopathology, **148**, 1-6

Kang, Z., H. Buchenauer (1999): Immunocytochemical localization of *Fusarium* toxins in infected wheat spikes by *Fusarium culmorum*. Physiol. Mol. Plant Pathol. **55**, 275-288.

Matthies, A., Buchenauer, H. (2000): Effect of tebuconazole (Folicur®) and prochloraz (Sportak®) treatments on Fusarium head scab development, yield and deoxynivalenol (DON) content in grains of wheat following artificial inoculation with *Fusarium culmorum*. Journal of plant diseases and protection **107**(1), 33-52.

Mauler-Machnik, A. & Zahn, K. (1994): Ährenfusariosen an Weizen - neue Erkenntnisse zur Epidemiologie und zur Bekämpfung mit Folicur (Tebuconazole). Pflanzenschutz-Nachrichten Bayer **47**(2), 133-160.

Mauler-Machnik, A., Rosslenbroich, H-J., Dutzmann, S., Applegate, J. & Jautelat, M. (2002): JAU 6476 - a new dimension DMI fungicide. Proceedings of the BCPC Conference – Pests and Diseases 2002, 389-394.

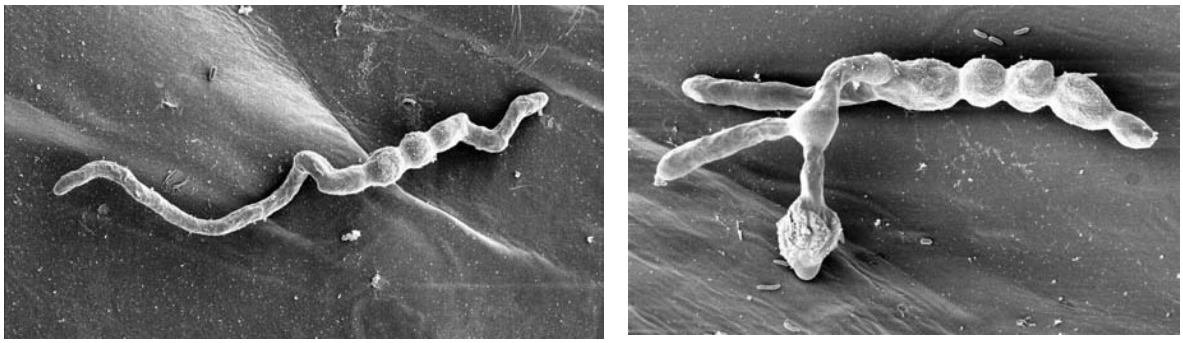
Obst, A., Bauer, G., Beck, R. & Lepschy, J. (2000): Zusammenfassende Bewertung der Ergebnisse des LBP-Forschungsverbunds *Fusarium*. Bodenkultur und Pflanzenbau - Schriftreihe der Bayerischen Landesanstalt für Bodenkultur und Pflanzenbau, **3/00**, 105-107.

Schaafsma A.W., Phibbs T.R., Paul D.E. & Tamburic-Ilincic L. (2001): *Fusarium* control with fungicides. PMR Report, ICAR 61006537.

Suty, A. & Mauler-Machnik, A. (1996): Ährenfusariose an Weizen – Neue Erkenntnisse zur Epidemiologie und Bekämpfung von *Gibberella zeae*, der Hauptfruchtform von *Fusarium graminearum* mit Folicur®. Pflanzenschutz-Nachrichten Bayer, **49**(1), 55-70.

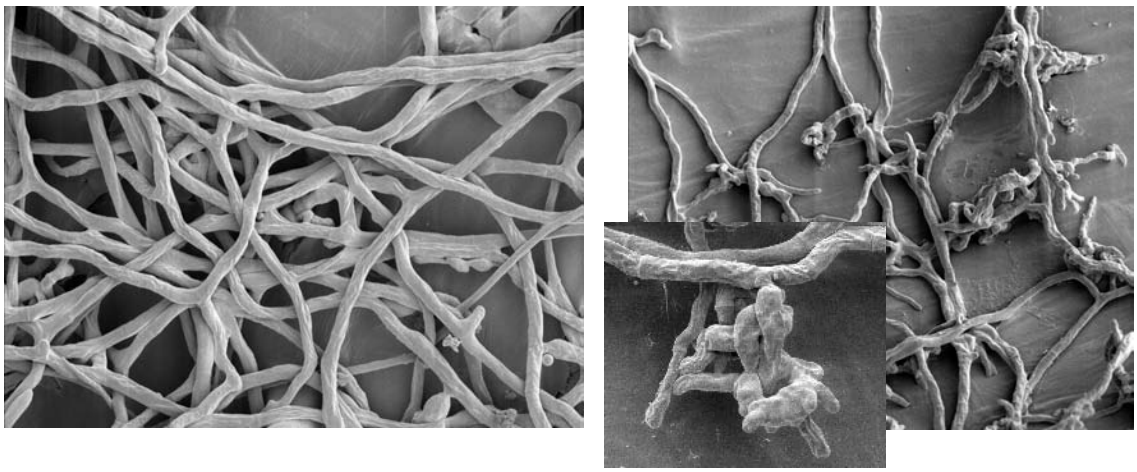
Suty, A., Mauler-Machnik, A. & Courbon, R. (1996): New findings on the epidemiology of Fusarium Head Blight on wheat and its control with tebuconazole. *Proceedings of the BCPC Conference - Pests and Diseases* 1996, 511-516.

Weingaertner, J., Krska, R., Praznik, W., Grasserbauer, M., Lew, H. (1997): Use of Mycosep multifunctional clean-up columns for the determination of trichothecenes in wheat by electron-capture gas chromatography. Fresenius Journal of Analytical Chemistry, **357**(8), 1206-1210.



untreated 12 hours after inoculation prothioconazole 1day after inoculation [I-1d]

Figure 1: Electron microscopical study on the effect of prothioconazole on development of *Fusarium graminearum* applied protectively one day before inoculation (pictures: Buchenauer & Kang, University of Hohenheim).



untreated 3 days after inoculation prothioconazole 3 days after inoculation [I+1d]

Figure 2: Electron microscopical study on the effect of prothioconazole on development of *Fusarium graminearum* applied curatively one day after inoculation (pictures: Buchenauer & Kang, University of Hohenheim).

Table 1. Efficacy of prothioconazole against *Fusarium roseum* and *M. nivale* on ear disease severity.

Treatment	Dose rate (g a.i./ha)	efficacy (% untreated) *Fusarium spp.* n* = 35	*M. nivale* n = 3	relative yield (%) n = 33
untreated	-	(31%)	(19%)	(73.3 dt/ha)
Tebuconazole	250	63	48	116
Prothioconazole	**200**	**73**	**76**	**125**

*n = number of trials

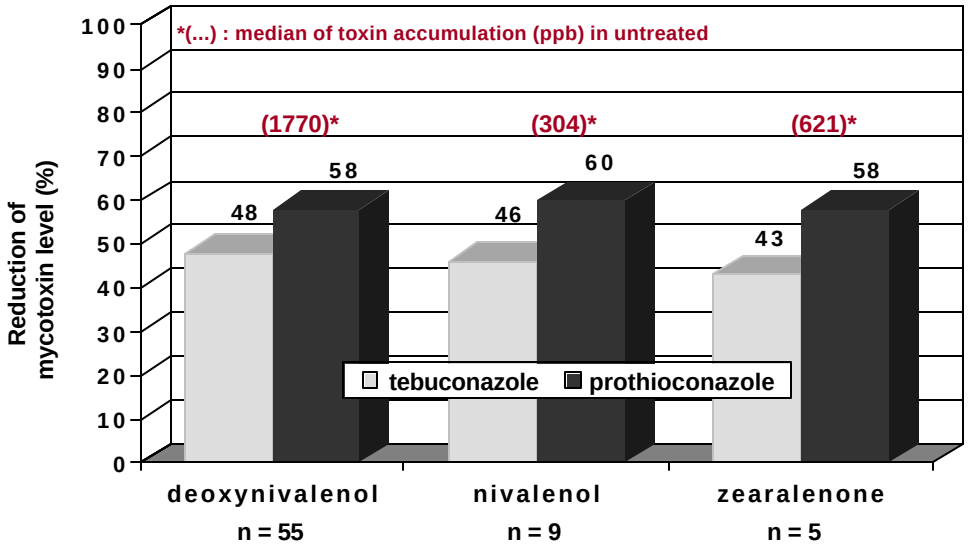


Figure 3. Effect of prothioconazole on reduction of mycotoxin level in wheat samples (n = number of trials), Europe 1998-2002.

THE USE OF *TRICHODERMA ASPERELLUM* AND THE YEAST *CRYPTOCOCCUS NODAENSIS* IN RUSSIA TO REDUCE FUSARIUM HEAD BLIGHT

L.V. Kolombet[1*], M.S. Sokolov[2], T.V. Pavlova[3], D.A. Schisler[4] and G.J. Samuels[5]

[1]State Research Center for Applied Microbiology, Obolensk, Moscow Region, Russia; [2]Research Center of Toxicology and Hygienic Regulation of Biological Products, Serpukhov, Russia; [3]All-Russia Research Institute of Biological Plant Disease Control, Krasnodar, Russia; [4]NCAUR, USDA-ARS, Peoria, Illinois, USA; and [5]USDA-ARS, Systematic Botany and Mycology Lab., Beltsville, USA
[*]Corresponding Author: PH: 7 (0967) 70-56-30; E-mail: kolombet_l@rambler.ru

ABSTRACT

A unique biocontrol strategy that combines seed pretreatment with a biofungicide "Mycol" (*Trichoderma asperellum* strain GJS 03-35) with spraying wheat plants during flowering with the yeast *Cryptococcus nodaensis* OH 182.9 (NRRL Y-30216) to reliably reduce FHB development have been developed. Tests of the "Mycol" preparation and the yeast OH 182.9 (EOD) have been performed on the spring wheat "Ivolga" in greenhouse conditions (the Moscow region) and on the winter wheat "Kupava" in field trials in the North Caucasian region. An isolate of *F. graminearum* was used to insure adequate levels of disease development in greenhouse and field experiments. Fusarium head blight (FHB) severity and incidence, as well as mycotoxin accumulation in wheat grains, was studied for single or combination treatments with the biological preparations. Mycol (in concentrations 0,1; 0,5; 1,0; 2,0 kg / 1 tone of seeds) was used for wheat seed pretreatment. The yeast preparation EOD ($2,0E•10^7$ cfu/ml) was applied by spraying wheat plants during flowering. Chemical pesticides (Raxyl, TMTD) and a biological preparation Agat-25K were used as alternative control seed treatments. In greenhouse experiments, inoculations of heads with either biological preparation 4 h prior to inoculation with conidia of *F. graminearum* significantly reduced FHB severity. For treatments consisting of Mycol and EOD, 1000 grain weights were equivalent or higher than for control plants (both infected, and not infected). Wheat seeds obtained from the plants protected by these biological preparations germinated rapidly and possessed high germination rates compared to the FHB control. In field trials, Mycol treatments clearly reduced FHB symptoms, apparently providing an immunizing effect against FHB. Mycol reduced FHB severity and enhanced yield of the wheat varieties used. The effect of Mycol used at a minimum test-dose (0,1 kg / 1 tone) was not so pronounced. The greatest reduction of FHB development was observed at a dose of Mycol of 1,0 kg per 1 tone of seeds used in combination with EOD spraying. Experimental results support the contention that the offered technology has good prospects in controlling FHB. The work was executed within the framework of partner ISTC project !2336p.

ACKNOWLEDGEMENT

The authors express sincere gratitude to participants of this research: Chuprina V.P., Gopalo N.M., Starshov A.A., Sidorov I.A., Esaulenko E.A., Kosareva N.I., Zhigletsova S.K., Bystrova E.V., Derbyshev V.V., Kiseleva N.I.

EFFECTS OF TILLAGE PRACTICES ON DON CONTENT IN BARLEY

J. Lajeunesse[1*], D. Pageau[1] and M. Savard[2]

[1]Agriculture and Agri-Food Canada, Research Farm, Normandin QC, Canada; and [2]Agriculture and Agri-Food Canada, Eastern Cereal and Oilseed Research Centre, Ottawa ON, Canada
[*]Corresponding Author: PH: (418) 274-3378 ext.239; E-mail: lajeunesseju@agr.gc.ca

ABSTRACT

Six tillage systems in barley (*Hordeum vulgare L.*) monoculture have been studied to compare chisel and no-till with conventional tillage. The experiment, conducted at the Research Farm of Agriculture and Agri-Food Canada at Normandin (Quebec), was initiated in 1990. The treatments were: T1: Conventional (fall molboard plowing and spring harrowing – 2 passes with a cultivator); T2: Chisel (fall) and spring harrowing (2 passes with a cultivator); T3: Chisel (fall) and spring harrowing (1 pass with a cultivator); T4: No tillage (fall) and spring harrowing (1 pass with a rotative harrow); T5: No tillage (fall) and spring harrowing (1 pass with a cultivator); T6: No-till (no tillage the previous fall and no harrowing in spring). Treatments were laid out in a complete randomized block design with four replications. Plot size was 10 m X 10 m. Barley seeding rate was 170 kg ha^{-1}. Because fusarium head blight (FHB) has become the most important cereal disease in Northern Quebec, DON content was measured in 2003 to determine the effect of soil tillage on FHB incidence in barley. According to treatments, mycotoxin content varied from 2.2 to 7.4 ppm. DON content was higher for no-till treatment (T6) than for other treatments (T1, T2, T3, T4, and T5). Because the fungus that causes FHB survives on residue left on soil, and according to the results of this trial, tillage practices that bury cereal residue could be used to reduce the amount of inoculum.

THE *FUSARIUM GRAMINEARUM* PKS12 GENE IS RESPONSIBLE FOR THE SYNTHESIS OF THE POLYKETIDE AUROFUSARIN

Sascha Malz[3], Morten N. Grell[1], Charlotte Thrane[2], Frank J. Maier[3], Pernille Rosager[1], Angelika Felk[3], Klaus S. Albertsen[1], Siegfried Salomon[3], Lisbeth Bohn[1], Wilhelm Schäfer[3] and Henriette Giese[1*]

[1]Department of Ecology, The Royal Veterinary and Agricultural University, DK-1871 Frederiksberg C, Copenhagen, Denmark; [2] Microbiological Laboratory, Plant Directorate, Building F, Skovbrynet 20, DK-2800 Lyngby, Denmark; and [3]University of Hamburg, Biocenter Klein Flottbek, Dept. of Molecular Phytopathology and Genetics, Ohnhorststr. 18, D-22609 Hamburg, Germany
[*]Corresponding Author: PH: 45 35282638; E-mail heg@kvl.dk

ABSTRACT

The red pigmentation of *Fusarium graminearum* and related species is due to the deposition of aurofusarin in the cell walls. To identify the polyketide responsible for the biosynthesis of this pigment random mutagenesis of *F. pseudograminearum* using *Agrobacterium* mediated transformation was carried out. Several mutants were identified that had altered pigmentation and plasmid rescue was carried out to identify the insertional events. All mutants had integration of the T-DNA in a region upstream from a putative transcription factor with homology to the aflatoxin gene, *aflR*. This region of the *F. graminearum* genome contain genes typical of polyketide gene clusters and identifies *?pks12* as the gene responsible for the synthesis of aurofusarin. Comparative PCR analyses of the aurofusarin gene cluster in *F. graminearum*, *F. culmorum*, and *F. pseudograminearum* show conserved organisation. The expression of individual genes in the cluster were analysed by RT-PCR, *?pks12* is silenced in all mutants and most of the adjacent genes show reduced levels of transcripts. To confirm that *?pks12* encodes the precursor for aurofusarin, targeted mutagenesis was carried out. All disruptants showed an albino phenotype. Physiological studies of the *?pks12* mutants were carried out to access the function of the aurofusarin. The *?pks12* mutants have higher growth rate and a 10-fold increase in conidia production compared to the wild type indicating that the pigment negatively affects growth rate. Infection studies were carried out on barley roots in a sterile culture system and by inoculation of wheat heads. The aurofusarin deficient mutants were fully virulent and it is concluded that this compound is not important for pathogenicity. HPLC analyses of aurofusarin deficient mutants confirmed the absence of aurofusarin in the mutants. In addition, these analyses showed that there is an increase in the level of the mycotoxin, zearalenone.

ALTERING AGRONOMIC PRACTICES TO REDUCE THE EFFECT OF FUSARIUM HEAD BLIGHT ON DURUM

W.E. May[1*], M R. Fernandez[2], F. Selles[2] and G.P. Lafond[1]

[1]Agriculture and Agri-Food Canada, Indian Head Research Farm, Indian Head, Saskatchewan, S0G 2K0, Canada; and [2]Agriculture and Agri-Food Canada, Semiarid Prairie Agricultural Research Centre, Swift Current, Saskatchewan, S9H 3X2, Canada

[*]Corresponding Author: PH: (306) 695-5225; E-mail: mayb@agr.gc.ca

ABSTRACT

Fusarium head blight (FHB) has become an important disease of cereals in moist regions of western Canada. This disease has played an important role in contributing to lower grain yields and substantial downgrading of durum wheat (*Triticum turgidum* L. var. *durum*). The objective of this study, conducted at three locations on the Canadian prairie, two in Saskatchewan and one in Manitoba, from 2001 to 2003, was to determine the effect of seeding density, nitrogen supply, fungicide treatment, and durum wheat cultivar on FHB development, grain quality, grade protection and economic return. A four-way factorial design was used with two seed densities (150 and 300 viable seeds m^{-2}), two nitrogen rates (75 and 100% of recommended rate), three cultivars (AC Avonlea, AC Morse and AC Navigator), and four fungicide treatments (no application, Tilt at flag leaf, Folicur at anthesis and Tilt at flag leaf followed by Folicur at anthesis). Increasing the seed density decreased FHB at 4 out of the 7 site year when FHB occurred, however increasing the seed density tended to increase leaf disease severity. The application of Folicur did not affect fusarium levels. The application of Tilt and /or Folicur decreased leaf disease at 6 out of 9 site years and affected yield at 5 out of 9 site years. There was no consistent effect from nitrogen or cultivar.

EFFICACY OF TRIAZOLE FUNGICIDES FOR FHB CONTROL WITH VARIOUS ADJUVANTS AND SPLIT TIMINGS OF APPLICATION

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

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

OBJECTIVE

To improve the efficacy of triazole fungicides in control of FHB using adjuvants and appropriate timings of application.

INTRODUCTION

Currently, the triazole fungicide Folicur (tebuconazole) has special exemptions in some states within the United States (US) for use on wheat and barley to suppress Fusarium head blight (FHB). Another triazole, JAU 6476 (prothioconazole), an experimental product from Bayer CropScience, is being tested in the US for suppression of FHB. A standard adjuvant recommended for use with tebuconazole is Induce, a petroleum-based non-ionic surfactant. Various private companies in the US sell non-ionic surfactants similar to Induce, or have other adjuvants for sale that are silicone-based or are encapsulating products (Thomsan, L, 1998). With so many products on the market, more information is needed about their efficacy with the triazoles. Preliminary tests indicated few differences among adjuvants when combined with Folicur (Jordhal et al. 2001).

Timing of application also is known to affect efficacy of fungicide applications for FHB control. In North Dakota, three spring cereals vulnerable to FHB are hard red spring wheat, durum wheat, and spring barley. The question on whether multiple infections of these crops by *Fusarium graminearum* can be controlled with a single, appropriately timed application of a triazole fungicide needs to be answered. Preliminary results indicated this may be possible in hard red spring wheat cultivars, but not in barley (Jordahl et al. 2003). Neate et al. (2003) reported that split applications of fungicide to barley did not provide a significant advantage over a single application under low disease pressure. Further studies with durum wheat and barley were needed.

MATERIALS AND METHODS

Hard red spring wheat ('Grandin'), durum wheat ('Monroe') and spring barley ('Robust') were grown in the greenhouse, and then exposed to single or multiple inoculations of *Fusarium graminearum* and single or multiple fungicide applications at various heading stages. For the adjuvant studies, all fungicide applications were applied once, at early flowering (Feekes 10.51) in spring wheat and durum wheat, and at early full head emergence (Feekes 10.5) in barley (Table 1). Adjuvants were mixed with 4 fl oz/acre of Folicur (tebuconazole) or with 5.7 fl oz/acre of JAU 6476 (prothioconazole) (Table 1). Experimental adjuvants were provided by Agrilliance LLC.

For the timing of application studies, inoculations and or fungicide applications were applied at head half emerged (Feekes growth stage 10.3), early flowering or full heading (Feekes 10.51 in wheat, Feekes 10.5 in barley), and at kernel watery ripe stage (Feekes 10.54) (Table 2). Folicur at 4 fl oz/acre or at reduced/split rates was used in the timing studies. For both the adjuvant and the application timing studies, fungicide applications were made using a track sprayer mounted with XR8001 flat fan nozzles oriented forward and backward at 60° angle from vertical, delivering 18.3 gpa at 40 psi. Plants were inoculated with a mixture of three *F. graminearum* isolates, delivered at a rate of 10,000 spores/ml, 20 ml/pot, per spray event with a DeVilbiss atomizer, 4 hrs after the fungicide was applied. Immediately following inoculation, plants were misted for 48 hours using a closed mist system at or near 100% RH at 23^0C (+ or – 5^0 C).

FHB incidence, head severity and field severity (incidence x head severity) were determined at kernel soft dough stage. Field severity values were analyzed using ANOVA at the 95% and 90% confidence intervals.

RESULTS

Adjuvants: Across grain classes and the two triazoles tested, no significant differences were observed among adjuvants tested, when analyzed at the 95% confidence level, but some differences were observed when adjuvant treatments alone were compared at the 90% confidence level (Table 1). The adjuvants Placement and the experimental adjuvant #1 (supplied by Agrilliance LLC) were consistent in having high FHB field severity values, while Preference and the combination of experimental adjuvant #1 plus Preference were consistently low in FHB field severity values across all grain classes and triazole treatments. Placement is an encapsulating adjuvant, Preference is a crop-based non-ionic surfactant and the composition of the experimental adjuvants is proprietary at this time. In general, adjuvants tested did not perform better than Induce adjuvant, except in barley, where some adjuvant combinations were better than Induce, when analyzed at the 90% confidence level.

Timing Studies: For barley, multiple inoculations significantly increased FHB field severities over single applications, with three inoculations and no fungicide treatment resulting in a 68.3% field severity (Table 2). With three inoculation events, a multiple, 3-way split application of Folicur (total product applied was 4 fl oz/acre) reduced FHB field severity to 42%, as compared to a 52% field severity with a single full rate application applied at full head emergence. FHB field severity values were the lowest with a single inoculation and when a full rate of Folicur was applied at early head emergence or at kernel watery ripe stage.

In durum, FHB field severity values were as high as 81.9% with three inoculations. With three inoculation events, a single full rate application of Folicur at Feekes 10.51 reduced the disease level significantly, to 18.5%. Three split rate multiple applications in combination with the three inoculations resulted in similar disease levels (20% field severity) as the single full rate application (Table 2).

CONCLUSIONS

Adjuvants: Some registered and experimental adjuvants will provide a slight enhanced control of FHB over the standard non-ionic product, when combined with Folicur or JAU 6476. Other adjuvants are not as satisfactory as the standard non-ionic surfactants commonly used.

Timing studies: In durum, a single, appropriate timing of a full rate of Folicur fungicide may significantly reduce FHB field severity caused by multiple infection events. In barley, multiple infection events are difficult to control with a single, full rate application or with multiple reduced rate fungicide applications. Multiple applications of higher rates may be necessary for FHB suppression in barley under severe disease pressure, or products with greater efficacy than Folicur may be needed.

ACKNOWLEDGEMENT

This material is based upon work supported by the U.S. Department of Agriculture, under Agreement No. 59-0790-9-053. This is a cooperative project with the U.S. Wheat and Barley Scab Initiative. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

REFERENCES

Jordahl, J., Meyer, S., and McMullen, M. 2001. Further studies on the effects of timing of application and of adjuvants on fungicide control of FHB. Page 65: 2001 National Fusarium Head Blight Forum Proceedings, Dec. 8-10, 2001, Erlanger, KY. Michigan State Univ., East Lansing, MI.

Jordahl, J., McMullen, M., and Meyer, S. 2003. Differential response of barley, hard red spring wheat, and durum wheat to multiple FHB infections and fungicide treatments.

Page 87 in: 2003 National Fusarium Head Blight Forum Proceedings, Dec. 13-15, 2003, Bloomington, MN. Michigan State Univ., East Lansing, MI.

Neate, S.M., McKay, K.R., and Halley, S.A. 2003. Split application of fungicides for increased control of FHB and DON in barley. Page 104 in: 2003 National Fusarium Head Blight Forum Proceedings, Dec. 13-15, 2003, Bloomington, MN. Michigan State Univ., East Lansing, MI.

Thomson, L. 1998. A Guide to Agricultural Spray Adjuvants used in the United States. Thomson Publications, Fresno, CA 93791.

Table 1. Effect of adjuvants on efficacy of triazole fungicides for control of FHB for each grain class, averaged across two triazole fungicides (Folicur = tebuconazole, applied at 4 fl oz/acre, and JAU 6476 = prothioconazole, applied 5.7 fl oz/acre; both Bayer CropScience products).

Adjuvant Treatments[a]	Rate/acre	Average FHB field severity		
		Spring wheat[b]	Durum wheat[c]	Barley[d]
Untreated		22.9	47.5	48.7
Induce	0.125%v/v	2.3	6.3	12.4
Exp. # 1 + Preference	2 fl oz + 0.25%v/v	1.9	5.3	6.7
Placement+ Preference	2 fl oz + 0.25%v/v	2.6	4.8	9.3
Exp. # 2	1.0% v/v	2.7	6.4	14.0
Exp. # 3	0.5% v/v	2.1	8.0	8.5
Rivet	0.5% v/v	2.4	3.2	12.0
Preference	0.25% v/v	1.3	4.2	7.7
Placement	2 fl oz	3.2	10.2	11.6
Exp. # 1	2 fl oz	2.9	11.8	11.3
	LSD 0.05	4.6	16.6	10.6
	LSD 0.10 (trts only)	1.1	6.6	4.1

[a] Induce adjuvant provided by Bayer CropScience; all other adjuvants provided by Agrilliance LLC; all applied to either Folicur (4 fl oz/acre) or JAU 6476 (5.7 fl oz/acre)
[b] Average of four trials; two with Folicur and two with JAU 6476
[c] Average of four trials; two with Folicur and one with JAU 6476
[d] Average of four trials; two with Folicur and two with JAU 6476

Table 2. Effect of single and multiple inoculations and Folicur fungicide (4 fl oz/acre + 0.125% v/v Induce adjuvant) applications on FHB field severity in barley and durum wheat, 2003-2004 greenhouse tests.

Trt #	Folicur Rate/ac	Fungicide application timing Feekes grwth stg[a]	Inoculation timing Feekes grwth stg[a]	**Barley** FHB field severity[b] %	**Durum** FHB field severity[b] %
1	--	--	10.5 (10.51)	9.1	22.3
2	--	--	10.54	10	0.8
3	--	--	10.5 (10.51) 10.54	42.3	65.7
4	--	--	10.3 10.5 (10.51) 10.54	68.3	81.9
5	4 Fl oz	10.5 (10.51)	10.5 (10.51)	0.5	1.5
6	4 Fl oz	10.54	10.54	0.1	0.2
7	2 Fl oz 2 Fl oz	10.5 (10.51) 10.54	10.5 (10.51) 10.54	14.7	25.7
8	1 Fl oz 2 Fl oz 1 Fl oz	10.3 10.5 (10.51) 10.54	10.3 10.5 (10.51) 10.54	42	20
9	4 Fl oz	10.5 (10.51)	10.5 (10.51) 10.54	13.8	17.9
10	4 Fl oz	10.5 (10.51)	10.3 10.5 (10.51) 10.54	52	18.5
11	4 Fl oz	10.54	10.5 (10.51) 10.54	35.3	46.6
12	4 Fl oz	10.54	10.5 (10.51) no inoc.	8	41.5

[a] Feekes 10.3 = head half emerged; Feekes 10.5 = early full head emergence; Feekes 10.51 = early flowering in wheat; Feekes 10.54 = kernel watery ripe stage

[b] Field severity = Incidence x Head Severity

INTEGRATED STUDY OF AERIAL APPLICATION PARAMETERS TO IMPROVE CONTROL OF FHB WITH FUNGICIDES

M. McMullen[1*], S. Halley[2], C. Hollingsworth[3], V. Hofman[4], B.K. Fritz[,5], I.W, Kirk[5], W.C. Hoffmann[5] and D.E. Martin[5]

[1]Dept. of Plant Pathology, North Dakota State Univ., Fargo, ND 58105, USA; [2]Langdon Research and Extension Center, Langdon, ND 58249, USA; [3]Univ. of Minnesota Northwest Research and Outreach Center, Crookston, MN 56716, USA; [4]Dept. of Agriculture and Biosystems Engineering, North Dakota State Univ., Fargo, ND 58105, USA; and [5]USDA/ARS, College Station, TX 77845, USA
*Corresponding Author: PH: (701) 231-7627; E-mail: mmcmulle@ndsuext.nodak.edu

ABSTRACT

A study of aerial application methods for fungicidal control of Fusarium head blight (FHB) was done in 2004 as an interdisciplinary effort between Pathology and Ag. Engineering researchers from North Dakota, Minnesota, and the USDA/ARS Aerial Application research team from College Station, Texas. Three commercial hard red spring wheat fields were identified for study, one in east central and one in northeast North Dakota, one in northeast North Dakota, and one in northwest Minnesota. Fungicide treatments were applied with an Air Tractor AT-402B using CP-03 nozzles during the week of July 5th, when crop growth stage was at early flowering. Two spray parameters, droplet size (175 and 350 µm) and water volume (3, 5 and 10 gpa), were tested at each of the three locations, with tTreatments were arranged as a 2 3 x 3 x 3 (3^3)farrangedactorial in a randomized complete block design with three replicates. The two three factors tested were droplet size (175 and 350 µm), and spray volume (3, 5 and 10 gpa), and location (St. Thomas, Crookston, and Hunter).Data was analyzed as a 3 x 3 x 2 factorial, using SAS and the GLM procedure. The College Station, Texas, USDA/ARS Aerial Application Research Unit, using food grade dye and various methods of deposition measurement, studied spray deposition on the wheat heads. Results of the deposition studies are being submitted for publication in the *Crop Science* journal. In general, smaller spray rates with larger droplet sizes tended to result in greater deposition of active ingredient on the wheat heads. For determination of disease control, with the application methods, Folicur (tebuconazole) fungicide was applied at 4 fl oz/A with an addition of 0.125% v/v of Activator 90 non-ionic surfactant. Disease evaluations were made approximately three weeks following fungicide application, at soft dough stage of kernel development. Grain was harvested by the farmer cooperators using commercial harvest equipment, and yields were determined using weigh wagons. Sub-samples were saved for test weight and DON determinations. FHB incidences across locations and treatments ranged from 8.8 to 32.3%, field severities ranged from 0.4 to 2.3%, and yields ranged from 56.3 to 76.4 bu. /Aacre. FHB generally was significantly decreased and yield increased with fungicide treatments, but few significant differences among treatments were observed. Location differences were significant (P = 0.1) across all parameters measured except test weight. Test weights were significantly different by droplet size (58.6 lb/bu with 175µm compared to 58.9 lb/bu with 350µm). Location x gallon/acre interactions were significant for FHB incidence, FHB field severity and test weight. A 3-way interaction between location x gallon/acre x droplet size also was significant. Therefore, additional field testing will be necessary to determine disease differences among application methods across locations.

ACKNOWLEDGEMENT

This material is based upon work supported by the U.S. Department of Agriculture, under Agreement No. 59-0790-9-053. This is a cooperative project with the U.S. Wheat and Barley Scab Initiative. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

RESULTS OF THE UNIFORM FUNGICIDE TRIAL ON BARLEY, NORTH DAKOTA, 2004

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

Dept. of Plant Pathology, Walster Hall, North Dakota State University, Fargo, ND 58105, USA
*Corresponding Author: PH: (701) 231-7627, Email: mmcmulle@ndsuext.nodak.edu

ABSTRACT

As part of the national uniform scab fungicide trial, six fungicide treatments were compared for control of Fusarium head blight (FHB) in 'Robust' spring barley at the Fargo, ND Agriculture Experiment Station. The barley was drilled into wheat stubble on April 28, 2004. Herbicide applications of Puma + Harmony GT + MCPA ester were made at the 5-leaf stage. Corn grain inoculated with *Fusarium graminearum* was spread evenly among plots. Following head emergence, a misting system provided added water to the plots when the nighttime humidity dropped below 90%. Fungicides were applied on July 1, at early full head emergence (Feekes 10.5). Applications were with a backpack-type sprayer equipped with two XR8001 flat fan nozzles oriented toward the grain head at a 30 degree angle from the horizontal. The fungicides were applied at 18.5 gpa with 40 psi. Disease notes were taken at soft dough stage of development and the crop was harvested on August 17th. The fungicide treatments included Folicur (tebuconazole) at 4 fl oz/A, Tilt (propiconazole) at 4 fl oz/A, a Bayer Co. experimental compound JAU 6476 (prothioconazole) at 5 fl oz/A, JAU 6476 at 2.85 fl oz/A + Folicur at 3.17 fl oz/A, a Valent Co. experimental compound V-10116 (metconazole) at 6 fl oz/A, and V-10116 at 4 fl oz/A. Results indicated that all treatments significantly reduced FHB field severity and DON (deoxynivalenol) and all treatments significantly increased yield over the untreated check. Fungicide treatments did not differ significantly from each other, but the experimental products generally provided slightly better disease control than the Folicur or Tilt. FHB field severity reductions ranged from 72.5 to 85%, DON reductions ranged from 48.9 to 69%, and yield increases ranged from 9.6 to 13.9%. Results of this trial will be published in *Fungicide and Nematicide Tests.*

ACKNOWLEDGEMENT

This material is based upon work supported by the U.S. Department of Agriculture, under Agreement No. 59-0790-9-053. This is a cooperative project with the U.S. Wheat and Barley Scab Initiative. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

WHEAT UNIFORM FUNGICIDE TRIALS, ND, 2004

M. McMullen[1*], J. Lukach[2], K. McKay[3] and B. Schatz[4]

[1]Dept. of Plant Pathology, North Dakota State University, Fargo, ND 58105; [2]Langdon Research Extension Center, Langdon, ND 58249; [3]North Central Research Extension Center, Minot, ND 58701; and [4]Carrington Research Extension Center, Carrington, ND 58421

[*]Corresponding Author: PH: (701) 231-7627; E-mail: mmcmulle@ndsuext.nodak.edu

OBJECTIVE

To evaluate experimental fungicides for control of Fusarium head blight (scab) and leaf diseases in hard red spring and durum wheat in North Dakota.

INTRODUCTION

Uniform fungicide trials have been established across grain classes and environments as part of the U.S. Wheat and Barley Scab Initiative (McMullen and Milus 2002). The purpose of these trials is to evaluate efficacy of fungicides in reducing Fusarium head blight severity (FHB), Fusarium damaged kernels (FDK), and deoxynivalenol (DON) levels. North Dakota continues to participate in these trials and tests fungicides at several locations across grain classes and cultivars.

MATERIALS AND METHODS

A uniform set of six fungicide treatments were evaluated on hard red spring and durum wheat in ND in 2004 (Table 1). Fungicides tested included Folicur (tebuconazole), which had a Section 18 exemption for use on wheat in ND in 2004, JAU 6476 (prothioconazole), an experimental fungicide from Bayer CropScience, and V-10116, an experimental product from Valent. Artificial inoculum in the form of inoculated grain was dispersed in plots at Fargo and Langdon, wheat straw was distributed at Carrington, and natural inoculum was the source of infections at Minot. 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. Water volume was 18-20 gpa applied at 40 psi. Disease ratings were taken at soft dough kernel stage. Plots were harvested with small plot combines. DON levels were determined by the NDSU Veterinary Toxicology Lab. Plots were in a Randomized Complete Block design and data were statistically analyzed across locations using ANOVA.

The uniform trial was established at four locations: Fargo in the southeast; Langdon in the northeast; Carrington in the central part of the state; and at Minot in the north central region. Each site represents different environment, soil type, and cropping practices. Fungicides were evaluated over two wheat classes, 'Reeder' hard red spring wheat and 'Lebsock' durum wheat.

RESULTS AND DISCUSSION

FHB field severities varied across sites and wheat class. Field severity on untreated spring wheat averaged as high as 12.5% at Fargo on spring wheat, but was less than 1% on spring wheat at Langdon and on durum wheat at Minot. Because of the very low levels of FHB on spring wheat at Langdon and on durum wheat at Minot, Table 1 contains data only from hard red spring wheat at Fargo and Carrington and from durum wheat at Langdon. All fungicide treatments significantly reduced FHB field severity over the untreated check, and the combination treatment of JAU 6476 + Folicur had the lowest FHB field severity among fungicide treatments (Table 1). All treatments significantly reduced FHB DON ppm, with the two V -10116 resulting in the lowest DON levels. All treatments increased yield, from six to 12.7 bu, with the high rate of V-10116 resulting in the highest yield improvement.

Test weights were significantly improved by most treatments. All fungicide treatments significantly reduced the level of leaf disease from the untreated check but did not differ from each other.

ACKNOWLEDGEMENT

This material is based upon work supported by the U.S. Department of Agriculture, under Agreement No. 59-0790-9-053. This is a cooperative project with the U.S. Wheat and Barley Scab Initiative. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

REFERENCE

McMullen, M. and Milus, E. 2002. History and accomplishments of the USWBSI uniform fungicide and biological control trials, 1998-2002. Page 96 in: Proc. 2002 National Fusarium Head Blight Forum, Erlanger, KY, Dec. 7-9, 2002. U.S. Wheat and Barley Scab Initiative, Michigan State Univ., East Lansing, MI.

Table 1. Effect of fungicides on fungal leaf disease and FHB field severity, DON, FDK, yield and test wt., averaged across Carrington, Fargo and Langdon, ND locations and across spring wheat and durum wheat grain classes, 2004.

Treatment and rate/acre[1]		FHB FS[2] %	DON[3] ppm	FKD[4] %	Leaf disease[5] % severity	Yield Bu/A	Test wt Lbs/bu
Untreated check		10.6 a	9.5 a	10.1 a	35.2 a	55.5 c	55.2 c
Folicur 3.6 EC	4 fl oz	4.5 bc	5.8 bc	7.2 a	11.5 b	65.6 ab	57.2 ab
Tilt 3.6 EC	4 fl oz	5.5 b	6.3 b	6.7 a	14.0 b	61.6 bc	56.3 bc
JAU6476 480SC	5 fl oz	3.6 bcd	5.3 bcd	5.2 a	9.3 b	67.2 ab	57.6 ab
JAU6476 480SC + Folicur 3.6F	2.85 fl oz 3.17 fl oz	2.2 d	5.4 bcd	5.8 a	8.0 b	67.4 ab	57.7 a
V-10116 1.81 FL	6 fl oz	2.7 cd	4.7 cd	5.5 a	10.5 b	68.2 a	57.4 ab
V-10116 1.81 FL	4 fl oz	3.4 cd	4.6 d	5.7 a	11.3 b	65.9 ab	57.7 a

Numbers followed by different letters are significantly different at the 95% confidence level, using LSD analysis.
[1] All fungicide treatments had 0.125% Induce added; JAU6476 (prothiocoanzole) is an experimental fungicide from Bayer; V-10116 (metconazole) is an experimental fungicide from Valent;
[2] FHB FS = Fusarium head blight field severity; field severity = incidence x head severity;
[3] DON (deoxynivalenol = vomitoxin) levels were only available from Carrington and Fargo at time of this report;
[4] FDK = Fusarium damaged kernels; data from Fargo and Langdon sites available at time of this report; and
[5] Leaf spot diseases primarily tan spot and Septoria leaf spot complex.

PROTHIOCONAZOLE FUNGICIDES AGAINST FHB IN WHEAT, 2003/2004 RESULTS

A. Mesterházy*, G. Kászonyi, B. Tóth, T. Bartók and M. Varga

Cereal Research non-profit Co., 6726 Szeged, P.O.Box 391. Hungary
*Corresponding Author: PH: 36 30 415 9730; E-mail: akos.mesterhazy@gk-szeged.hu

OBJECTIVES

According to many field and other tests the prothioconazole fungicides are superior against FHB in wheat. Our data originated mostly from dry years; and the difference between tebuconazole and prothioconazole fungicides were small. 2004 was much more humid, therefore the chance was there to detect differences between them.

INTRODUCTION

Most presentations of the Chemical Control Sessions of the National Fusarium Head Blight Forums dealing with AMS 21619 showed better performance that the tebuconazole fungicides did. However, the difference was not always convincing and the efficacy was often poor. We come to the conclusion that incomplete spraying technology explains much of the diverging results. According to Bayer the following covering was found on the heads: 30-39 of the head was covered on the front side, but only 1-2.1 % on the back side. As the translocation between palea and glume or grain is poor, and no translocation occurs from leaves to head, the fungicide concentration will be very uneven. Some landing spores will be inhibited to infect, but other not. Therefore significant infection can be observed on treated plots even they were sprayed with the most effective fungicide. When the fungicides cannot be placed uniformly on the whole surface of the head, the fungicides are not responsible for the moderate or low effect.

MATERIAL AND METHODS

The tests were made in 2003 and 2004. Three cultivars with differing resistance were used (Zugoly, Samson, Bence), three plot replicates (5 m²) for a cultivar were used for a fungicide treatment. Within each plot four isolates of *Fusarium* were used in three replicates as head of groups consisting of 15-20 heads (Mesterházy et al. 2003). Spraying terming: full flowering. Inoculation: one and three days after fungicide treatment in 2113 and 2004, respectively. Evaluation: FHB, FDK, yield loss and DON contamination. Fungicides: Kolfugo S 1.5 l/ha, 20 % carbendazime, Caramba 1.0 (2000) and 1.2 L/ha (2001), metconazole 60 g/L, Falcon 460EC 250 g spiroxamine, 167 g tebuconazole and 43 g triadimenole in one liter. In 2003 AMS 21619 and Prosaro (125 g prothioconazole and 125 g tebuconazole/L) was tested in two concentrations. The Input, (125 g prothioconazole and 500 g spiroxamine) was tested first in 2004. For 2004The composition of the other fungicides is presented at Mesterházy (2003).

RESULTS AND DISCUSSION

Table 1 shows the 2003 data. The prothioconazole fungicide (Prosaro) showed somewhat better results than Folicur Solo did across isolates and cultivars, but the difference according to different traits were not always significant. When we see the heaviest epidemics of the twelve, the situation looks somewhat different (Table 2). The Fusarium check for the two F. culmorum isolates was very high, more than 70 %. For isolate 12551 the difference between Falcon 460 EC and Prosaro 1 l/ha is significant, but the difference for Folicur Solo is not. Compared to the other isolates, here is a tendency for an increasing difference.

Table 3 presents the DON data for Zugoly according to isolates. The case is similar we have seen at FDK values in Table 2.

In 2004, the situation is different. Of the data I present only the FDK data. Table 4 presents the FDK data on the three cultivars on the isolate Fg 12377. This isolate produced the most severe symptoms. For this reason the differences between fungicides can be seen the best. Zugoly is the susceptible cultivar; here only the two prothioconazole fungicides performed well and this performance differed significantly from Folicur Solo or Falcon, the best fungicides until now. For the more resistant Samson also the tebuconazole fungicides gave identical results with Prosaro and Input, the rest had significantly higher indices. For the more resistant cultivar Bence all fungicides were good except Tango Star. It is remarkable that FDK values in Bence are about the value of Zugoly for Prosaro and Input. For the other isolates the values were zero or lower than one percent.

The mean values across isolates and cultivars are shown in Table 5. Prosaro 1.0 L/ha differed significantly from Solo at every trait, even the differences are smaller than presented in Table 4. Efficacies are for Prosaro 95-96 %for FHB and FDK and at 70 % for yield response.

The new prothioconazole fungicides are very promising also for the susceptible variety group where control was problematic in the last years by tebuconazole fungicides. Even they were the most effective fungicides the most sensitive cultivars could not be protected. The most sensitive cultivars can be protected successfully only with the prothioconazole fungicides, more resistant varieties can be protected successfully also with other compounds. Wilcoxson (1996) stated that a fungicide control is acceptable when infection severity, in our case FDK is lower than five percent. The Hungarian rules classify scabby kernels as dangerous part and the limit is maximally two percent. When efficacy is 50 %, all staples above five % infection severity cannot be used. When efficacy is 90 %, 20 % natural infection severity is the limit. When we consider DON limit value at 1 ppm, the situation will not be better much better, see Table 3. Of course, this is valid at full cover with fungicides. As present spraying technology cannot achieve this, the most important task is to improve spraying technology.

ACKNOWLEDGEMENTS

Authors are indebted for financial support from Bayer AG, OTKA projects TS040887 and D38486, as well as FVM project 38194/2003 for technology development.

REFERENCES

Mesterházy, Á. 2003. Control of Fusarium head blight of wheat by fungicides. In: Leonard, K. and Bushnell, W. (Eds.): Fusarium head blight of wheat and barley. APS Press, St. Paul. 363-380.

Mesterházy Á., T. Bartók and Cs. Lamper. 2003. Influence of cultivar resistance, epidemic severity, and *Fusarium* species on the efficacy of fungicide control of Fusarium head blight in wheat and deoxynivalenol (DON) contamination of grain. Plant Disease, 87:1107-1115.

Wilcoxson, R. D. 1996. Fungicides for control of Fusarium head blight – a review. Minn. Agr. Exp. Sta. Paper No. 22507, 19 pp.

Table 1. Fungicide control of FHB in wheat, general means across cultivars and isolates, 2003.

cultivars and isolates, 2003

Fungicide	Traits			
	FHB %	FDK %	Yield loss %	DON ppm
Prosaro 1.0	1.75	2.42	6.41	0.84
Prosaro 0.8	2.31	2.68	8.10	1.16
F. Solo 1.0 +Kolf. 1.5	2.49	5.13	12.15	1.04
Falcon 460EC 0.8	2.82	5.71	14.17	1.52
Folicur Solo 1.0	3.05	5.18	11.80	1.21
Caramba 1.2	3.29	11.31	13.21	3.14
Juwel 1.0	4.92	10.50	14.31	2.71
Tango Star 1.2	4.93	7.00	13.43	1.47
Kolfugo 1.5	15.81	20.77	22.78	5.67
Fusarium check	20.72	26.52	32.52	17.24
Mean	6.21	9.72	14.89	3.60
LSD 5 %	2.15	3.13	4.19	1.46

Table 2. Chemical control of FHB in wheat. FDK values on susceptible Zugoly according to isolates, 2003.

Fungicides and rates	Isolates				Gen.
	12377Fg	44Fg	12375Fc	12551Fc	Mean
Prosaro 0.8	0.00	0.04	0.58	2.51	0.78
Prosaro 1.0	0.11	0.07	1.13	4.20	1.38
Folicur Solo 1.0	0.27	0.29	4.42	4.13	2.28
Tango Star 1.2	0.80	0.47	2.51	6.89	2.67
F. Solo 1.0 +Kolf. 1.5	0.56	0.22	3.02	9.78	3.39
Falcon 460EC 0.8	0.13	0.07	4.13	11.22	3.89
Juwel 1.0	0.91	0.36	5.24	21.16	6.92
Caramba 1.2	1.13	1.20	21.13	18.65	10.53
Kolfugo S 1.5	2.73	1.07	26.98	54.73	21.38
Fus. check	4.98	13.73	74.11	79.00	42.96
Mean	1.16	1.75	14.33	21.23	8.01
LSD 5 %	12,12	12,12	12,12	12,12	5,42

Table 3. Chemical control of FHB. DON contamination (ppm) for cv Zugoly, 2003.

Fungicides	Isolates				Mean
	12377Fg	44Fg	12375Fc	12551Fc	
Prosaro 1.0	0.00	0.00	0.07	1.50	0.39
F. Solo 1.0 +Kolf. 1.5	0.03	0.00	1.30	1.47	0.70
Prosaro 0.8	0.20	0.00	0.20	1.37	0.44
Folicur Solo 1.0	0.20	0.00	0.83	1.10	0.53
Tango Star 1.2	0.27	0.00	1.07	2.63	0.99
Falcon 460EC 0.8	0.13	0.03	1.83	5.57	1.89
Juwel 1.0	0.53	0.37	2.60	9.80	3.33
Caramba 1.5	0.23	0.53	15.50	13.73	7.50
Kolfugo 1.5	0.93	0.13	12.37	19.80	8.31
Fusarium check	1.83	5.13	94.03	66.67	41.92
Mean	0.42	0.54	11.43	11.01	5.85
LSD 5 %	5.09	5.09	5.09	5.09	2.55

Table 4. Fungicides against FHB in wheat, FDK data for Zugoly, isolate Fg. 12377.

Treatments	Cultivars			Mean
	Zugoly	Samson	Bence	
Prosaro 1.0	**5.00**	**2.33**	**5.44**	4.26
Input 1.0	**2.33**	**0.56**	**3.89**	2.26
Falcon 0.8	28.89	**3.56**	**7.33**	13.26
Folicur Solo 1.0	32.78	**1.89**	**8.33**	14.33
Kolfugo S 1.5	52.22	47.78	**6.00**	35.33
Tango Star 1.0	66.67	43.33	29.44	46.48
Fusarium check	70.00	73.33	27.78	57.04
Mean	36.84	13,19	7,24	15,96
LSD 5 %	9.64	9.64	9.64	5.57

EFFICACY OF FUNGICIDES AND BIOCONTROL AGENTS ON FHB OF WHEAT IN ARKANSAS, 2004

Eugene A. Milus*, Peter Rohman and Samuel Markell

Department of Plant Pathology, University of Arkansas, Fayetteville, AR, 72701, USA
*Corresponding Author: PH: 479 575-2676, E-mail: gmilus@uark.edu

OBJECTIVE

To identify fungicides and biological control agents that are effective against Fusarium head blight (FHB).

INTRODUCTION

Identifying fungicides and biocontrol agents that reduce incidence and severity of FHB and levels of 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 was part of the Uniform Fungicide and Biocontrol Trial that is coordinated by the Chemical and Biological Control Committee.

MATERIALS AND METHODS

The moderately susceptible soft red winter wheat cultivar 'Agripro Patton' was planted at the University Farm at Fayetteville on 9 October 2003. Seed was treated with Dividend fungicide (1 fl oz / cwt) for loose smut, Stagonosproa blotch, and seedling diseases and Gaucho insecticide (3 fl oz / cwt) for aphids and barley yellow dwarf. Individual plots were 7 rows by 13 ft. Plots were fertilized with a total of 100 lb nitrogen as ammonium nitrate (75 lb applied on 5 March and 25 lb applied on 5 April). Ryegrass and broadleaf weeds were controlled with recommended herbicides. Infested corn kernel inoculum of Fusarium graminearum was applied to the plots on 31 March at the rate of 6 kernels / sq ft. Fungicides were applied in a randomized complete block design with six replications on 26 April when 50% of the main stems had begun to flower. Treatments were applied at the rate of 20 gal per acre. The mist system operated on several days between 31 March and 26 April to promote sporulation on the inoculum and for eight 10-minute periods between midnight and 8:00 am on nine mornings (27 and 28 April, and 4, 6, 8, 12, 15, 19, and 21 May) to promote infection. On 20 May, plots were rated for the percentage of foliage with stripe rust that developed naturally late in the season. On 25 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.

RESULTS AND DISCUSSION

Relative to past years, little FHB developed in the plots even though sporulation was evident on the inoculum during flowering. None of the treatments had a significant effect on any of the FHB variables. All of the fungicides were highly effective against stripe rust, and TrigoCor 1448 significantly increased stripe rust severity. Tilt and V-10116 at 6 fl oz per acre increased yield significantly compared to nontreated check #2 (the check with the highest yield), but these yield increases appeared to be related to controlling stripe rust rather than FHB.

ACKNOWLEDGMENT

This material is based upon work supported by the U.S. Department of Agriculture, under Agreement No. 59-0790-9-054. This is a cooperative project with the U.S. Wheat & Barley Scab Initiative. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

Table 1. Effects of fungicides and biological control agents on Fusarium head blight, stripe rust, yield, and test weight of Agripro Patton soft red winter wheat at Fayetteville, AR, in 2004.

Treatment and amount of product per acre	Yield (bu/ac)	Test Wt. (lb/bu)	Plot Severity (%)	Infected Head Severity (%)	Incidence of Infected Heads	% Visual Scabby Seed	% Stripe Rust
Tilt 3.6EC 4.0 fl oz	100.3	54.7	7.8	24.0	0.3	2.0	0
V-10116 1.81FL 6 fl oz + 0.125% Induce	99.1	57.8	7.0	20.2	0.3	4.0	0
JAU6476 480SC 2.85 fl oz + Folicur 432SC 3.17 fl	98.7	55.3	6.1	22.7	0.3	3.0	0
1BC full strength broth 20 gal	95.3	56.5	6.5	18.7	0.4	3.0	32
Folicur 432SC 4 fl oz + 0.125% Induce	95.2	55.4	5.9	19.4	0.3	3.0	0
JAU6476 480SC 5 fl oz + 0.125% Induce	93.2	57.3	5.8	17.8	0.3	3.0	1
V-10116 1.81FL 4 fl oz + 0.125% Induce	91.9	57.0	6.0	18.1	0.3	2.0	0
TrigoCor 1448 full strength broth 20 gal	90.8	56.5	9.5	26.1	0.4	3.0	51
Nontreated check #2	90.7	55.9	5.3	14.8	0.3	3.0	34
C3R5 full strength broth 20 gal	89.6	55.4	4.4	14.7	0.3	3.0	40
AS 54.6 full strength broth 20 gal	88.6	54.5	6.5	18.3	0.4	3.0	32
Flutriafol 1.04EC 14 fl oz	87.7	56.7	7.7	21.7	0.4	4.0	0
Nontreated check #1	87.2	54.4	7.9	20.4	0.4	5.0	35
LSD (P=0.05)	8.0	NS	NS	NS	NS	NS	15

COMPETITIVE MICROSATELLITE PCR FOR MEASURING THE GROWTH OF *FUSARIUM GRAMINEARUM* AND *TRICHODERMA ATROVIRIDE* ON BT MAIZE RESIDUES

A. Naef [1*] and G. Défago[1]

[1]Plant Pathology group, Institute of Plant Science, ETH Zürich, Switzerland
[*]Corresponding Author: PH: 0041 (0)1 632 38 76; E-mail: andreas.naef@ipw.agrl.ethz.ch

ABSTRACT

In the last decade transgenic plants which contain genes encoding for insecticidal crystal proteins from *Bacillus thuringiensis* (Bt) have become increasingly popular. The biggest part was Bt maize, being cultivated on 9.1 billion hectares worldwide in 2003. This rapid increase in the global agricultural area cultivated with Bt maize could have an effect on microbially mediated processes and functions. Of particular interest is the survival of pathogenic organisms like mycotoxigenic *Fusarium* and their antagonists on maize residues. *Fusarium*-colonized maize residues serve as inoculum source for the infection of subsequent crops. We investigated whether the Bt-toxin in residues of genetically modified maize has an impact on the growth of the DON producing *Fusarium graminearum* strain GZ3639 and the potential antagonist *Trichoderma atroviride* strain P1. We developed two PCR assays to measure the growth of *F. graminearum* and *T. atroviride* in microcosms with residues of Bt maize. The PCR assays are based on a competitive PCR between microsatellite alleles of two strains of a haploid fungal species. Before DNA is extracted from a sample, a defined amount of mycelium of a second strain of the same species is added. The DNA of this second strain works as internal standard during DNA extraction and as competitor during the PCR amplification of a species-specific, polymorphic microsatellite. Using fluorescence-labeled primers, the amplification products can be separated and quantified with a sequencer. In contrast to other PCR assays, this method is not biased by a decreasing amount of plant DNA in the microcosm. The PCR assays have been used to measure the growth of *F. graminearum* and *T. atroviride* on -radiation-sterilized residues of two transgenic Bt maize varieties and their non transformed isogenic lines. Residues were collected at maturity on a field trial in 2002 and 2003. For one variety, we found a negative effect of the Bt transformation on the growth of *T. atroviride* for both years. On the same variety, *F. graminearum* grew less only on residues from 2003 but not from 2002. For the other variety, no significant effect was found in any year for both fungi. Generally the year had a greater impact on the growth of both fungi than variety or Bt transformation. Our result suggest, that Bt toxin has no direct effect on the growth of the two fungi, but isolines may carry further genetic differences in addition to the inserted Bt gene.

CHEMICAL CONTROL FOR FUSARIUM HEAD BLIGHT IN WINTER WHEAT AND MYCOTOXIN CONTAMINATION IN JAPAN

Takashi Nakajima

National Agricultural Research Center for Kyushu Okinawa Region, Suya #2421,
Nishigoshi, Kikuchi, Kumamoto 861-1192, JAPAN
Corresponding Author: PH: 81-96-242-7728; E-mail: ntakashi@affrc.go.jp

ABSTRACT

The provisional standard of 1.1 ppm for deoxynivalenol (DON) in wheat was determined by Japanese government in 2002. Therefore, re-evaluation of registered fungicides and screening new candidates for control of mycotoxin contamination are considered mandatory. We tested totally 24 kinds of fungicides differing mode of action. Three experiments were conducted for two years. In paddy field, we sprayed fungicides at two days before flowering and 5 days after flowering. Inoculations were done at just flowering and 7 days after flowering. We used DON producer in 2002 and mixture of DON and nivalenol (NIV) producer were sprayed in 2003. An automatic sprinkler system was used to promote disease development. In addition, experiment in upland field was done in 2003. Corn grain inoculum of mixture of DON and NIV producer were used under natural rainfall condition. As a result in 2002, most of all fungicides controlled FHB disease severity, especially tebuconazole and captan and oxin-copper were highly effective. Azoxystrobin was not so effective but efficacy was about 40. As for DON in the same test, efficacy of DON was lower than that of disease severity. Tebuconazole, captan and oxin-copper decreased significantly DON level than control plot. On the contrary, azoxystrobin increased DON level significantly. In case of paddy field in 2003, most of all fungicides except trifulumizole were highly effective. The reason of failier in trifulumizole was unknown. As for mycotoxin in the same test, control of DON+NIV was difficult than disease severity. In the condition of 2003, two times application was not enough to decrease mycotoxin level. Thiophanate-methyl sol, cooper hydroxide, captan, and two-kinds of phosphorous acid, tebuconazole and metoconazole decreased significantly DON+NIV level than control plot. Trifulumizole was not effective both disease and toxin control. Azoxystrobin and mixture of azoxystrobin and propiconazole were effective for disease control but not for mycotoxins. We inoculated corn grain inoculum of DON+NIV mixture in 2003 of upland field to simulate natural infection. In this case, most of all fungicides were highly effective. To control disease severity, two times application was enough in this case. As for mycotoxin in the same test, control of DON+NIV was difficult than that of FHB. Efficacy of mycotoxin control was lower than that of paddy field, in which spore inoculation was done. It is possible that corn inoculum supply conidiospore continually during maturing period. Therefore, non visible infection might increase mycotoxin level. Thiophanate-methyl sol decreased significantly DON+NIV level than thiophanate-methyl powder. Tebuconazole and metoconazole were confirmed to decrease significantly DON+NIV level than control plot. On the other hand, azoxystrobin increased DON+NIV level, especially NIV level significantly. In this case mixture of propiconazole and azoxystrobin did not increase mycotoxin level but did not decrease. Interestingly, mode of action of kresoxim-methyl is similar to that of azoxystrobin, but effect on mycotoxin level seems to be different.

EFFECT OF STRAW MANAGEMENT AND TILLAGE SYSTEMS ON DON CONTENT IN CEREALS

D. Pageau[1*], J. Lajeunesse[1], M.E. Savard[2] and S. Rioux[3]

[1]Research farm, Agriculture and Agri-Food Canada, Normandin QC Canada; [2]Eastern Cereal and Oilseed Research Centre, Agriculture and Agri-Food Canada, Ottawa ON Canada; and [3]Centre de recherche sur les grains (CEROM), Sainte-Foy QC, Canada
[*]Corresponding Author: PH: (418) 274-3378 ext. 228; E-mail: pageaud@agr.gc.ca

ABSTRACT

In Northern Quebec, Canada (Saguenay-Lac-Saint-Jean area), barley production is very important but fusarium head blight (FHB) has become a major problem in this region. In 2001, about 10 % of the barley acreage (1 800 ha) had a DON content superior to 2 mg kg^{-1}. In 2002, the problem was more severe with 40 % of the barley area infected with FHB. The economic losses associated with FHB in barley were estimated at 2 million Canadian dollars during those 2 years in the Saguenay-Lac-Saint-Jean region. In fall 2002 and spring 2003, several management systems (straw removal, use of disk harrow or cultivator) were applied in barley, oat and wheat fields to measure the effect of straw incorporation on DON content in grain harvested in 2003. Direct seeding, chiseling and moldboard plowing were also evaluated. No inoculation was performed on those trials. DON content in grain varied from 4.9 to 7.4 mg kg^{-1} in oat samples and from 5.9 to 8.9 mg kg^{-1} in wheat samples. For both oat and wheat, the treatments had no significant effect on DON content. DON content varied from 10.3 to 40.3 mg kg^{-1} in barley and was significantly higher in chisel and no-till treatments compared to moldboard. Straw management or spring harrowing had no effect on DON content in barley. The results from 2003 indicate that moldboard plowing can reduce DON content in barley. However, tillage system had no significant effect on mycotoxin content in wheat and oat. Straw management had also little effect on DON content in cereals.

USE OF GREEN MANURES TO INHIBIT *FUSARIUM GRAMINEARUM* ON WHEAT RESIDUES

C.A. Perez, R. Dill-Macky* and L.L. Kinkel

University of Minnesota, Department of Plant Pathology, St. Paul, MN 55108
*Corresponding Author: PH: 612-625-2227; E-mail: ruthdm@umn.edu

ABSTRACT

Fusarium head blight epidemics originate largely from inoculum associated with host residues, especially those of corn and small grain cereals. Research has shown that green manures (GMs) can have a significant effect on the intensity of a range of diseases on diverse range of crops, influencing pathogens directly through the breakdown of glucosinolates or by releasing fungitoxic compounds, or indirectly by influencing indigenous microbial populations. Preliminary studies have demonstrated that green manures may increase the population of streptomycetes and also that these microorganisms may affect the activity of *Fusarium graminearum*. In this way strategies that enhance the frequency or intensity of *Fusarium*-inhibitory streptomycetes in soil may contribute to a reduction in *F. graminearum* inoculum and thus disease development. The overall objective of this study was to quantify the effect of green manures on the frequency of soil-borne antagonists inhibitory to *F. graminearum* and to determine the intensity of *F. graminearum* inhibition. Three experiments were conducted in the greenhouse in 2004. *Fusarium*-infected wheat (*Triticum aestivum*) nodes, collected from naturally infected field sites, were incorporated into soils collected from wheat production fields in Minnesota. Three treatments, two green manures (common buckwheat [*Fagopyrum esculentum*] and sorghum-sudangrass [*Sorghum bicolor - S. vulgare* hybrid]), and a fallow (no green manure), were evaluated. The experiments were established in 10-inch pots each experiment in a randomized complete block design with 16 replicates. The *F. graminearum* populations on residue, and the frequency and intensity of *F. graminearum* inhibitors/ inhibitory activity in the soil were monitored over three months following the incorporation of the green manures grown for six weeks prior to incorporation. Total bacteria in soil were determined by soil dilution plating onto antibiotic amended oatmeal agar medium. Streptomycete densities were determined following dilution plating onto water agar overlaid with starch-casein agar; an adaptation of the method developed by Herr in 1959 (Phytopathology 49:270-273). *Fusarium*-inhibitory activity was determined by overlaying a soil dilution on water agar with a second water agar layer, incubating for three days at 28ºC and then overlaying with a suspension of *F. graminearum* macroconidia in molten potato dextrose water agar. These triple-layered plates were incubated for an additional three days prior to assessment. *Fusarium*-inhibition was determined by measuring the zones surrounding streptomycetes colonies where *F. graminearum* failed to grow. The total bacteria recovered from soil following the incorporation of buckwheat and sorghum-sudangrass tended to increase, with statistically significant differences detected for buckwheat in all experiments although only for sorghum-sudangrass in one of the three experiments. The density of streptomycetes recovered was not significantly influenced by the GMs, although a trend to increased numbers of streptomycetes was observed. The density of *F. graminearum*-inhibitory streptomycetes in soil increased significantly in both GM treatments in comparison to the fallow for at least one sampling time in each experiment. Both GMs were observed to increase the efficacy of *F. graminearum*-inhibitory streptomycetes, determined using the number and inhibition zone size in the triple-layer method, in comparison to the fallow, although the results were inconsistent. Green manures did not significantly impact the rate of residue decomposition or the population of *F. graminearum* in wheat residue. The low level of initial colonization of the wheat nodes by *F. graminearum*

may have reduced our power to detect differences among treatments. A field study has been established to further examine the impact of green manures on antagonists to *F. graminearum*. These results suggest that GMs might affect the soil population and activity of *Fusarium*-antagonists and thus may provide a complementary tool to reduce *Fusarium* inoculum.

STUDIES ON THE INTERACTION BETWEEN FUNGICIDES, SAPROPHYTIC MICROFLORA AND *MICRODOCHIUM NIVALE*,ON FUSARIUM HEAD BLIGHT IN WHEAT CAUSED BY *FUSARIUM CULMORUM*

S.R. Pirgozliev[1,2], S.G. Edwards[1*], M.C. Hare[1] and P. Jenkinson[1]

[1]Crop and Environment Research Centre, Harper Adams University College, Newport, Shropshire TF10 8NB, UK; and [2]Current address: Agriculture and Agri-Food Canada, Vineland Station, Ontario, L0R 2E0, CANADA
[*]Corresponding Author: PH: 44 1952 815226; E-mail: sedwards@harper-adams.ac.uk

ABSTRACT

Microdochium nivale, a non-mycotoxigenic species involved in Fusarium head blight (FHB) complex and saprophytic microflora have been suggested to have an effect on the field performance of fungicides for control of FHB caused by *Fusarium* species. In a range of glasshouse experiments the effects of metconazole and azoxystrobin on the interactions between *Fusarium culmorum* and *M. nivale, Alternaria tenuissima* or *Cladosporium herbarum* and the development of FHB and deoxynivalenol (DON) production were studied. Fungicides metconazole and azoxystrobin were applied in all experiments at full ear emergence, wheat heads were inoculated with *F. culmorum* at mid-flowering, while *A. tenuissima*, *C. herbarum* or *M. nivale* were inoculated at ¾ ear emergence or 24 hours after *F. culmorum* inoculation (mid-flowering). When *A. tenuissima*, *C. herbarum* or *M. nivale* were introduced to wheat ears at ¾ ear emergence before inoculation with *F. culmorum* at mid-flowering resulted in an increase of FHB severity, *Tri*5 DNA and DON concentration in harvested grain, but in the case of *A. tenuissima* it was not significant. Inoculation with *C. herbarum* or *M. nivale* at ¾ ear emergence led to increased DON concentrations in grain compared to the control treatment by 34 and 151% respectively. Application of metconazole resulted in reduction of FHB severity, *Tri*5 DNA and DON concentration in grain in all of the trials. When azoxystrobin was applied after plants were inoculated with *M. nivale* at ¾ ear emergence, or before introduction of this fungus on ears after *F. culmorum* at mid-flowering, there was an increase in DON concentration in grain by 56% and 30% respectively. However this increase was not significantly different from the control treatment. This work indicates that poor performance of fungicides under field conditions and increased mycotoxin concentration in grain of wheat after application of particular fungicides, such as azoxystrobin, maybe due to the presence of non-target species such as *Alternaria* spp. or *Cladosporium* spp. or the non-toxin producing FHB species, *M. nivale*.

CROP ROTATION AND TILLAGE SYSTEM EFFECTS ON DON CONTENT IN WHEAT AND BARLEY PRODUCTION IN QUEBEC, CANADA

S. Rioux[1*], D. Pageau[2], J. Lafond[2], J. Lajeunesse[2], M.E. Savard[3] and G. Tremblay[4]

[1]Centre de recherche sur les grains (CEROM), Sainte-Foy QC, Canada; [2]Research Farm, Agriculture and Agri-Food Canada, Normandin QC, Canada; [3]Eastern Cereal and Oilseed Research Centre, Agriculture and Agri-Food Canada, Ottawa ON, Canada; and [4]CEROM, Saint-Bruno-de-Montarville QC, Canada
[*]Corresponding Author: PH: (418) 528-7896; E-mail: sylvie.rioux@cerom.qc.ca

ABSTRACT

Two field trials initiated in 1999 have been conducted for comparing the effect of crop sequences and two tillage systems on Fusarium head blight (FHB) in wheat and barley. At the Saint-Hyacinthe site, in the Montreal area, crops were maize (M), soybean (S) and wheat (W), and the two sequences were MSW and SMW. At the Normandin site, located 300 km north of Quebec city, crops were barley (B), canola (C), and field pea (P). The five 4-y crop rotations were BBBB, CPBB, PCBB, BCPB, and BPCB. The tillage treatments were conventional (moldboard plough) and reduced tillage (chisel at Normandin, and no-till at Saint-Hyacinthe) in fall. Experiments were exposed to natural infection. DON content in grain samples was analysed from 2001 to 2003. At Saint-Hyacinthe in 2001 and 2002 and Normandin in 2001, the treatments had no significant effect on DON content. However, in 2003 at Saint-Hyacinthe, DON content was significantly lower for the MSW x conventional tillage combination (2.7 ppm) than for the three other combinations (3.3 to 3.6 ppm). In 2002 at Normandin, DON content was significantly higher in reduced tillage (0.60 ppm) than in conventional tillage (0.36 ppm). In 2003, DON content was also significantly higher in reduced tillage but only for the three rotations in which barley was seeded the previous year (13.1, 14.1, and 16.4 ppm). There were no differences between the seven other combinations (4.8 to 6.5 ppm). These results suggest that in Quebec, in barley monoculture or when the previous year's crop is barley, ploughing crop residues may help to decrease the FHB incidence. They also indicate that rotation with canola and field pea during the 2 years preceding a barley crop may be effective in reducing DON content in either conventional or reduced tillage, and that only 1 year of soybean between maize and wheat was not effective under reduced tillage. However, none of the rotation x tillage combinations tested could, under a strong disease pressure, reduce the DON content under the maximum level of 1.0 ppm accepted by the swine industry. Therefore, growers should use as many control methods as they can to reduce the risk of infection by the pathogen, e.g. early seeding, resistant cultivars, rotation, and fungicides.

FUNGICIDE SPRAY DEPOSITION ON WHEAT HEADS FROM VARIOUS NOZZLE CONFIGURATIONS

B.E. Ruden[1*], M.A. Draper[1], K.R. Ruden[1], D.S. Wittmeier[1] and S.M. Thompson[1]

[1]Plant Science Department, South Dakota State University, Brookings, SD 57007, USA
*Corresponding Author: PH: (605) 688-4596; E-Mail: ruden.brad@ces.sdstate.edu

ABSTRACT

Fusarium head blight (FHB) epidemics in localized areas of the US have caused significant yield and quality losses of wheat and barley in recent years. Control of this disease has been difficult, because of the complex in the host/pathogen interaction. Fungicide application has become an accepted method for FHB control. Previous studies have shown paired nozzles pointed forward and backward provide better coverage and better FHB control than standard flat fan nozzles pointed downward. However, these studies did not address detailed parameters of spray deposition on varying wheat head structures and the relationship of this coverage to FHB control. The objective of this trial was to take initial steps in quantifying the parameters surrounding spray deposition on wheat heads and to identify methods whereby optimized fungicide application for efficacy can occur. Spring wheat (cvs Oxen and Ingot) were planted at the South Dakota State University Agronomy Farm and treated at anthesis (Feekes growth stage 10.51) in a single direction into the wind with a tank mixture of Folicur (tebuconazole) at a rate of 4 fl oz/a (292.30 ml/ha) and Induce adjuvant (0.125% v/v) supplemented with a fluorescent orange water soluble dye (3% v/v). The mixture was applied at 40 psi (275.79 kPa) at a rate of 18.6 gpa (173.97 l/ha). Nozzle configurations (treatments) included: 1) one flat fan nozzle pointing straight down (XR TeeJet 11002), 2) one flat fan nozzle angled 45° forward (XR TeeJet 10002), or 3) a twin-orifice flat fan nozzle (Twinjet TJ11002). Varieties and treatments were randomized in a 2 X 3 factorial design with four replications with varieties and nozzle types as factors. Plots were inoculated by spreading *Fusarium graminearum* (Fg4) inoculated corn (*Zea mays*) grain throughout the field and providing overhead mist irrigation on a 16 hr/8 hr on/off schedule (overnight mist) throughout anthesis. Wheat heads were evaluated for spray coverage and deposition pattern as well as for FHB incidence, head severity and total FHB damage and location of diseased spikelets relative to direction of sprayer travel. Further, plot yield, test weight, and *Fusarium* damaged kernels (FDK) was measured. Digital pictures of the incoming and outgoing side of the head were taken under UV light and spray coverage of the imaged was analyzed digitally. Light winds led to incomplete coverage of the head with the incoming spray side of the head showing greater spray deposition. All nozzle configurations provided reasonable spray coverage on the incoming side, while the side away from the application generally received little or no product, regardless of nozzle configuration. No nozzle tested in this trial overcame the problem of poor deposition on the back of the head, although differences were observed. Awns of the wheat plant collected a significant portion of the applied fungicide mix. Initial data on FHB infection appears to show that there may be an effect of applied fungicide penetrating to the rachis of the head and limiting FHB infection to single spikelets, thus reducing FHB spread within the head.

USDA-ARS, OHIO STATE UNIVERSITY COOPERATIVE RESEARCH ON BIOLOGICAL CONTROL OF FUSARIUM HEAD BLIGHT 1: USE OF DIATOMACEOUS EARTH AS A CARRIER FOR FORMULATIONS OF THE ANTAGONIST *CRYPTOCOCCUS NODAENSIS* OH 182.9

D.A. Schisler[1*], S. Zhang[1,2], M.J. Boehm[2] and P.E. Lipps[3]

[1]National Center for Agricultural Utilization Research (NCAUR), USDA-ARS, Peoria, IL 61604, USA; [2]Dept. of Plant Pathology, The Ohio State University, Columbus, OH 43210, USA; and [3]Dept. of Plant Pathology, The Ohio State University/OARDC, Wooster, OH 44691, USA

[*]Corresponding Author: PH: (309) 681-6284; E-mail: schislda@ncaur.usda.gov

OBJECTIVES

To assess the feasibility of pilot-plant-scale production of a dried, formulated FHB biocontrol product composed of biomass of the FHB antagonist *C. nodaensis* OH 182.9 imbedded in a variety of diatomaceous earth matrices. Additionally, to assess the survival and efficacy of the dried product in laboratory and field tests, respectively.

INTRODUCTION

One of the most effective yeast strains discovered in our collaborative research (U.S. patented strain *Cryptococcus nodaensis* OH 182.9 (NRRL Y-30216), Schisler et al. 2003) was selected for testing against FHB in the 2001 Uniform Wheat Fungicide and Biocontrol Trial (UWFBT). Biomass of OH 182.9 was produced in our pilot plant facility, concentrated, frozen and used at 15 field trial sites across the United States. This biocontrol preparation significantly reduced FHB when results from all test sites were pooled (Milus et al., 2001) and compared favorably with the fungicide Folicur 3.6F (tebuconazole).

The development of a dried biocontrol product would have potential advantages of ease of handling, convenience in transportation, favorable economics and acceptance by consumers and commercial developers. In the development process, dehydration of antagonist biomass can adversely affect antagonist viability and efficacy (Wraight et al., 2001) as can cryoprotectants if they can be metabolized by the pathogen target (Schisler et al., 2004a). An air-dried OH 182.9 product would be more economically feasible for industrial production than a freeze-dried product. In work described elsewhere in these proceeding (Zhang et al., 2004), we discovered that cold temperature shock during production of biomass of OH 182.9 enhanced the survival of air-dried cells over time. Diatomaceous earth (DE) is an effective filter aid that can be used for embedding microbial biomass to produce a friable, moist product that can then be readily air-dried. The impact of a range of grades of DE on biocontrol agent survival and maintenance of efficacy in general and of OH 182.9 in particular has not been previously reported.

MATERIAL AND METHODS

Production of a dried diatomaceous earth product containing Cryptococcus nodaensis OH 182.9

A semidefined complete liquid medium (SDCL; Schisler, 2004a) with carbon:nitrogen ratio of 11 and total carbon loading of 14 g/L was used in all instances for production of biomass in liquid culture. For production of biomass in a B Braun D-100 fermentor, seed inoculum was produced in Fernbach flasks (1.5 L SDCL medium in 3.0 L capacity flask) at 25ºC and 250 rpm for 24 h. Starter inoculum was then added to the D-100 fermentor at approximately 5% (vol/vol) which resulted in an initial absorbance (A_{620}) of approximately 0.175. Reactor medium pH, temperature, dissolved O_2, antifoam, and agitation rate were monitored and/or maintained to insure near identical production runs. After 24h of incubation at 25ºC, the

reactor temperature was reduced to 15ºC to enhance OH 182.9 cell tolerance to drying stress (Zhang et al., 2004). After completion of biomass production at approximately 48h, cells in the broth were concentrated into a paste using a Sharples 12-V tubular bowl centrifuge. Cell paste was incorporated into various diatomaceous earth (DE) products (Table 1) at 150 ml paste to 1000 ml DE (vol/vol) using a blender. Friable DE products were then spread on trays, dried at approximately 95% RH and 25ºC for 24h to a final moisture content of approximately 5-7% (wet weight basis). DE products were then vacuum packed in foil pouches and stored for 21 weeks at 4ºC while being monitored periodically for cell survival (Fig 1).

Field testing of a dried Cryptococcus nodaensis OH 182.9 product

The soft red winter wheat cultivars Elkhart (susceptible) and Freedom (moderately resistant) were grown in both Peoria, IL and Wooster, OH. Cells of OH 182.9 dried in DE MN-51 and stored for 3-6 weeks were used in all field studies. Immediately prior to use, the DE product was rehydrated at 8:1 (water:product; wt/wt), agitated for 10 minutes, and decanted 5 minutes after agitation ceased (~1 x 10^7 CFU/ml). Additional field treatments were fresh biomass of OH 182.9 harvested from 48h Fernbach shake flasks (~5 x 10^7 CFU/ml), Folicur applied at the recommended rate, a water/tween 80 control and an untreated control. All treatments were applied at the beginning of wheat flowering at 80 gal/acre. Corn kernels colonized by *Gibberella zeae* were scattered through plots (~25 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 is being tabulated (ongoing). Randomized complete block designs were used in both trials (n=6 in Peoria; n=4 in Wooster) and data analyzed using JMP software (ANOVA; SAS Inc., NC).

RESULTS AND DISCUSSION

Regardless of the DE used to make a dried OH 182.9 product, the product CFU's were virtually unchanged over the course of 21 weeks of storage at 4 C (Fig 1). Because the MN 51 product lost less CFU's immediately after drying than the others, this product was selected for pilot scale production and field efficacy testing.

Field performance of the dried DE product was variable across sites and wheat cultivars. Although disease level was relatively low in Peoria, Freedom wheat treated with rehydrated cells of OH 182.9 in DE (MN 51) had significantly lower disease severity compared to the untreated check (Table 2), tended lower in FHB disease incidence and had statistically identical severity compared to the Folicur treatment. No treatment effects were found on Elkhart in Peoria. In Wooster where the overall disease level was higher, the dried product did not reduce disease symptoms on either wheat cultivar while freshly produced cells of OH 182.9 significantly reduced severity on Freedom and Elkhart by as much as 56% and performed statistically better and worse than Folicur on Freedom and Elkhart, respectively (data not shown).

These results indicate that the development of a commercially feasible dried FHB biological control product containing OH 182.9 as an active ingredient is possible, especially in light of advancements made in developing commercial-scale production of stress tolerant cells of OH 182.9, UV protectants, and the discovery of new biological control strains that could be effectively combined with strain OH 182.9 (Schisler 2004b). Research devoted to optimizing biological control efficacy through the use of stickers, activators, and combinations of biocontrol agents with diverse modes of action, should position this biological control as an important tool to utilize in combination with reduced levels of fungicides, resistant varieties, improved spray coverage technologies and disease forecasting to minimize the impact of Fusarium head blight.

ACKNOWLEDGEMENTS

This material is based upon work supported by the U.S. Department of Agriculture. This is a cooperative project with the U.S. Wheat & Barley Scab Initiative.

DISCLAIMER

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

REFERENCES

Milus, E.A., Hershman, D., and McMullen, M. 2001. Analysis of the 2001 uniform wheat fungicide and biocontrol trials across locations. Proceedings of the 2001 National Fusarium Head Blight Forum, Kinko's, Okemos, MI. pgs 75-79.

Schisler, D.A., Khan, N.I, and Boehm, M.J. 2003. Issued patent. Yeasts for reducing Fusarium head blight in cereals and selection thereof. #6,562,337; May 13, 2003.

Schisler, D.A., Slininger, P.J., Behle, R.W., and Jackson, M.A. 2004a. Formulation of *Bacillus* spp. for biological control of plant diseases. Phytopathology 94:1267-1271.

Schisler, D.A., Khan, N.I., Boehm, M.J., Zhang, S., and Slininger, P.J. 2004b. Selection and field evaluation of choline-utilizing microbial strains as potential biocontrol agents of Fusarium head blight. Phytopathology 94:(S93).

Wraight, S.P., Jackson, M.A., and DeKock, S.L. 2001. Production, stabilization and formulation of fungal biocontrol agents. In: Fungi as Biocontrol Agents, T.M. Butt, C. Jackson, and N. Magan, eds., CAB International.

Zhang, S., Schisler, D.A., Jackson, M.A., Boehm, M.J., and Slininger, P.J. 2004. USDA-ARS, Ohio State University Cooperative Research on Biological Control of Fusarium Head Blight 2: Cold Temperature Shock during Production of *Cryptococcus nodaensis* OH 182.9 Enhances Cell Survival after Air-Drying. Proceedings of the 2004 National Fusarium Head Blight Forum, Kinko's, Okemos, MI. (this volume).

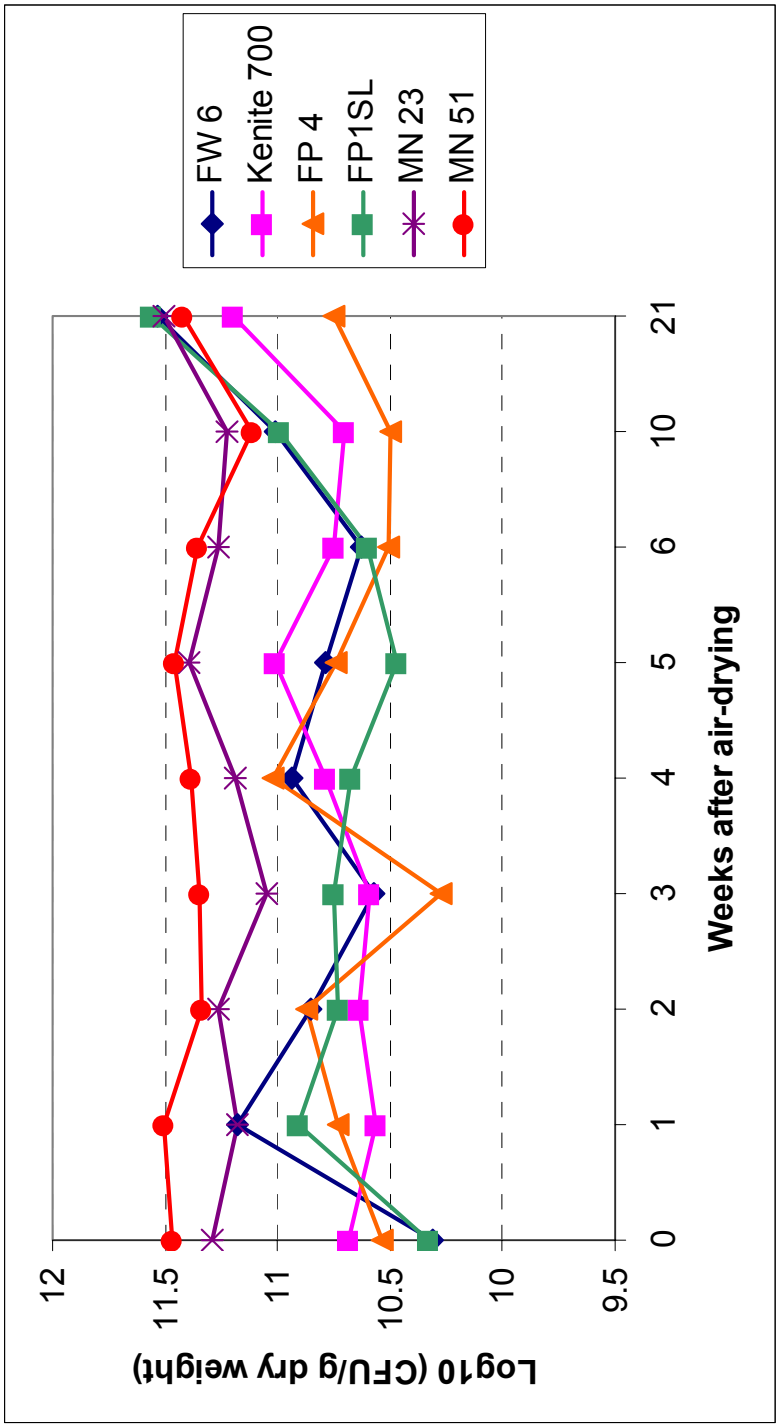


Figure 1. Survival of 100L fermentor-produced cells of *C. nodaensis* OH 182.9 after blending and air-drying in various grades of diatomaceous earth and storage at 4°C.

Table 1. Characteristics of various diatomaceous earth (DE) products used to formulate FHB antagonist *Cryptococcus nodaensis* OH 182.9.

DE Product[1]	pH	Permeability (Darcys)	Mean Particle Diameter (µm)
FW 6	9.0	0.48	18.0
Kenite 700	7.0	1.30	24.0
FP 4	8.8	0.30	15.0
FP1SL	6.5	0.07	12.5
MN 23	7.0	ND[2]	5.0
MN 51	7.5	ND	15.0

[1]Eagle-Picher Minerals, Inc.
[2]Not determined

Table 2. 2004 Peoria, IL field trial of an air-dried diatomaceous earth (MN 51) product containing FHB biocontrol agent *Cryptococcus nodaensis* OH 182.9 on winter wheat cultivar "Freedom"[1,2].

Treatment	DS (%)		DI (%)		100-kw (g)	
Untreated control	2.0	ab	9.2	a	3.76	a
Tween 80 control (0.036%)	1.4	bcd	7.8	a	3.85	a
Folicur 3.6F[3]	1.0	cd	6.1	a	3.67	a
Fresh OH182.9	1.3	bcd	7.8	a	3.73	a
DE dried OH182.9	1.1	cd	6.4	a	3.78	a

[1]Within a column, means without a letter in common are significantly different (P=0.05). Mean comparisons were performed on arc-sine transformed data. Back-transformed values are presented.
[2]DS = disease severity, DI = Disease incidence, 100-kw = 100-kernel weight
[3]Applied at recommended label rates.

BIOLOGICAL INACTIVATION OF FUMONISINS

M, Täubel[1]*, E. Vekiru[2], A. Frank[2], E.M. Binder[3], A.P. Loibner[4], R. Braun[4] and G. Schatzmayr[1]

[1]Biomin Innovative Animal Nutrition GmbH, Herzogenburg, Austria; [2]University of Natural Resources and Applied Sciences, Vienna, Dept. for Agrobiotechnology (IFA-Tulln), Center for Analytical Chemistry and Christian Doppler Laboratory for Mycotoxin Research, Tulln, Austria; [3]Erber AG, Herzogenburg, Austria; and [4]University of Natural Resources and Applied Sciences, Vienna, Dept. for Agrobiotechnology (IFA-Tulln), Institute for Environmental Biotechnology, Tulln, Austria
*Corresponding Author: PH: 43 227266280505; E-mail: martin.taeubel@biomin.net

ABSTRACT

Fumonisins are a group of quite recently found mycotoxins mainly produced by *Fusarium moniliforme* and *Fusarium proliferatum*, which are very common contaminants of cereal grains, especially of maize. Among these the fumonisins B_1 and B_2 are produced most abundantly in nature and quantitatively may be of greatest toxicological concern (Sydenham *et al.*, 1992). Fumonisins have been shown to produce a wide range of pathological effects in animals, including the economically important disease symptoms of leucoencephalomalacia in horses and pulmonary oedema in swine. In addition, these compounds exhibit toxic effects to turkey poults and broiler chicks and cause nephrotoxicity, hepatotoxicity and hepatocellular carcinoma in rats. Although definite evidence of carcinogenicity in humans is lacking, oesophageal cancer occurs at greater frequency in world regions where corn is the dietary staple and levels of *Fusarium* and fumonisin contaminations are high.

The economic implications of animal feeds contaminated with high levels of fumonisins are significant (Shepard *et al.*, 1996), since contamination of corn and corn-based products with these mycotoxins is reported frequently and in many countries worldwide. This implies the need for appropriate decontamination strategies, and hereof biological detoxification - meaning the transformation of fumonisins via microorganisms or specific enzymes - seems to be promising. The microbial/enzymatic breakdown into compounds that are no longer toxic would provide a very gentle, effective and environmentally friendly way of deactivating fumonisins. Such a mechanism was already described for the yeast *Exophiala spinifera* as well as for an aerobic bacterium (Duvick *et al.*, 1998), in the course of complete metabolization of the toxin.

Based on these facts a project was initiated with the aim to find microorganisms with the capability to deactivate fumonisins through enzymatic transformation. The respective organism is intended to be used as part of a feed additive to ensure detoxification of fumonisins in the intestinal tract of animals during feed digestion. A screening for aerobic and anaerobic microorganisms with FB_1-transforming potential was realized by performing fumonisin-degradation experiments in liquid culture media as well as in buffered systems. Besides testing promising bacterial and yeast strains of culture collections, several different habitats, e.g. rumen fluid or intestinal segments of pigs, were investigated with regard to the presence of toxin-reducing, microbial activity. Different environmental samples were also under investigation, as for example soil. In one of these samples, fumonisin-reducing activity could be detected leading to trials to isolate the respective microorganisms.

REFERENCES

Duvick et al. (1998); K. Kohmoto and O. Yoder (eds.): Molecular Genetics of Host-Specific Toxins in Plant Disease, Kluwer Academic Publishers, 369-381.

Shepard et al. (1996); J AOAC Int 79, 6671-687.

Sydenham et al.(1992); J AOAC Int 75, 313-318.

EFFECTS OF FUNGICIDES APPLIED AT ANTHESIS ON FUSARIUM HEAD BLIGHT AND DEOXYNIVALENOL IN WHEAT IN ANKARA AND SAKARYA PROVINCES

Tunali, B.[1*], Erdurmus, D.[1], Ozseven, I.[2], Buyuk, O.[1] and Araz, A.[1]

[1]Plant Protection Central Research Institute, Bagdat Str. No.250 Yenimahalle, 06170 Ankara, TÜRKIYE; and [2]Agricultural Research Institute, Sakarya, TÜRKIYE
*Corresponding Author: PH: 90 312 3445994/154; E-mail: berna_tunali@zmmae.gov.tr

ABSTRACT

Tebuconazole and Chlorothalonil reduced head blight incidence, visually scabby kernels and Deoxynivalenol concentration. The greatest reduction of FHB incidence with Tebuconazole(60 ml/100l). It was applied middle of the anthesis with spore suspension of *Fusarium graminearum* and *Fusarium culmorum*.

Fungicides treatment increased thousand kernel weight and yield. Deoxynivalenol content was determined from harvested seed samples during 2003. Samples were analyzed using high performance liquid chromatography (HPLC). Deoxynivalenol was detected range 0 to 4.28 µg/g.

Additional key words: wheat, deoxynivalenol, *Fusarium graminearum*, *Fusarium.culmorum*, Tebuconazole ,Chlorothalonil

POSSIBILITIES OF FHB *(FUSARIUM GRAMINEARUM* SCHWABE*)* CONTROL BY FUNGICIDES IN WHEAT

L. Tvaruzek[1*] and L. Si[2]

[1]Department of Integrated Plant Protection, Agricultural Research Institute Kromeriz, Ltd., Kromeriz, Czech Republic; and [2]Agricultural University of Hebei, College of Plant Protection, Baoding, P.R. China
[*]Corresponding Author: PH: 420 573 317 138; E-mail: tvaruzek@vukrom.cz

ABSTRACT

The effect of wheat treatment with fungicides and their mixtures on FHB (Fusarium head blight) was assessed in a field experiment under conditions of artificial inoculation with *Fusarium graminearum*. The FHB infection level as the percentage of spike tissue necrotized by the pathogen was assessed in the field during the grain filling period. The number of scaby grains was determined in a laboratory using a "paper roll test" – germination test in fungicide medium containing active agent iprodione. Finely, mycotoxin DON content was evaluated immunologically by ELISA.

We assessed the efficacy of 24 different treatments with fungicides based on one as well as more agents and the TM-mixtures of these products. The infection level was compared with the inoculated and non-treated control.

The most effective reduction in DON content was found for triazoles tebuconazole, metconazole and mixture of tebuconazole+propiconazole at full rates. Mixtures of strobilurin product trifloxistrobin at the rate of 75 g/ha together with reduced rates of triazoles showed efficacy which was not statistically different in comparison with a full rate of tebuconazole in mixture with prochloraz.

The mixed fungicide Charisma (flusilazole+famoxadone) with declared efficacy against FHB did not show DON reduction alone but in mixture with half rate of tebuconazole (125 g/ha) DON content was reduced to 1/ 3 of the non-treated plot level. Also, the mixtures of Charisma with flusilazole, metconazole and prochloraz showed the increase in efficacy.

The use of reduced rates of stobilurin fungicide Amistar (azoxystrobin) – 0.3 and 0.6 l/ha in mixture with Artea fungicide (propiconazole+cyproconazole) reduced DON highly significantly, too. There were no differences between treatments based on this Artea fungicide (alone or in mixtures) in DON content but significantly more scaby grains were found after Artea alone as compared to both mixtures with Amistar.

Highly significant correlations were found between the following traits: FHB – DON and number of scaby grains - DON (positive levels), FHB - yield and DON - yield (negative levels). The significant correlation coefficient characterized the relationship yield – number of scaby grains (negative level).

ACKNOWLEDGEMENT

This research programme is conducted as a part of the project: ME 618 and GACR 521/02/0099.

SIGNIFICANT ACCOMPLISHMENTS AND FUTURE ENDEAVORS IN CHEMICAL APPLICATION

Gary R. Van Ee[1*], Scott A. Halley[2] and Vernon L. Hofman[3]

[1]Department of Agricultural Engineering, Michigan State University, East Lansing, MI, 48824, USA; [2]Langdon Research Extension Center, 9280 107th Ave. NE, North Dakota State University, Langdon, ND, 58249, USA; and Extension Ag & Biosystems Engineering, Box 5625, North Dakota State University, Fargo, ND, 58015, USA
[*]Corresponding Author: PH: 517-353-4508; E-mail: vanee@egr.msu.edu

ABSTRACT

The seven variables that significantly influence fungicide efficacy are: application timing, active ingredient (AI) selection, "post application" weather, target plant type, application rate, deposition efficiency, and coverage uniformity. Currently US growers trying to control Fusarium head blight (FHB) on wheat and barley have only one fungicide available and it is available on EUP label ("Emergency Use Permit"). Folicur is Bayer product and its application timing and maximum rate are specified by the EUP. A second experimental chemistry numbered JAU6476 by Bayer is in the field testing stage. A label for a blended JAU 6476/ Folicur product is anticipated in one to two years. Growers can select the variety of wheat or barley they plant but they have no control of the weather. Recent North Dakota field studies have shown a direct and significant relationship between fungicide dose and efficacy but even two times the maximum rate does not guarantee 100% control of FHB, therefore rate reductions are not recommended. Thus the application technology researcher is left with two variables to optimize: deposition efficiency and coverage uniformity.

Deposition efficiency and coverage uniformity are affected by spray volume, drop size, and the methodology of droplet transport. North Dakota research documented that replacing one vertically mounted flat fan nozzle with two flat fan nozzles delivering 50% less solution oriented forward and backward and angle 60° downward from vertical improves efficacy. 2004 field studies extensively tested the effects of varying spray volumes and drop sizes for both aerial and ground application. Nearly all the treated plots were significantly better than the unsprayed checks, but due to low disease pressure resulting from below average summer temperature none of the application variables produced different effects. 2004 ground application deposition studies showed that the deposition on the grain heads increased as the nozzles are angled from zero to 60° from vertical for both standard hydraulic nozzle and air assist sprayer systems. Two hydraulic nozzles angle forward and backward were better than one or two nozzles angled forward. Preliminary 2004 results indicate that the local systemic activity of both Folicur and JAU 6476 was enough to overcome any differences in coverage uniformity between the several different application technologies tested. A normal season with greater disease pressure may produce different results.

The grower must be concerned about more than FHB control. Significant increases in yields and test weight are frequently caused by the fungicide's control of leaf diseases. Improvement in yield and quality factors as a result of fungicide efficacy improvement is difficult to delineate between FHB and foliar disease. Often control of FHB is quantified by the measurement of the toxin deoxynivalenol from the grain sample. Fungicide application that targets the grain head for only FHB control is often not feasible or practical from a grower's perspective. An economically sound spraying methodology must have both an AI and application equipment that target the whole plant disease complex.

FACTORS THAT CAN AFFECT FIELD EFFICACY OF BIOLOGICAL CONTROL AGAINST FUSARIUM HEAD BLIGHT

Gary Y. Yuen* and C. Christine Jochum

Department of Plant Pathology, University of Nebraska, Lincoln NE 68583-0722
*Corresponding Author: PH: (402)472-3125; E-mail: gyuen1@unl.edu

ABSTRACT

Lysobacter enzymogenes C3 is a bacterial strain with biological control activity against Fusarium head blight (FHB) of wheat caused by *Fusarium graminearum*. While it is unique in having the potential to suppress FHB through direct antagonism and induction of host resistance, it is similar to other FHB biocontrol agents in that the achievement of consistent field control of FHB using C3 is a challenge. This poster summarizes greenhouse and field research conducted during the last three years to identify application factors and strategies that can influence the effectiveness of C3 in FHB biocontrol. C3 efficacy was found to be independent of cell concentration. Various dilutions of C3 broth cultures yielded similar levels of disease control in greenhouse experiments, while C3 efficacy in field experiments varied despite relatively uniform population levels of C3 being applied across trials. Timing of C3 application also was not an important factor as pre-anthesis applications of C3 in greenhouse and field experiments were as effective as C3 treatments made at the onset of anthesis. Among factors that were important to efficacy was uniformity of deposition. In the greenhouse, protection by C3 was localized to wheat spikelets to which the bacterium was applied. In the field, FHB control was achieved only in experiments in which C3 was applied in relatively high volumes that allow uniform coverage of wheat heads, whereas no efficacy was found in any experiment in which C3 was applied in low volumes that provide non-uniform treatment. Application strategies, including combining C3 with other biological control agents or with fungicides, will be examined as to their potentials for providing effective FHB control. In addition, results obtain using C3 will be discussed in relations to the use of biological agents in general as a tool for managing FHB.

RESULTS FROM THE 2004 STANDARDIZED EVALUATION OF BIOLOGICAL AGENTS FOR THE CONTROL OF FUSARIUM HEAD BLIGHT

G.Y. Yuen[1*], B.H. Bleakley[2,3], M.A. Draper[3], C.C. Jochum[1], E.A. Milus[4], K.R. Ruden[3] and L.E. Sweets[5]

[1]Dept. of Plant Pathology, University of Nebraska, Lincoln, NE 68583, USA;[2]Biology and Microbiology Dept., South Dakota State University, Brookings, SD 57007, USA; [3]Plant Science Dept., South Dakota State University, Brookings, SD 57007; [4]Dept. of Dept. of Plant Pathology, University of Arkansas, Fayetteville, AR 72701, USA; and [5]Dept. of Plant Microbiology and Pathology, University of Missouri, Columbia, MO 65211, USA;
[*]Corresponding Author: PH: (402)472-3125; E-mail: gyuen1@unl.edu

OBJECTIVE

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

INTRODUCTION

Biological control agents with the potential for controlling FHB in the field have been identified (da Luz et al., 2003), the most extensively studied in the US being the yeast *Cryptococcus nodaensis* OH 182.9 (Khan et al., 2004), strains of *Bacillus* spp, including Trigocor 1448 (Stockwell et al., 2001) and 1BA (Draper et al., 2001), and *Lysobacter enzymogenes* strain C3 (Yuen and Jochum, 2002). These agents were effective when evaluated separately in field tests (Stockwell et al., 2001; Khan et al., 2004; Yuen and Jochum, 2002). To better gauge the potentials of biocontrol agents for commercial development, however, direct comparison of agents over a wide range of environmental conditions and crop genotypes is necessary. The Uniform Fungicide and Biological Control Trials (UFBT) supported by the USWBSI provides an avenue for wide-scale, standardized field testing (Milus et al., 2001), but for most biocontrol agents, systems for large scale propagation and formulation are unavailable, and thus it is difficult to evaluate biological agents in the same standardized trials as chemical fungicides. Informal efforts were undertaken in 2001 through 2003 to compare a set of biocontrol agents across several states, with procedures varying among the locations (Yuen et al., 2003). No one strain, however, was superior or consistently effective in these studies. But out of this collective effort came a mutual appreciation of the difficulties in working with microorganisms originating from different laboratories, along with the recognition that standardized methods are needed in order to compare results from one location to another. Given that biocontrol agents for FHB, in their current state, require special procedures as to propagation, handling and quality control, a USWBSI-funded program for uniform evaluation of biological agents on wheat and barley separate from the UFBT was initiated in 2004. The results of the 2004 efforts on wheat analyzed across locations are reported here.

MATERIALS AND METHODS

Five trials were conducted across four states on a range of classes (Table 1). A sixth trial in South Dakota on barley also was conducted as part of the uniform evaluation, but its results are reported in a separate paper. In each trial, four biological agents (Table 2) were tested. A culture of each organism was provided to the researcher in each location and inoculum for treatment was propagated by the researcher following instructions provided by the organism's supplier. The pre-application population of each agent in the inoculum was determined by the local researcher using dilution plating. In addition to the biological agents, there was a non-treated control and a treatment with the fungicide tebuconazole, as Folicur 432SC, 4.0 fl oz/

A, amended with 0.125% Induce. One application was made per treatment at early flowering (Feekes 10.51) in 20 gal/acre using a CO2-pressurized sprayer (approximately 40 psi) equipped with flat-fan nozzles oriented forward and backward. The size and number of replicate plots varied among trials. Some of the trials were inoculated with *Fusarium graminearum* and utilized mist irrigation systems to stimulate infection. In all trials, FHB incidence (% heads infected per plot), severity (%spikelets infected per diseased head), and index (plot severity) were determined from at least 40 heads per plot around 3 weeks after anthesis. The incidence of Fusarium-damaged, kernels (FDK) were determined after harvest. Samples from each plot were to USWBSI-designated laboratories for analysis of DON content. Results from all trials were analyzed together using ANOVA, with trials being treated as blocks. The trials conducted on two cultivars in Missouri were considered to be separate trials. Consult individual state trial reports for results at each location.

RESULTS AND DISCUSSION

FHB pressure varied considerable among the trials, with incidence ranging from 40 to 99% and severity ranging from 16 to 52% in the controls. None of the treatments with a biological agent or with Folicur 432SC had a significant effect on any disease parameter compared to the control across the trials (Table 3). The agents also were ineffective in all of the individual trials; Folicur 432SC provided a significant reduction in DON in the Missouri trial on 'Truman' but otherwise had no effect in individual trials (data not shown).

Biocontrol agent numbers in the inoculum cultures varied considerably among agents and among locations. In many instances, cell concentrations determined at the time of application were several orders of magnitude lower than expected. The low population numbers applied could have been a contributing factor to lack of efficacy in the biological treatments. This experience points to the need for better control over microorganism numbers when testing biological agents. The fact that Folicur also was ineffective across these trials is an indication that suppression of FHB under field conditions remains a difficult objective to achieve using biological or chemical treatments.

ACKNOWLEDGEMENTS

We thank Gary Bergstrom and David Schisler for providing biocontrol agents and valuable suggestions. This material is based upon work supported by the U.S. Department of

Agriculture, under Agreement No. 59-0790-1-079. This is a cooperative project with the U.S. Wheat & Barley Scab Initiative. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

REFERENCES

Da Luz, W.C., C.A. Stockwell, and G.C. Bergstrom. 2003. Biological Control of *Fusarium graminearum.* Pages 381-394 in: Fusarium Head Blight of Wheat and Barley. K.J. Leonard and W.R. Bushnell, eds. APS Press.

Table 1. 2004 uniform biological control trial locations, wheat cultivars, and researchers.

State	Wheat market class and cultivar	PI and Institution
AR	Soft red winter wheat 'Agripro Patton'	E. Milus, University of Arkansas
MO	Soft red winter wheat 'Elkhart' and 'Truman'	L. Sweets, University of Missouri
NE	Hard red winter wheat '2137'	G. Yuen, University of Nebraska
SD	Hard red spring wheat 'Ingot'	B. Bleakley and M. Draper, South Dakota State University.

Draper, M.A., Bleakley, B.H., Ruden, K.R. and Baye, N. 2001. Greenhouse screening of biological control agents for suppression of Fusarium head blight. Proceedings of the 2001 National Fusarium Head Blight Forum, pg. 48.

Milus, E.A., Hershman, D., and McMullen, M. 2001a. Analysis of the 2001 uniform wheat fungicide and biocontrol trials across locations. Proceedings of the 2001 National Fusarium Head Blight Forum, pg. 75-79.

Khan, N.I, Shisler, D.A, Boehm, M.J., Lipps, P.E., and Slininger, P.J. 2004. Field testing of antagonists of Fusarium head blight incited by *Gibberella zeae*. *Biological Control* 29:245-255.

Stockwell, C.A., G.C. Bergstrom, and W.C. da Luz. 2001. Biological control of Fusarium head blight with *Bacillus subtilis* Trigocor 1448: 2001 field results. Proceedings of the 2001 National Fusarium Head Blight Forum, pg. 91-95.

Yuen, G.Y and Jochum, C.C. 2002. Report of induced resistance and field biological control of Fusarium head blight By *Lysobacter enzymogenes* strain C3. 2002 National Fusarium Head Blight Forum Proceedings page 127.

Yuen, GY., C.C. Jochum, B.H. Bleakley, K.R. Ruden, M. Draper, D.A. Schisler, S. Zhang, M.J. Boehm, P.E. Lipps, and G.C. Bergstrom. 2003. Cooperative multistate field tests of biological agents for control of Fusarium head blight in wheat and barley. Proceedings of the 2003 National Fusarium Head Blight Forum: 113-115.

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

Organism	Supplier
Gram-positive bacterium AS 54.6	D. Schisler, NCUAR USDA-ARS, Peoria
Lysobacter enzymogenes C3R5	G. Yuen, University of Nebraska
Bacillus subtilis TrigoCor 1448	G. Bergstrom, Cornell University
Bacillus sp.1BC	B. Bleakley and M. Draper, South Dakota State University

Table 3. Results across five uniform biocontrol trials on wheat, 2004.

Treatment	% FHB incidence	% FHB severity	Index (%)	% FDK	DON (ppm)*
Non-treated control	60.9	29.6	18.7	5.2	3.7
Folicur 432SC	58.4	26.1	15.4	4.5	3.3
AS 54.6	63.6	29.3	19.6	5.8	3.7
C3R5	59.1	28.5	17.5	5.1	3.7
TrigoCor 1448	62.2	30.3	19.4	6.4	4.0
1BC	61.3	29.3	19.4	5.3	4.0

*Based on results from four trials.

USDA-ARS, OHIO STATE UNIVERSITY COOPERATIVE RESEARCH ON BIOLOGICAL CONTROL OF FUSARIUM HEAD BLIGHT 2: COLD TEMPERATURE SHOCK DURING PRODUCTION OF *CRYPTOCOCCUS NODAENSIS* OH 182.9 ENHANCES CELL SURVIVAL AFTER AIR-DRYING

S. Zhang[1,2 *], D.A. Schisler[1], M.A. Jackson[1], M.J. Boehm[2] and P.J. Slininger[1]

[1]National Center for Agricultural Utilization Research (NCAUR), USDA-ARS, Peoria, IL 61604; [2] Department of Plant Pathology, The Ohio State University, Columbus, OH 43210, USA
[*]Corresponding Author: PH: (309) 681-6293; E-mail: zhangs@ncaur.usda.gov

OBJECTIVES

To investigate the effect of temperature during liquid cultivation of *C. nodaensis* OH 182.9 on cell survival after air-drying, and on biocontrol efficacy of air-dried products.

INTRODUCTION

Cryptococcus nodaensis OH 182.9 (NRRL Y-30216), isolated from the anthers of wheat, significantly reduced FHB under greenhouse and field conditions when applied as fresh cell preparations and frozen cell concentrate products (Khan et al., 2004; Milus et al., 2001; Schisler et al., 2002). Development of dried products of OH 182.9 would have potential advantages of ease of handling, convenience in transportation, favorable economics and consumer acceptance. Field data from the 2002 UWFBT indicated that the freeze-dried OH 182.9 product maintained viability but was not as effective in reducing FHB as was the frozen cell concentrate tested in 2001. It is possible that melezitose, a trisaccharide cryoprotectant that was used to enhance the tolerance of OH 182.9 to freeze-drying, stimulated pathogen activity. In order to avoid this problem, air-drying without the addition of cryoprotectants was selected as a preferred process for dehydrating biomass of OH 182.9 (Schisler et al., 2004). The specific objective of this project was to investigate the impact of heat and/or cold shock during liquid cultivation on the storage stability and biocontrol efficacy of OH 182.9 cells in an inert diatomaceous earth carrier.

MATERIALS AND METHODS

Effect of timing and duration of heat and/or cold temperatures (Experiment 1). The temperature extremes used for heat and cold treatments were 31ºC and 15ºC, respectively. Cultures of *C. nodaensis* OH 182.9 were initially grown in SDCL (Slininger et al., 1994) at 25ºC and 250 rpm for 20 or 26 h. Cultures of OH 182.9 are in late exponential growth after 20 h and early stationary growth after 26 h (data not shown). To test the effect of heat and cold temperature shock, OH 182.9 cells then were subjected to various heat and/or cold temperature extremes (Table 1). This experiment was conducted twice with 3 replications per treatment.

Effect of intensity and duration of cold temperatures (Experiment 2). Because results from the heat and cold shock experiments indicated the potential benefit of cold shock to long-term survival of dried OH 182.9 cells, experiments were conducted to optimize the timing and duration of cold shock during cell cultivation. The cold shock temperatures tested were 5, 10 and 15ºC applied at the late exponential stage of growth (20 h) for 28 h or 4 h. (Table 2).

Survival of cells after air-drying and storage. Harvested cultures were mixed with 10% diatomaceous earth (Hyflo, Celite Corporation) (w/v) and dewatered using vacuum filtration. The resulting *C. nodaensis* OH 182.9:diatomaceous earth formulations were milled in a food processor, and placed in shallow pans in an air-drying chamber at 60-70% RH for approximately 20 h or until the moisture content of the

formulations was less than 4% [(W_{wet}-W_{dry}) × 100% /W_{wet}]. The dried OH 182.9 formulations were vacuum packed in plastic bags and stored at 4ºC or room temperature (25ºC) for cell survival tests. Cell survival was assessed by suspending 50 mg of air-dried samples in 50 ml of weak (0.03%) phosphate buffer, mixing in a Stomacher 80 (Seward Inc., England) for 60 s, and dilution plating on 1/5 TSA. Since no colonies were recovered in some treatments when samples were stored at room temperature after 14 weeks, 500 mg samples were used instead of 50 mg for determining colony forming units (CFU). Data (CFU per gram of dry weight) was converted to logarithmic values and analyzed using JMP software (SAS Inc., NC)

Greenhouse bioassays of air-dried OH 182.9 products against FHB. Experiments were conducted in the greenhouse where temperatures ranged from 17-20ºC at night and 25-28ºC during the day. Two wheat (cultivar Norm) seedlings per plastic pot were grown in air-steam pasteurized potting mix in a growth chamber at 25ºC with a regime of 14 h light/ day for 7-8 weeks prior to use. Wheat heads were inoculated at anthesis by spraying cell suspensions of OH 182.9 products from Experiment 2 in weak PO_4 buffer with 0.036% Tween 80. One gram of an air-dried OH 182.9 product was added to 50 ml of PO_4 buffer and mixed in a Stomacher 80 (Seward Inc., England) for 60 s. This suspension (approx. 1-5×10^7 CFU/ml) was used to inoculate 4 plants representing a total of 12-16 heads. Heads were then challenged by spraying with 12 ml of a conidial suspension of *G. zeae* (1-2 ×10^4 conidia / ml) in weak PO_4 buffer with 0.036% Tween 80. Treated pots were arranged in a completely randomized design with four replications for each treatment. Each experiment was conducted 2 or 3 times. Wheat heads inoculated only with a suspension of *G. zeae* served as a disease control. Inoculated plants were incubated in a plastic humidity chamber for 3 days before being transferred to greenhouse benches. FHB severity was visually estimated using a 0 to 100% scale at 10-14 days after inoculation. Disease severity data were normalized using the arcsine transformation before analysis of variance (ANOVA).

RESULTS AND DISCUSSION

In general, air-dried cells from cultures incubated at 15ºC for 28 h after 20 h at 25ºC (T5, Table 1) maintained viability better than those from other treatments (Figure 1). Heat treatment during cell growth did not have a significant effect on cell survival. Exposure of cultures to cold temperatures during the late exponential growth stage of OH 182.9 (T5) significantly increased the storage stability of air-dried cells compared to cells exposed to cold during early stationary growth (Figure 1, T6).

A prolonged moderately cold shock after an initial period of normal incubation significantly enhanced storage stability with the highest $\log_{10}$CFU/g dry weight (7.6 for T5) at 18 weeks stored at room temperature after air-drying (Table 2, Figure 2). However, prolonged cold shock of cells at the lowest temperature (5ºC) tested had an adverse effect on cell survival, with the lowest $\log_{10}$CFU/g dry weight of 5.6 for T1 at 18 weeks, compared to a value of 6.2 for control cells (T7)(Figure 2). Similar results were observed from the air-dried OH 182.9 products stored at 4ºC (data not shown).

The biocontrol efficacy of air-dried products of OH 182.9 stored at 25ºC and 4ºC was assessed in the greenhouse. After air-drying, OH 182.9 products from T1, T3, T5, and T6 (Table 2, Table 3) significantly reduced disease severity of FHB compared to the untreated control (P = 0.05). After 6 weeks storage at 4ºC, air-dried OH 182.9 produced from T1, T2, T3, T5 and T7 retained biocontrol capacity. However, for OH 182.9 products stored at room temperature (25ºC), only air-dried products from T1, T3 and T5 significantly protected wheat plants from FHB. Fermentation conditions during OH 182.9 production and the storage conditions for dried cell products can be managed to enhance product stability and biological control performance.

ACKNOWLEDGEMENTS

This material is based upon work supported by the U.S. Department of Agriculture. This is a cooperative project with the U.S. Wheat & Barley Scab Initiative.

DISCLAIMER

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

REFERENCES

Khan, N. I., Schisler, D. A., Boehm, M. J., Lipps, P. E., and Slininger, P. J. 2004. Field testing of antagonists of Fusarium head blight incited by *Gibberella zeae*. Biological Control 29:245-255.

Milus, E. A., Hershman, D., and McMullen, M. 2001. Analysis of the 2001 uniform wheat fungicide and biocontrol trials across locations. Pages 75-79 in: Proceedings of the 2001 National Fusarium Head Blight Forum, Kinko's Okemos, MI.

Schisler, D. A., Khan, N. I., Boehm, M. J., and Slininger, P. J. 2002. Greenhouse and field evaluation of biological control of Fusarium head blight on durum wheat. Plant Disease 86: 1350-1356.

Schisler, D.A., Zhang, S., Boehm, M.J., and Lipps, P.E. 2004. USDA-ARS, Ohio State University cooperative research on biological control of Fusarium head blight 1: use of diatomaceous earth as a carrier for formulations of the antagonist *Cryptococcus nodaensis* OH 182.9. Proceedings of the 2004 National Fusarium Head Blight Forum, Kinko's Okemos, MI. (this volume).

Slininger, P. J., Schisler, D. A., and Bothast, R. J. 1994. Two-dimensional liquid culture focusing: A model of selecting commercially promising microbial isolates with demonstrated biological control capability. Pages: 29-32 in: Improving Plant Productivity with Rhizosphere Bacteria. M. H. Ryder, P. M. Stephens, and G. D. Bowen, eds. 3rd International Workshop on Plant Growth-Promoting Rhizobacteria. Graphics Services, CSIRO Division of Soils: Glen Osmond, Adelaide, Australia.

Table 1. Descriptions of heat and cold temperature applications during liquid cultivation of OH 182.9 (Experiment 1).

Treatment	Application of heat and cold temperatures
T1	20 h 25ºC ? 2 h 31ºC ? 2 h 25ºC ? 24 h 15ºC
T2	26 h 25ºC ? 2 h 31ºC ? 2 h 25ºC ? 18 h 15ºC
T3	20 h 25ºC ? 2 h 31ºC ? 26 h 25ºC
T4	26 h 25ºC ? 2 h 31ºC ? 20 h 25ºC
T5	20 h 25ºC ? 28 h 15ºC
T6	26 h 25ºC ? 22 h 15ºC
T7	48 h 25ºC (standard control)

Table 2. Descriptions of cold temperature applications during the liquid cultivation of OH 182.9 (Experiment 2).

Treatment	Application of heat and cold temperatures
T1	20 h 25ºC ? 28 h 5ºC
T2	20 h 25ºC ? 4 h 5ºC ? 24 h 25ºC
T3	20 h 25ºC ? 28 h 10ºC
T4	20 h 25ºC ? 4 h 10ºC ? 24h 25ºC
T5	20 h 25ºC ? 28 h 15ºC
T6	20 h 25ºC ? 4 h 15ºC ? 24 h 25ºC
T7	48 h 25ºC (standard control)

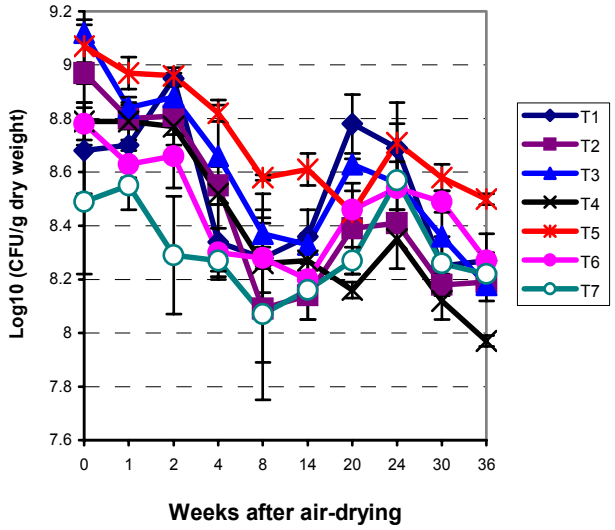


Figure 1. Effect of heat and/or cold temperatures on cell survival of OH 182.9 after air-drying (stored at 4ºC) (Experiment 1).

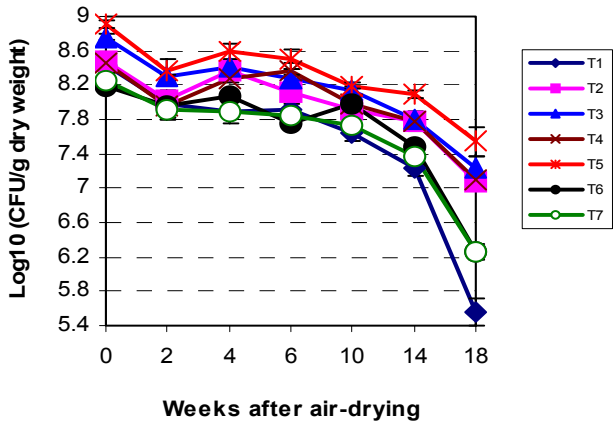


Figure 2. Impact of cold treatments during OH 182.9 biomass production on cell survival after air-drying (stored at 25ºC) (Experiment 2).

Table 3. Efficacy of cold shocked, air-dried OH 182.9 products from Experiment 2 in reducing FHB severity (%) in greenhouse tests[1].

		6 weeks after air-drying	
	After air-drying	25ºC	4ºC
Treatment	(% reduction vs CK)	(% reduction vs CK)	(% reduction vs CK)
T1	16 b (66)	35 b (53)	20 bc (51)
T2	28 ab (40)	55 ab (27)	22 bc (46)
T3	23 b (51)	42 b (44)	14 c (66)
T4	26 ab (45)	58 ab (23)	25 abc(39)
T5	23 b (51)	36 b (52)	10 c (76)
T6	23 b (51)	45 ab (40)	37 ab (10)
T7	31 ab (34)	49 ab (35)	13 c (68)
CK	47 a	75 a	41 a
$LSD_{0.05}$	24	33	17

[1]The cold temperature shock treatment regime utilized to produce cells in the air-dried products tested are described in Table 2.