Table 4. Agronomic traits and reaction to FHB and leaf diseases of Glenn and five most grown hard red spring wheat cultivars in North Dakota, USA, during the 2002-2004 period.

				Reaction[1]					
Variety	Days to heading	Height	Lodging	Leaf rust	Tan Spot	FHB	Test weight	Protein	Grain yield
	Days	cm	1-9				Kgm^{-3}	%	$Kgha^{-1}$
Glenn	65	87	0.7	R	MS/MR	MR/R	806	15.8	4421
Alsen	65	84	1.1	MR/MS	S	MR	770	15.6	4317
Dapps	65	91	1.2	R/MR	MR	MS	772	16.4	4209
Parshall	65	94	1.3	MS/S	MS	MS	768	15.6	4347
Reeder	66	83	0.5	S	MR	S	755	15.4	4519
Steele-ND	66	87	1.9	R/tMR	MS/MR	MR/MS	772	15.6	4552

[1]R=resistant, MR=moderately resistant, MS=moderately susceptible, S=susceptible

Table 5. Fusarium head blight (FHB) severity, Tombstone and Deoxynivalenol toxin levels; leaf rust , stem rust , tan spot, and Septoria nodorum reactions of HRSW cultivars under natural (3 locations) and artificial (7 locations) inoculation in the filed and greenhouse conditions (4 tests) in Fargo, ND from 2001 to 2004.

Genotype	FHB Severity (Field test under natural infection) [1]			FHB Severity (Field test under artificial inoculation)			FHB GH	SR[2]	TS	SN
	SEV (%)	TMB (%)	DON (ppm)	SEV (%)	TMB (%)	DON (ppm)	SEV (%)		(1-5)	(1-5)
Glenn	7.6	0.7	0.4	18.9	16.0	4.0	16.3	R	3	3
Steele-ND	19.3	1.3	0.9	31.5	26.5	5.3	24.6	R	4	3
Alsen	7.0	0.9	0.8	28.7	20.9	4.8	10.8	R	5	5
Reeder	26.2	5.7	1.5	58.9	37.2	10.3	42.0	R	4	4
2398	41.8	5.4	2.0	75.2	51.7	9.9	55.5	R	-	-

[1]SEV=Severity; TMB= Tombstone; and DON= Deoxynivalenol toxin;
[2] SR= Stem rust; TS= Tan spot; SN= Spetoria nodorum; R=Resistant and MS=Moderate susceptible.

The ratio of FHB incidence to severity was significantly higher for NC Neuse than for the other cultivars (P d•0.05). Lower ratios of incidence to severity support the hypothesis of Type I resistance, while higher ratios support the hypothesis of Type II resistance.

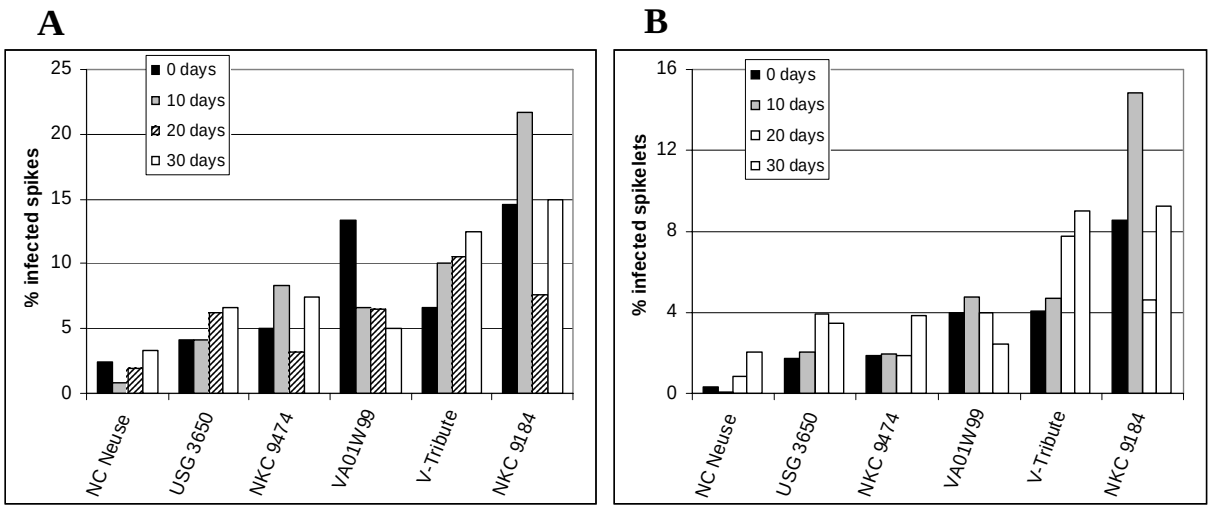

Fig. 1. A. Incidence (% infected spikes) and **B.** severity (% infected spikelets) of FHB in six soft red winter wheat cultivars inoculated with *F. graminearum* spores and subjected to four durations of post-anthesis misting (0, 10, 20 and 30 days). Disease assessments were not available for cultivar Ernie.

Neural Network. In 2005 only the Logistic Regression model approach was used.

In phase II of the analysis (2004), the total data set (n=124) was partitioned into two data sets with one data set (n=86) used for model development. The remaining cases were assigned to a data set used only for model validation. A similar approach was employed in phase III of the analysis (2005), with 108 of the total 154 cases used for model development. However, in phase III we also used a procedure known as 0.632+ Bootstrap. This bootstrap procedure randomly samples the total data set with replacement 200 times and allows for model development and validation on each of the samples. Model fit and accuracy are then based on bootstrap estimates of model parameters, thus minimizing the potential for overfitting the model to a small data set.

Candidate models were selected based on ability to correctly predict epidemics (% accuracy), balance between ability to predict epidemics (% sensitivity) and non-epidemics (% specificity) and measures of model fit. Model errors were evaluated for possible patterns in predictions that might be further explained by additional variables or time periods not currently considered by the models.

RESULTS AND DISCUSSION

Variable selection - The best subsets method of variable selection successfully identified variables related to disease epidemics. In general, temperature variables representing the number of hours that temperature was between 9 and 30°C were selected compared to other representations of temperature, including duration of temperature between 12 and 30°C and 15 and 30°C. Variables summarizing relative humidity were selected over those that used dewpoint temperature to estimate moisture levels. Variables representing the duration of rainfall were selected instead of variables representing summations or frequency of rainfall (number of days with rain). When variables summarizing weather conditions for 3-, 5-, 7- or 10-days periods prior to flowering were considered, only variables from a seven day period were selected by the best subsets analysis. The selected variables (Table 2) are consistent with research results from studies investigating the pathogen reproduction (Dufault et al. 2005). Variables describing crop management types (spring vs winter wheat), or specific production practices (presence of corn residue at a given location or the use of resistant cultivars) were also selected for further model development.

Modeling results Phase II - Among the statistical techniques evaluated, logistic regression and CART had the highest accuracy for all three models (Table 3). A model that used only duration of favorable temperature and humidity for winter wheat without corn residue and additional interaction terms describing interactions between temperature and humidity and hours of rain had the higher prediction accuracy than other models evaluated. For the logistic and CART approaches, this model correctly classified more than 80% of the cases and more than 80% sensitivity and specificity for all pooled cases (training and validation, over both wheat types). Errors of the model appear to be associated with favorable weather conditions during flowering or grain-filling periods of growth that are not considered by the pre-flowering models.

Modeling results Phase III - Logistic regression models were the focus of the phase III analysis, because of their accuracy in the phase II analysis and relative ease of deployment as a simple equation. In this phase of the analysis, we successfully reduced the number of variables used in the models. A candidate model for spring wheat used only mean relative humidity for 7-days prior to flowering and cultivar resistance to FHB as independent variables (Table 4). This model correctly classified 78% of the cases from spring wheat production regions. However, the model has slightly higher sensitivity than specificity indicating that it may overestimate the risk of a FHB epidemic in some years. Bootstrap estimates of model accuracy are similar to the more traditional approach to model validation but have a slightly lower specificity. A model that estimates the risk of a FHB epidemic for winter wheat in fields without corn residue or other local inoculum source was also developed in the phase III analysis. This model uses only mean relative humidity to predict

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Table 1. Effect of residue destruction on; residue dry matter (number of nodes/m^2), survival of *F. graminearum* (FG) in nodes, the population of FG in soil at the time of planting, airbone inoculum of FG at anthesis and early dough, and colonization by FG of a subsequent wheat crop of the FHB-susceptible cultivar Wheaton.

Burning[1]	Nodes (no./$m^{2)}$	FG survival (%)	FG in soil (cfu/g)	Airborne FG (cfu/Petri plate)		Wheaton FG Colonization (%)
				Anthesis	Early Dough	
Control	62 a[2]	33.0 a	693 a	7.6 a	15.1 a	18.4 a
Light	46 b	13.1 b	598 b	6.6 a	12.2 b	17.7 a
Severe	36 c	9.0 b	522 b	4.8 b	9.8 c	11.3 b

[1]Control, non-burned residues; Light, one pass with an alfalfa burner (1.3 m/s); Severe, one pass with an alfalfa burner (0.5 m/s)
[2]Means followed by different letters within a column are significantly different at P=0.05 level.

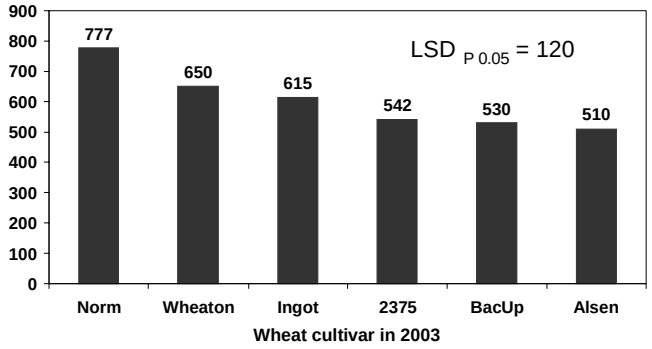

Fig. 1. Effect of the cultivar of 2003 wheat crop on populations of *F. graminearum* (FG) in soil in 2004.

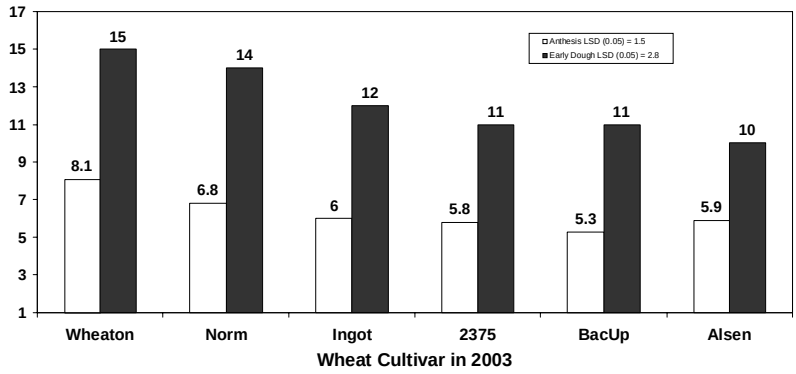

Fig. 2. Effect of the wheat cultivar in 2003 on airborne inoculum (cfu/Petri plate) of *F. graminearum* (FG) within the canopy of the 2004 wheat (cv. Wheaton) at anthesis and early dough growth stages.

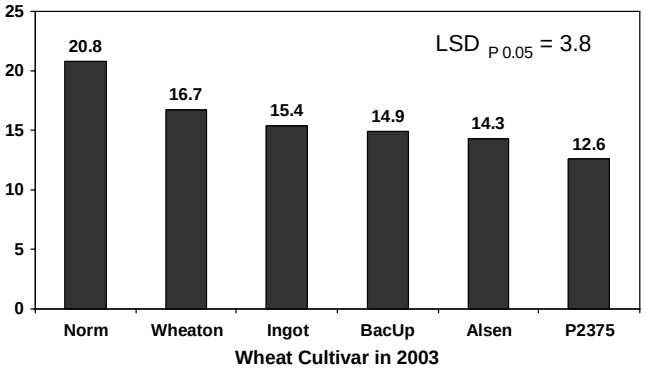

Fig. 3. Effect of wheat cultivar in 2003 on the colonization by *F. graminearum* (FG) of 2004 wheat (cv. Wheaton) at the hard dough growth stage.

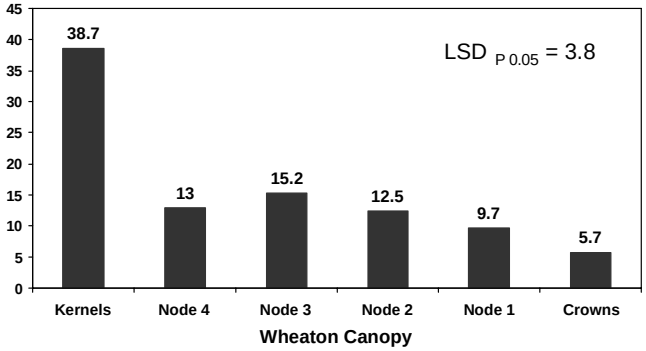

Fig. 4. Incidence of *F. graminearum* (FG) in kernels, node and crown tissues of Wheaton wheat (2004) at the hard dough growth stage.

Table 1. Effect of fungicides on Fusarium head blight (FHB) incidence, head severity, field severity, DON, Fusarium damaged kernels (FDK), yield and test wt., averaged across four hard red spring wheat trials at Carrington, Fargo and Langdon, ND, 2005

Treatment and rate/acre[1]		FHB I[2] %	FHB HS[2] %	FHB FS[2] %	DON[3] ppm	FKD[4] %	Yield Bu/A	Test wt Lbs/bu
Untreated check		59.2	28.7	17.5	7.8	13.8	40.3	58.3
Folicur 3.6 EC	4.0 fl oz	41.1	19.6	9.0	5.8	7.7	49.7	59.1
Prosaro 421 SC	6.5 fl oz	35.0	17.6	7.4	4.0	5.9	53.7	59.9
BAS555 01 F	13.5 fl oz	38.4	17.5	7.8	4.1	7.0	51.4	59.5
BAS555 01 F	10.0 fl oz	42.4	21.2	9.2	4.6	5.6	50.4	59.5
Punch	6.0 fl oz	48.1	22.8	11.4	6.6	8.0	47.6	59.0
Punch	8.0 fl oz	44.0	19.3	10.1	6.0	8.1	47.3	59.1
LSD 0.05		11.0	5.9	4.6	1.1	2.8	2.3	0.7

[1] Folicur, Prosaro, and BAS555 treatments had 0.125% Induce added; Prosaro (19% prothioconazole + 19% tebuconazole) is an experimental fungicide from Bayer; BAS555 (metconazole) is an experimental fungicide from BASF; Punch (flusilazole) is an experimental product from DuPont

[2] FHB I = incidence; FHB HS = head severity; FS = Fusarium head blight field severity; field severity = incidence x head severity;

[3] DON (deoxynivalenol = vomitoxin) levels were only available from the Fargo location at the time of this report;

[4] FDK = Fusarium damaged kernels

Table 1. Fungicide effect on Fusarium head blight index.

Trial		Wheat	Most effective Treatment[a]				Disease index (%)	
State/PI	Location	Type	Treat	IND (%)	% Control	*P value*	Mean	Max
IL/Adee	Monmouth	W	2,3,4,6	0.02	91.81	0.002	0.07	0.67
IL/Fakhoury	Carbondale	W	7	0.11	88.5	0.089	0.81	3.24
IN/Shaner	Lafayette	W	…	…	…	…	0.00	0.00
	Butlerville	W	…	…	…	…	0.00	0.00
LA/Padgett	Macon Ridge	W	4	0.37	82.22	0.029	1.56	5.26
MD/Grybauskas	Beltsville	W	3	1.62	89.64	<0.001	6.37	25.90
MI/Hart	East Lansing 1	W	…	…	…	…	0.00	0.00
	East Lansing 2	W	…	…	…	…	0.00	0.00
MN/Hollingsworth	Crookston 1	S	3	3.36	45.4	<0.001	4.55	7.20
	Crookston 2	W	4	0.66	47.6	0.089	1.17	2.62
MO/Sweets	Columbia 1	W	6	0.00	100	0.151	0.55	3.15
	Columbia 2	W	6	0.00	100	0.170	0.59	2.80
ND/McMullen	Fargo	S	3	2.97	85.92	<0.001	6.91	23.00
	Carrington 1	S	3	19.50	45.45	0.004	25.68	55.00
	Carrington 2	S/D	3	16.25	41.44	0.069	21.54	37.00
	Langdon 1	S/D	4	1.60	71.93	0.067	4.36	16.00
	Langdon 2	S	3	2.25	59.82	0.015	3.88	8.00
	Langdon 3	S	7	3.15	56.55	<0.001	4.81	7.90
SD/Draper	Brookings 1	S	3	35.83	21.42	0.122	42.23	60.44
	Brookings 2	S	2	27.72	45.26	<0.001	39.21	54.62
	Watertown 1	S	5	10.70	49.17	0.057	14.16	37.14
	Watertown 2	S	5	6.91	59.26	0.008	10.95	26.44
	Groton 1	S	5	7.80	59	0.042	12.01	39.94
	Groton 2	S	5	6.09	28.57	0.299	7.23	14.00
VA/Stromberg	Warsaw	W	2	2.68	64.89	0.001	4.54	8.40

[a] Treat = the most effective treatment (s) within each trial based on the pair-wise difference between mean IND for each treatment and the check; IND (%) = mean index across plots receiving the most effective treatment; % control = percent control; *P* value = level of significance from *F* test of the difference between mean IND across plots receiving the most effective treatment and the untreated check. All tests of significance were done using arcsine-transformed IND.
… = Trials with no disease.

Table 2. Fungicide effect on DON.

Trial[a]		Wheat	Most effective Treatment[b]				DON (ppm)	
State/PI	Location	Type	Treat	DON	% Reduction	*P value*	Mean	Max
MD/Grybauskas	Beltsville	W	3	2.40	84.42	<0.001	7.90	24.50
MN/Hollingsworth	Crookston 1	S	3	2.23	53.40	<0.001	3.50	5.70
	Crookston 2	W	4	0.73	26.82	0.329	1.01	1.80
ND/McMullen	Fargo	S	3	4.00	48.37	<0.001	5.55	8.50
	Carrington 1	S	7	4.85	51.74	0.041	6.33	19.10

[a]DON data were not available for some trials or available but equally low (below 1 ppm) for all treatments.
[b]Treat = the most effective treatment within each trial based on the pair-wise difference between mean DON for each treatment and the check; DON (ppm = mean DON across plots receiving the most effective treatment; % reduction = percent reduction in DON; *P* value = level of significance from *F* test of the difference between mean DON across plots receiving the most effective treatment and the untreated check. All tests of significance were done using log-transformed.

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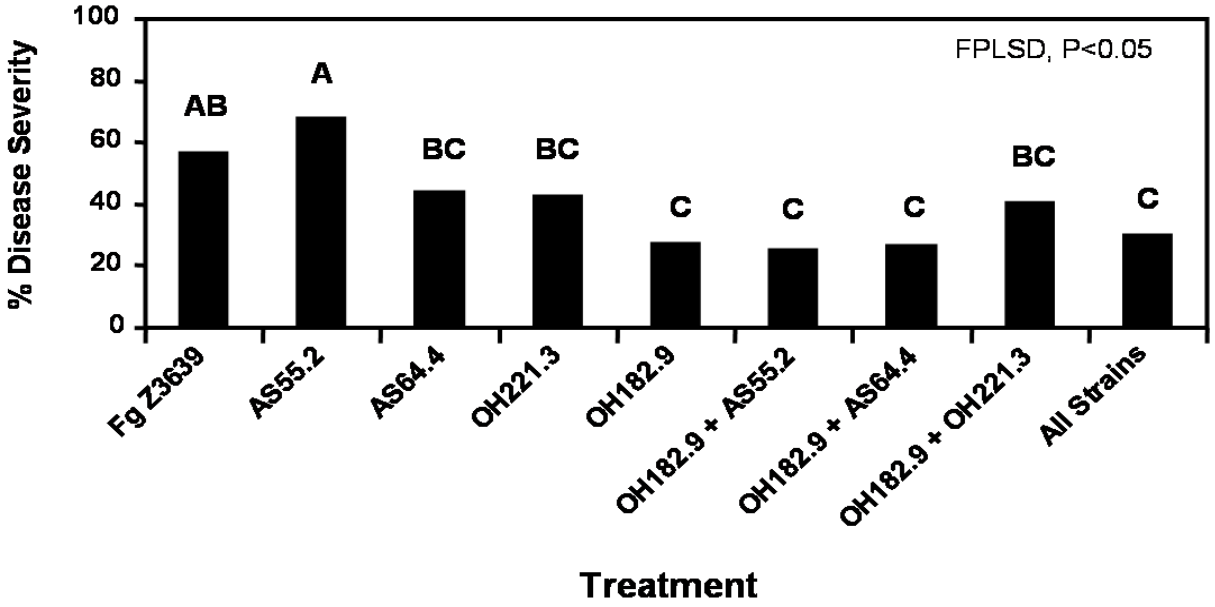

Figure 1. Influence of choline metabolizing strains AS 55.2, AS 64.4 and OH 221.3 alone or in combination with *C. nodaensis* OH 182.9 on FHB incited by *Fusarium graminearum* isolate Z-3639 in greenhouse tests.