Combining Management Strategies to Reduce the Negative Effects of Fusarium Head Blight on Barley

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INTRODUCTION

The barley breeding community has started to incorporate resistance to Fusarium head blight (FHB) into some of their new material. The breeders readily admit that the challenge is far greater and much more complicated than incorporating traits like stronger straw or lower protein into barley. Progress has been made though and new lines have been released and will soon be released that have resistance improvement over what is being planted now by growers. In order to assist the breeding programs and sustain an already struggling industry, applied researchers have been looking at incorporating additional management strategies to reduce the negative effects of FHB on barley. Some of these strategies, including resistant cultivars, are crop rotation and the use of fungicide to protect the barley head. Fungicide is labeled and recommended to be applied once when the main stem head has extruded from the sheath and extended. The reason for this is that most fungicide is localized systemic and protects mostly up and outward from the point of deposition. Two factors are critical to the performance of fungicide for the protection of barley, 1) timing and 2) coverage. Studies were recently conducted to demonstrate the benefits of incorporating these strategies. The objectives of our studies were to: 1.) compare an experimental line with improved resistance to the accumulation of deoxynivalenol (DON) in the grain with what is currently being grown in the region and 2.) to compare two spray application techniques for applying the fungicide and a recommended timing with a slightly early, from recommended, timing and a slightly late timing.

MATERIALS AND METHODS

Experimental sites. Research trials were planted 16 and 12 May 2008 and 2009, respectively, at the NDSU Langdon Research Extension Center Langdon, North Dakota (N48° 45.3', W98° 17.5'). The soil types were a Barnes /Svea complex (fine-loamy, mixed superactive Frigid, Calcic Hapludolls/ mixed superactive Frigid, Pachic Hapludolls) (Soil Survey Staff, 2010). Site preparation included fall tillage with a chisel plow and a spring tillage with a spring tooth cultivator with attached harrows. The plots were planted with an John Deere double-disk type drill, 15-cm row spacing twenty rows wide. Crop production practices for barley for Northeast North Dakota recommended by the North Dakota State University Extension Service were followed (Kandel, 2007). After the final herbicide application, a supplemental watering system was installed at each location to enhance disease development. The sprinkler systems consisted of manifolds and uprights with orifices at grain head height and were fed by water from the Langdon Rural Water Users Association. The uprights were spaced 9.1 x 12.2m (30 x40 ft) and equipped with impact type sprinkler heads equipped with orifices that deliver 2.7 GPM at 207 kPa (30 psi). The watering system was operated to wet the inoculum and the foliage extending the normal nightly dew period to encourage development of FHB. The *Fusarium* inoculums were hand-broadcast at a rate of 200 grams/ plot to facilitate the development of FHB. The inoculum was prepared at Langdon by similar modified method on barley grain (Dill-Macky, 2003). The method was modified by adding 3.2 kg (7 lb) of water to 9.5 kg (23 lb) clean barley grain and soaking overnight in room with temperature less than 12.8 degrees C (55 degrees F). The following day the blend was thoroughly mixed and a *F. graminearum* isolate collected from the area was added. Twice weekly the grain is thoroughly mixed by hand. A clean white mycelium develops over the next three to five weeks. After complete coverage by the mycelium, the infested grain is stored in chest type freezer until needed for application. The inoculum is removed, unthawed, to allow for mixing and hand-broadcast three and two weeks prior to the initiation of main stem head extension.

Experimental design. The experimental designs were randomized complete block with split plot arrangement with four replications. Three passes consisting of 15 cm (6-inch) 20 row randomized strips were planted for each cultivar and experimental line which constituted our whole plot. Treatments constituting our split were applied perpendicular to the planting direction.

Experimental treatments. Whole plot treatments included the barley cultivar Tradition. Tradition was planted on the majority of malt barley acreage in North Dakota. Tradition was compared to the experimental line ND20448. ND20448 is a line developed by the North Dakota State University barley breeding program. ND20448 is being tested as a potential release, 2011, as a malt industry acceptable line and has been reported to have one-third less DON accumulation in the grain than other malt cultivars. Both lines are 6-row phenotypes. Treatments included an 1) untreated check, applications of fungicide applied with nozzles mounted with a 2, 3, 4) vertical orientation or mounted on a swivel and 5, 6, 7) oriented downward from horizontal 30 degrees and forward toward the direction of travel. The vertical orientation is the most common orientation supplied as standard equipment on most crop sprayers and is recommended for the application of most herbicides. The treatments were applied at Feekes growth stages (GS) 2, 5) **10.3**, 3, 6)**10.5** and 4, 7) **5 days after 10.5**. Growth stage 10.5 has the main stem head fully extended from the boot and is the recommended fungicide application timing for protection against FHB. Growth stage 10.3 has the main stem head just emerged from the boot but not yet extended. The flag leaf may interfere with the application of fungicide and limit coverage at this growth stage. Prosaro, a 50/50 blend (prothioconazole/tebuconazole) 421SC (0.203 kg a.i. /ha) is marketed by Bayer CropScience, Research Triangle Park, North Carolina 27709, USA. This translates to 6.5 fl oz/acre. Both tebuconazole and prothioconazole were applied at 93.5 L/ha (10 GPA) in tank mixes that included the non-ionic surfactant Induce (Helena Chemical Co., Collerville, Tennessee 38017) at 0.125% v/v. Fungicide was applied with a four-nozzle tractor-mounted boom equipped with four XR8001 nozzles (Spraying Systems™ Co. North Avenue, Wheaton, Illinois 60189) spaced 51 cm (20 inches) apart. The boom was attached to a CO_2 – pressurized sprayer delivering operating at a pressure of 276 kPa (40 psi). Approximately 20 days after the fungicide application at Feekes GS 10.5, twenty heads and five leaves were sampled from each plot. The heads were evaluated to determine FHB incidence (number of spikes infected) and severity of the infected heads (number of FHB infected kernels per head divided by total kernels). FHB index is the summation of the incidence times the severity. The leaves were evaluated to determine the % diseased tissue sample. The plots were harvested on 21 Aug and 1 Sept, respectively, with a Hege plot combine and the sample processed to determine yield, test weight and plump on the barley. Deoxynivalenol concentrations in the grain samples were determined by the barley quality laboratory at North Dakota State University by gas chromatography with electron capture detection (Tacke and Casper, 1996). Data were analyzed with the general linear model, GLM (SAS Institute, Inc., Cary, NC). Fisher's protected least significant differences (LSD) were used to compare means at the 5% probability level (Table 4). The Kolmogorov-Smirnov test was used to test for normality of data.

RESULTS AND DISSCUSSION

The statistics are reported in Table 1. The experimental line ND20448 had a slightly greater FHB incidence than the cultivar Tradition, 99.6 vs 97.4 percent. The FHB incidence assessment is a visual assessment and in barley the visual FHB assessments do not always have strong correlations with the DON accumulations. These results are excellent examples. The primary concern in the malt market is the DON accumulation in the seed. Test weight was greater on Tradition than the ND20448, 48.5 vs 47.0 lb/ bushels but both test weights were excellent. All other factors were not different between the two lines including yield and DON accumulation at 0.7 ppm for each line. This is the DON level averaged across all treatments, most of them receiving fungicide. Differences in DON levels between the two untreated lines averaged over both years were 15.4 % less ppm for the ND20448 versus the Tradition. Differences among treatments are reported in Table 2. A FHB incidence was measured for treatment. Differences were minimal. Applying fungicide earlier than recommended was only slightly more effective in reducing DON than not applying fungicide. However applications of fungicide at recommended timings or slightly later reduced DON accumulation to levels so that no discounts would have been levied on the barley sample. Interestingly, the late application timing applied with the vertical nozzle orientation had significantly lower DON levels than the recommended application timing with the vertical nozzle. Further testing is warranted to determine the cause of this occurrence. Head coverage was significantly greater when the forward oriented nozzle was used for application nearly doubling the amount of fungicide deposited on the grain head compared to the vertical nozzle configuration. The foliar disease levels were almost not existent in 2009, average 7.4%, compared to 2008 levels of 23.6% which would be considered low. Average coverage levels were about 1/3 lower in 2009 than 2008 which would be a reflection of environmental conditions during the spray application. An interaction was measured for seed weight and environment. Tradition seed weight was 48.9 in 2008 and decreased to 48.0 in 2009. In contrast, ND20448 had test weight of 46.3 in 2008 and an increase to 47.8 in 2009. From a limited amount of experience with ND20448, the line ND20448 has a slight reduction compared to Tradition in agronomic performance when grown in an environment that is conducive to the development of root disease. Avoidance of plant sites that would have high levels of inoculum of root pathogens is recommended. An environment*treatment interaction was also measured. Most of the effect was a magnitude effect except for the late timing with the vertically oriented nozzle configuration which was marginally greater in 2009 than 2008.

This material is based upon work supported by the U.S. Department of Agriculture, under Agreement No. 59-0790-8-069. 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 author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

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Table 1 Source of variation and confidence intervals for Fusarium head blight incidence, head severity, index, leaf disease, yield, test weight, plump, deoxynivalenol accumulation and coverage on barley Langdon 2008 and 2009.

	Fusarium head blight								
Source of variation	Incidence	Head Severity	Index	Leaf Dis.[a]	Yield	Test weight	Plump	DON[b]	Cov.[c]
cultivar	0.0462	0.0576	0.0519	0.8009	0.2043	0.0248	0.145	0.9647	0.2621
treatment	0.0469	0.7745	0.4940	0.2370	0.375	0.0764	0.1464	<0.0001	<0.0001
cult[d]*trt[e]	0.6404	0.7994	0.8156	0.9611	0.9791	0.9859	0.1845	0.7027	0.7124
time	0.2126	0.1677	0.1578	0.0062	0.0650	0.7014	0.1161	0.6959	0.0040
cult*time	0.3081	0.9736	0.9132	0.5068	0.1842	0.0268	0.1024	0.8687	0.5127
trt*time	0.1916	0.2663	0.2165	0.3942	0.4698	0.2680	0.7287	0.1371	0.0018
cult*trt*time	0.6013	0.57	0.4596	0.3481	0.2754	0.8893	0.7273	0.5211	0.1650
%C.V.	2.4	16.3	16.8	59.6	9.7	1.6	2.0	42.7	27.8

[a] Dis. = disease, [b] DON = deoxynivalenol accumulation in the grain, [c] Cov. = coverage, [d] cult = cultivar, and [e] trt = treatment.

Table 2. Fusarium head blight incidence, head severity, index, leaf disease, yield, test weight, plump, deoxynivalenol accumulation and coverage by barley line or nozzle orientation and timing, Langdon 2008 and 2009.

		Fusarium head blight								
Barley Line		Incidence (%)	Head Severity (%)	Index (%)	Leaf Dis.[a] (%)	Yield (bu/a)	Test weight (lb/bu)	Plump (%)	DON[b] (ppm)	Cov.[c] (abs[d])
ND20448		99.6	11.5	11.4	15.9	117.7	47.0	96.3	0.7	0.30
Tradition		97.4	9.1	8.7	15.7	122.8	48.5	93.1	0.7	0.25
LSD $_{(0.05)}$		2.1	NS	NS	NS	NS	1.1	NS	NS	NS
Nozzle Orient.[e]	Timing									
Untreated	na	97.8	10.2	9.9	15.1	114.0	47.2	93.4	1.2	0.04
30°F	10.3	98.4	10.5	10.3	11.5	120.2	47.8	94.6	1.0	0.47
30°F	10.5	98.4	9.8	9.4	13.5	121.4	47.7	95.0	0.4	0.45
30°F	10.5+5days	96.9	10.2	9.9	17.6	120.9	48.0	94.9	0.4	0.33
Vertical	10.3	99.7	10.8	10.7	20.0	119.4	47.7	94.6	0.9	0.22
Vertical	10.5	99.1	10.1	9.9	15.6	123.9	48.0	95.0	0.5	0.21
Vertical	10.5+5days	99.1	10.2	10.0	15.2	121.9	47.8	95.3	0.3	0.23
LSD $_{(0.05)}$		2.6	NS	NS	NS	NS	NS	NS	0.2	0.06

[a] Dis. = disease, [b] DON = deoxynivalenol accumulation in the grain, [c] Cov. = coverage, [d] Abs = absorbance, and [e] orient. = orientation.