BARLEY SCAB: FORECASTING TO MANAGEMENT

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Outline

- DON prediction model
- Contribution of secondary tillers to final DON level in harvest grain

Development of Weather-Based Predictive Models for Fusarium Head Blight and Deoxynivalenol Accumulation for Spring Malting Barley

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Bondalapati et al. 2011. Plant Disease. DOI: 10.1094/PDIS-05-11-0389

Fusarium Head Blight (FHB)

- Caused by *Gibberella zeae* (Schwein) petch (anamorph: *Fusarium graminearum* Schwabe)
- Economic losses due to
  - Blighting of florets (reduction in grain number)
  - Disruption of grain fill (shriveled kernel- light test weight)
  - Quality compromised (mycotoxin contamination – DON)

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Impact on barley

- Low tolerance for DON in malting barley
- Gushing in absence of agitation
- Severe discount of crop rejection if the DON level exceeds 0.5 mg/kg

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FHB management in barley

- FHB resistance is not adequate
- Inoculum management through crop or residue management
- Fungicide application – timing is critical
- Development of risk advisory system help to make informed management decision

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Objectives

- develop a FHB infection model based on temperature and wetness duration, and
- develop risk models that were predictive of DON levels greater than 0.5 mg/kg.

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Materials & methods

- RCBD – 4 reps
- Regionally adapted-malting barley in multiple locations
  - SD (2005-10), MN (2005, 2007-09), MT (2006)
- 2005-09: to develop potential predictive models
- 2010 (ND, SD): validation.
- At least 'Conlon' (2-row), 'Robust' and 'Tradition' (6-row) common
- Plot sixe: 1.5m x 4.6m
- Natural infection

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Materials & methods

- Disease rating at 18-21 dai heading (Z85) – 25 heads per plot
- DON analyses on harvested grain
- Weather data temperature, RH and precipitation (incidence and rate) – used for calculating other variables
- 9 days preceding and including heading day
- Binary response variable eonomic DON (eDON) – economically significant DON – 0.5 mg/kg

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Infection model @ controlled envt.

- Non-linear relationship between temp (*t*) and duration of continuous wetness (*w*) expressed using modified Weibull function given by Duithe (1997)

$$Y = f(w,t) = A\left(1 - \exp\left\{-\left[B(w-C)\right]^{D}\right\}\right)$$

- Where B varies with temperature according to

$$B = f(t) = E\left[(H+1)/H\right]H^{1/(H+1)}\left\{\exp\left[(t-F)G/(H+1)\right]\right\}/\left\{1+\exp\left[(t-F)G\right]\right\}.$$

- **A** = upper limit of the response, **B** = intrinsic rate of increase in repose with respect to *w*, **C** = lag period of *w* before response begins, **D** = periods of wetness in which response decelerates, **E** = scale of response to *t*, **F** = proportional to optimal *t*, **G** = intrinsic rate of change in the response with respect to *t*, **H** = asymmetry in the response to *t*.

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Infection model @ controlled envt.

- FHB infection in wheat data (Anderson, 1948) used for estimation of parameters
- Response variable: proportion of symptomatic wheat spikelets at a given *t and w*
- To reduce over parameterization, *A*, *C*, and *F* were fixed to 1, 12 and 25, respectively
- Best-fit parameter estimates for *D*, *E*, *G*, and *H* were obtained using Marquardt iterative method of the NLIN procedure in SAS

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Infection model @ controlled envt.

Parameter estimates and associated statistics for the Weibull model using disease incidence data from a control envt. Study with wheat.

Parameter[z]	Estimate	Asymptotic Standard Error	95% confidence interval	
			Lower	Upper
D	2.6475	0.0903	0.8859	1.2628
E	0.0252	0.0015	0.0222	0.0282
G	0.4804	0.4354	1.7393	3.5558
H	1.0744	0.0436	0.3895	0.5713

z Parameter estimates were obtained by using the Marquardt procedure defined in PROC NLIN in SAS.

The response variable was considered as proportion of inoculated wheat spikelets blighted at different temperatures and exposure period to wetness provided by Andersen (1948).

The parameters A, C, and F were fixed at 1, 12 h and 25oC as explained previously.

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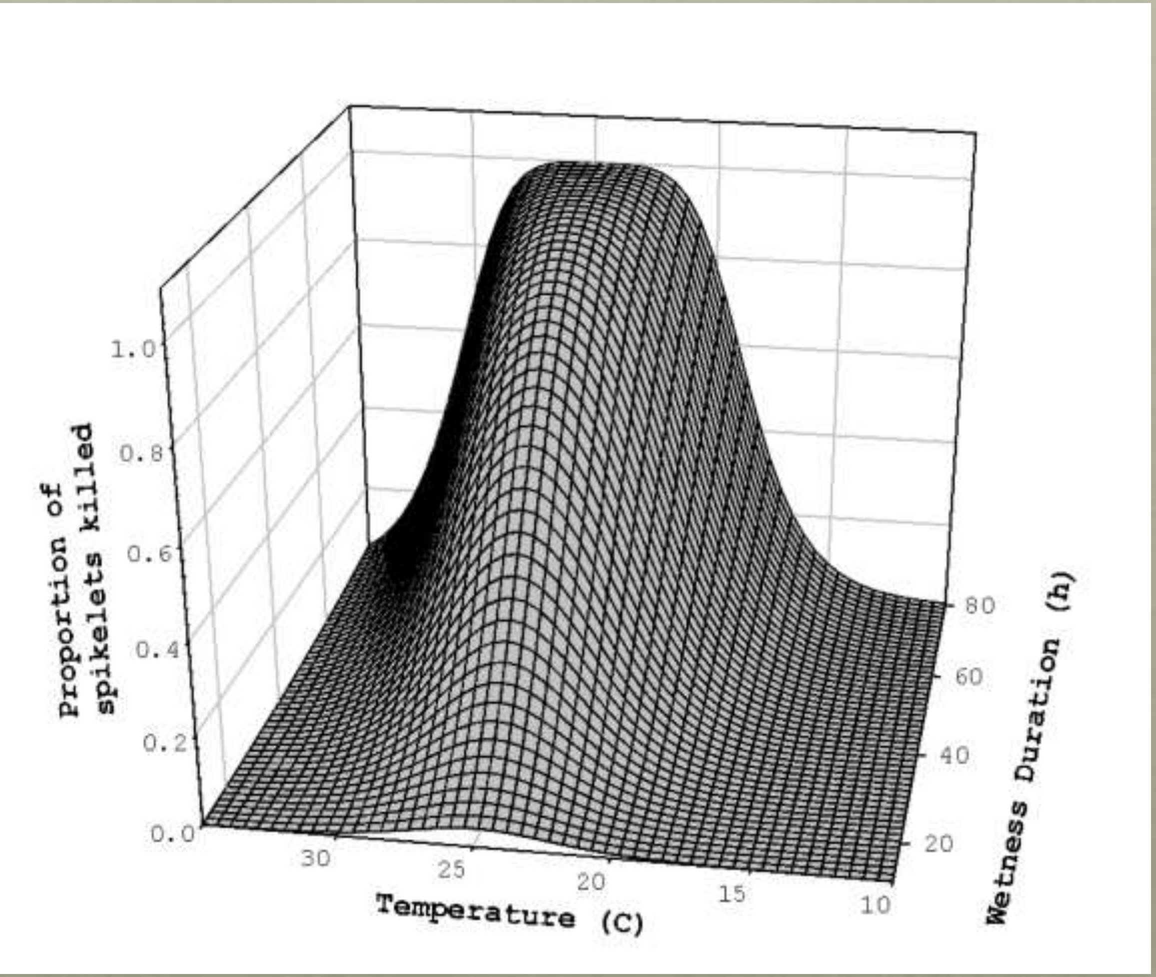
Infection model @ controlled envt.



Predicted response surface generated by the Weibull function using disease incidence data from a controlled environment study with wheat. The parameters *A, C, D, E, F, G* and *H* were 1.0, 12.0, 2.6475, 0.0252, 25.0, 0.4804, and 1.0744, respectively

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Extension of infection model to field

- Several input variables were developed to estimate *t* and *w*
- Temperature: average hourly temperature (AvgT), average daily min. temp (AvgMinT), avg. daily max temp (AvgMaxT)
- Wetness duration: no. of hours with RH ≥ 90%(RH90), longest uninterrupted duration of hours with RH ≥ 90% (drRH90), and weighted duration of hours with RH ≥ 90% (wRH90)

$$\text{wRH90} = \sum_{i} x_i \left[1 + \frac{W_i}{\sum_i W_i} \right]; \quad W_i = \begin{cases} x_i - 8 \text{ if } x_i > 8; \\ 0 \text{ otherwise} \end{cases}$$

x_i = instance of uninterrupted wetness duration (h) when RH ≥ 90%
i = indicator to represent such uninterrupted durations in the 10-day interval

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Extension of infection model to field

- For each event, *Y* was calculated using eqn 1 replacing *t* and *w* with different variables

$$Y = f(w,t) = A\left(1 - \exp\left\{-\left[B(w-C)\right]^{D}\right\}\right)$$

- Total of 9 variables were calculated (weibull variables)

- Parameters *A*, *C*, and *F* fixed at 1, 0 and 25 and estimates from the fitting of the model to Anderson's data were used for *D*, *E*, *G*, and *H*

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Extension of infection model to field

Variable name	t	w	Disease Metrics[y]			
			Incidence	Field severity	DON	eDON
Wb$_1$	AvgT	RH90	0.55^{***z}	0.37^{***}	0.40^{***}	0.62^{***}
Wb$_2$		drRH90	0.44^{***}	0.37^{***}	0.24^{**}	0.59^{***}
Wb$_3$		wRH90	0.57^{***}	0.42^{***}	0.39^{***}	0.60^{***}
Wb$_4$	AvgMinT	RH90	0.45^{***}	0.27^{***}	0.39^{***}	0.58^{***}
Wb$_5$		drRH90	0.49^{***}	0.43^{***}	0.29^{***}	0.63^{***}
Wb$_6$		wRH90	0.47^{***}	0.30^{***}	0.40^{***}	0.60^{***}
Wb$_7$	AvgMaxT	RH90	0.36^{***}	0.35^{***}	0.22^{**}	0.40^{***}
Wb$_8$		drRH90	0.55^{***}	0.71^{***}	0.14^{*}	0.47^{***}
Wb$_9$		wRH90	0.30^{***}	0.29^{***}	0.20^{**}	0.35^{***}

Pearson correlation coefficient between variables obtained from Weibull function and the disease metrics

z ***: Significantly different from zero at $P < 0.001$ level; **: Significantly different from zero at $P < 0.05$ level; *: Significantly different from zero at $P < 0.1$ level.

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Model validation

- Accuracy of logistic regression using a validation data set of 29 events collected from 10 research fields from SD and ND in 2010
- Independent of events that were used to develop regression models
- An event was observed as +ve eDON when eDON was ≥ 0.5 mg/kg and predicted as +ve eDON when the probability of being +ve eDON was ≥ p^*
- Prediction accuracies (total accuracy, sensitivity and specificity) – comparing the observed and predicted responses

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Logistic regression models for eDON

#	Model equation[w] ($\beta_0 + \beta_1 \times X$)	AUROC[x]	p^{*x}	Predictor variable value at p^{*y}	Training Data (n=150) TPP[x]	Training Data (n=150) TNP[x]	Training Data (n=150) Total accuracy	Validation Data (n=29) TPP[x]	Validation Data (n=29) TNP[x]	Validation Data (n=29) Total accuracy
1	$-3.34 + 5.39 \times Wb_1$	0.89*[z]	0.23	0.40	76	85	83	82	58	72
2	$-3.20 + 134.34 \times Wb_2$	0.88*	0.33	0.02	79	94	91	59	75	66
3	$-3.85 + 5.16 \times Wb_3$	0.88*	0.28	0.56	82	84	84	82	75	79
4	$-2.34 + 37.96 \times Wb_4$	0.89*	0.13	0.01	91	75	79	100	33	72
5	$-2.91 + 2410.36 \times Wb_5$	0.87*	0.34	0.00	74	92	88	59	75	66
6	$-2.48 + 26.90 \times Wb_6$	0.88*	0.16	0.03	85	79	81	71	50	62
7	$-3.91 + 3.86 \times Wb_7$	0.80*	0.23	0.70	82	67	71	82	50	69
8	$-2.08 + 14.76 \times Wb_8$	0.72*	0.46	0.13	41	96	84	53	92	69
9	$-3.99 + 3.58 \times Wb_9$	0.79*	0.37	0.97	68	81	78	71	50	62

w Model equation was expressed in terms of *logit*(p), where *logit*(p) = *log*(p/(1-p)). That is, right side of the model equation *logit*(p) = $\beta_0 + \beta_1 X$ was given.

x AUROC- area under the ROC curve; *p**-The cut-off probability to classify an event as positive eDON event based on maximizing Youden's index; TPP- Sensitivity; TNP-Specificity.

y The value of the corresponding predictor obtained from , where *p** was obtained from Youden's index, and, estimates for β_0 and β_1 were given in the model equation.

z *- Significantly greater than 0.5 at P<0.001 level.

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Optimal decision threshold (p_T)

- Models 3, 4 & 6 (higher sensitivities) used for used for calculating p_T for a given level of *Prev* (a *priori* probability that DON conc. will be greater than the threshold value of 0.5 mg/kg

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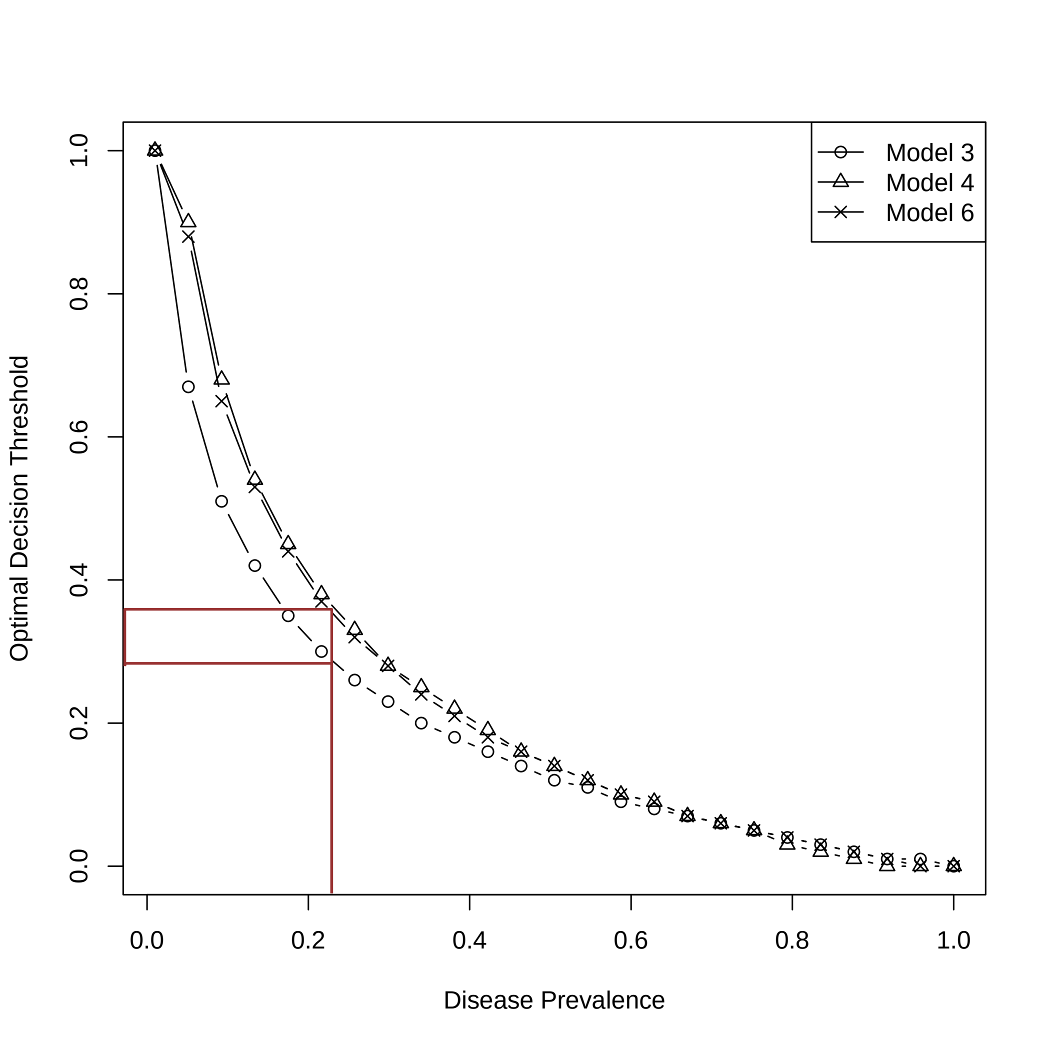
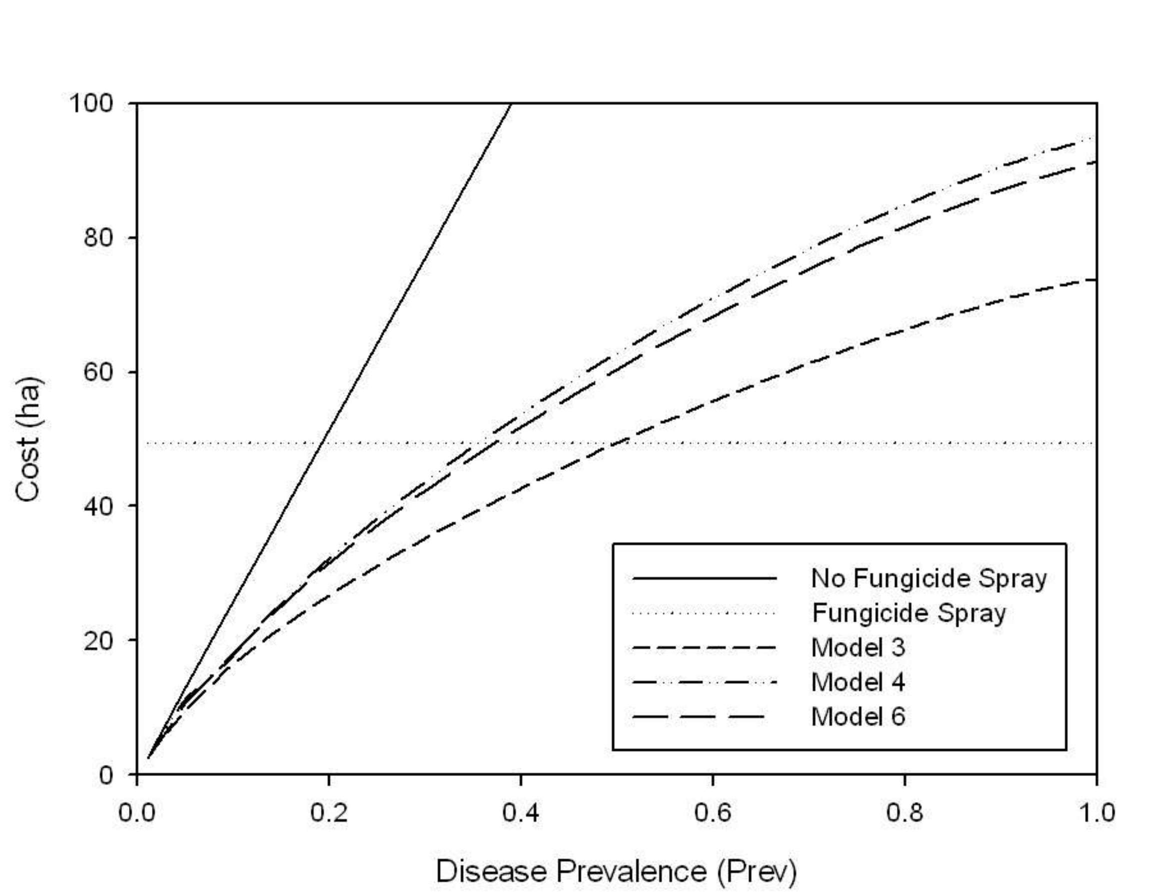


Relationship between optimal decision threshold (p_T) and disease prevalence (*Prev*) for the selected models 3, 4 and 6. At each *Prev*, p_T was obtained by minimizing the total average cost associated with misclassified events.



Average costs per hectare associated with no recommendation of fungicide spray, recommendation of fungicide spray at all times and the models 3, 4 and 6. The average cost for fungicide spray per hectare is $50. Costs are expressed in terms of U.S. dollar per hectare.

- Model 3: 18 False positive (training); 3 (validation)
- 50% from Conlon (2-row)
- False negative: 6 (training); 3 (validation)
- 2 of 6 intense rainfall or humidity >90% within 3 days after heading
- Remaining : DON just slightly above the threshold or were from 6-row cultivars
- Further validation – representing wide weather conditions
- Cultivar resistance inclusion required – currently underway
- Model may fail if weather become highly conducive beyond model's period

NDSU

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FARGO, ND

Small Grain Disease Forecasting Home | **Small Grain Diseases Explained** | **Other Crop & Weather Information**

The Small Grains Disease Forecasting Models are maintained and supported by the NDSU Department of Plant Pathology

The NDSU Small Grains Disease Forecasting Models assist producers in estimating the possibility of disease in their crops and give recommendations as to possible preventative applications and times for these applications. This is done in conjunction with NDAWN weather station locations within North Dakota and sections of western Minnesota and eastern Montana.

The forecasting models will return in 2012.

August 15, 2011

Attention: This forecasting service has ended for 2011. Now that we are approaching on receiving the final product of all our hard work done throughout the season, I wish you all the best for a healthy bumper crop. Good bye until the year 2012. For an update on 2011 small grain diseases in North Dakota, please read weekly pest reports.

Contribution of Secondary Tillers to Total Deoxynivalenol Concentration in Harvest Grain

Background

- Higher number of tillers is desirable as it has positive impact on final grain yield
- Lateral tillers have delayed physiological development (Klepper et al., 1993)
- Late infection of wheat and barley results in low disease development but high DON concentration
- Delayed maturity of sec. tillers might be analog to the late infection

Hypothesis

- Secondary tillers tends to have higher DON concentration compared to that of main heads

Methods
Experiment

- Split-split plot design
- SDSU Agri. Experiment Station, Brookings, SD
- 5 reps

Methods
Plant materials

- Barley
  - ‘Quest’ (MR)
  - Robust’ (MS)
- Hard red spring wheat (HRSW)
  - SD3851 (cv ‘Brick’ MR, possesses *Fhb1* QTL)
  - SD3854 (MS, lacks *Fhb1* QTL)
- Hard red winter wheat (HRWW)
  - WesleyBC6 (MR, possesses *Fhb1* QTL)
  - WesleyBC70 (MS, lacks *Fhb1* QTL)

Methods
Inoculation

- 10 different isolates of *F. graminearum*
- 80,000 spores per ml; 200 ml per plot
- Backpack sprayer powered with CO_2
- Misting turned on 10 min per hour (5 pm – 7 am) for 14 days
- Inoculation at Feekes 10.5 and 11.2

Methods
Disease assessment & harvesting

- 25 main heads and 25 secondary tillers tagged (different color) in separate plots
- FHB incidence and severity assessed on tagged heads 18-21 DAI
- Tagged heads hand harvested and threshed
- Plots mechanically harvested at maturity


Tagged tillers


Tagged main spikes


Misting system

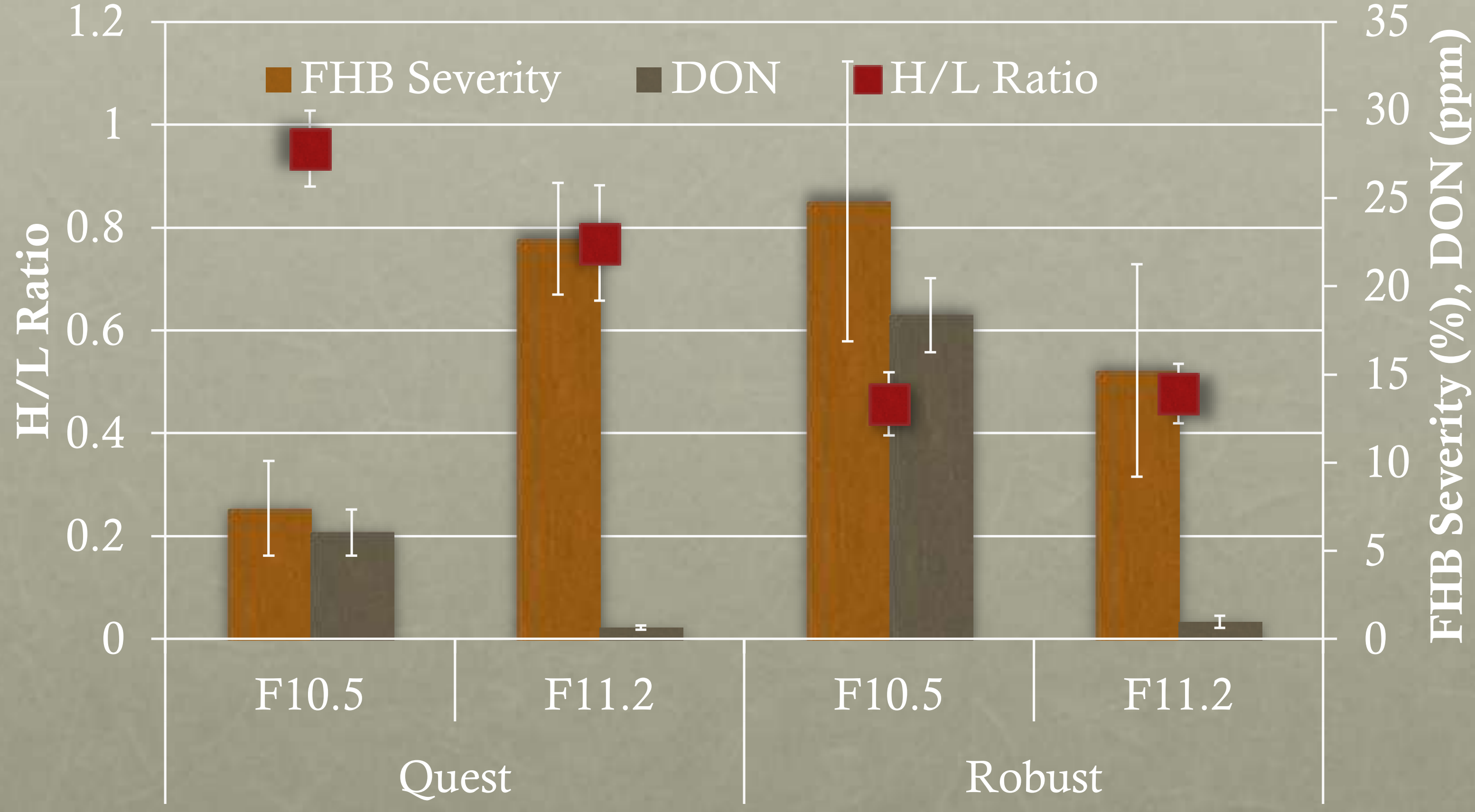
Methods
FDK & mycotoxins

- FDK assessment on head samples by counting scabby kernel in 100 random seeds (x 3)
- Harvest grain sample – FDK/VSK assessment on 25 g sample following to Mirocha et al (1998)
- Mycotoxin analyses in same samples - @ NDSU

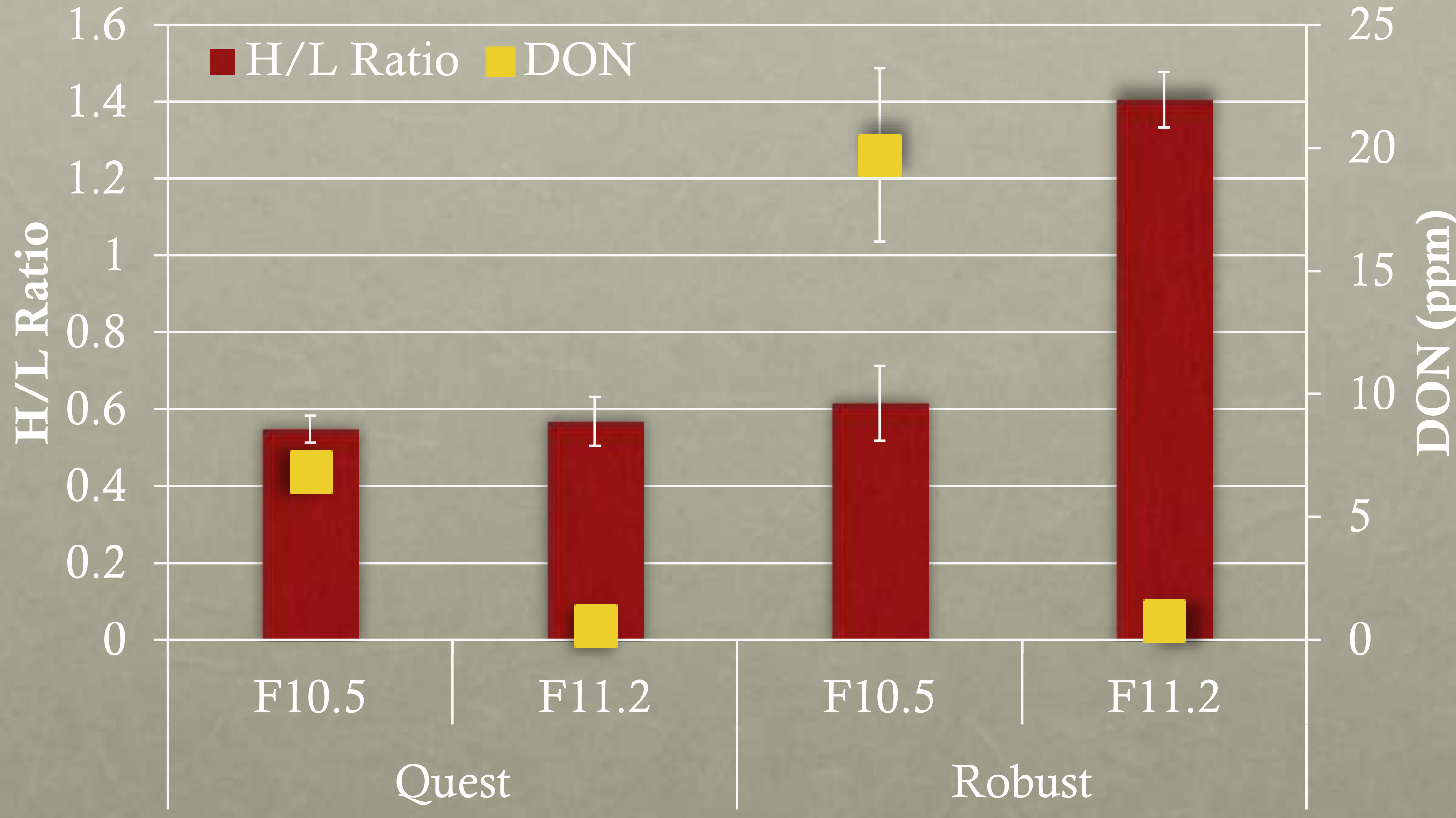
Methods
Barley H/L Ratio

- Wind speed 30 mph
- Heaviest (4) to lightest (1)
- H/L ratio = (3+4)/(1+2)

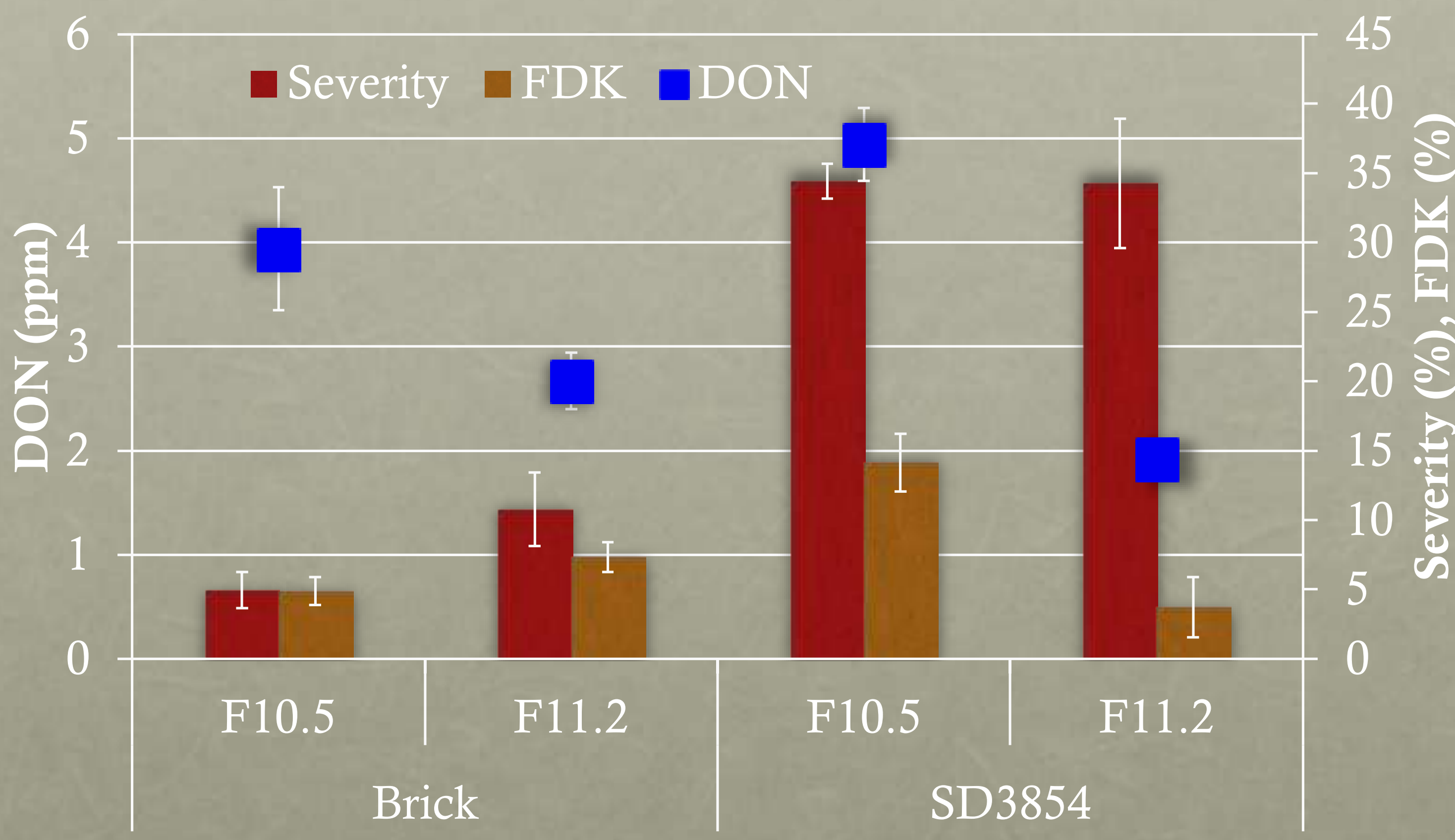
Results
Barley heads – H/L ratio & severity



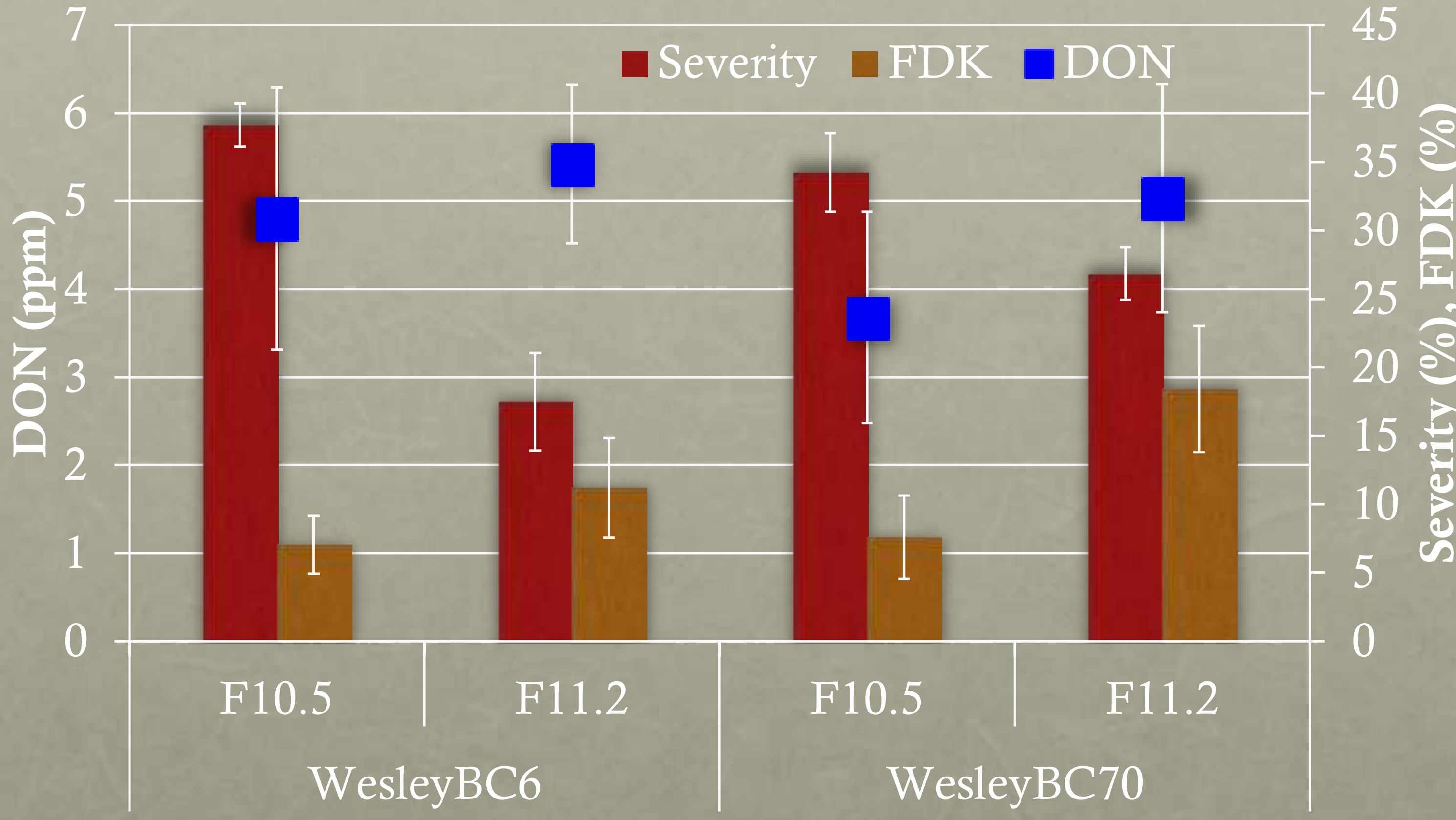
Results
Barley grains – H/L ratio & DON



Results
SW heads – Severity, FDK & DON



Results
WW heads – Severity, FDK & DON



Conclusion

- Tillers may not have higher contribution to total DON

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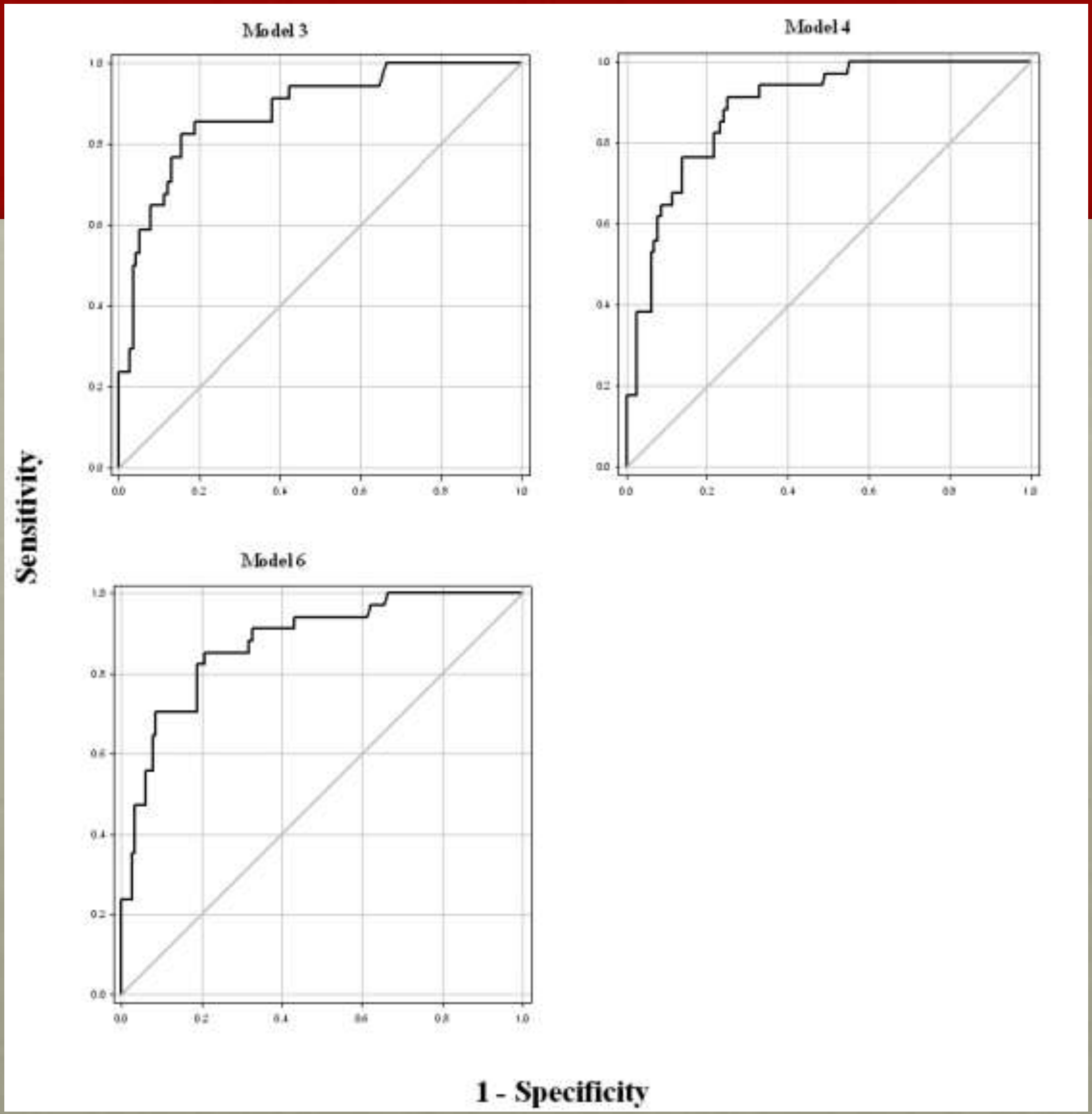
- C. Nelson (previously SDSU)

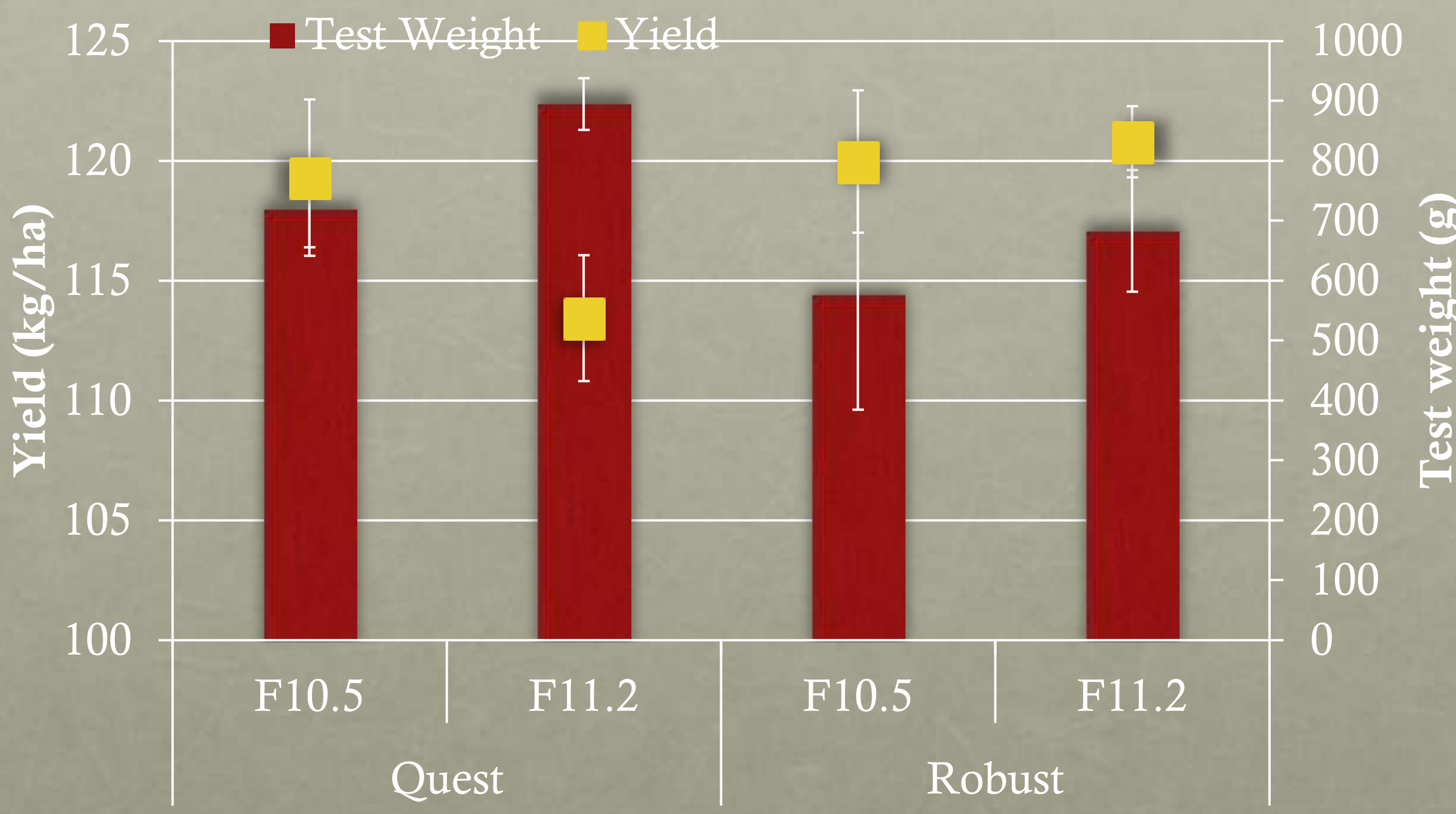
SDSU

US WHEAT AND BARLEY
SCAB INITIATIVE

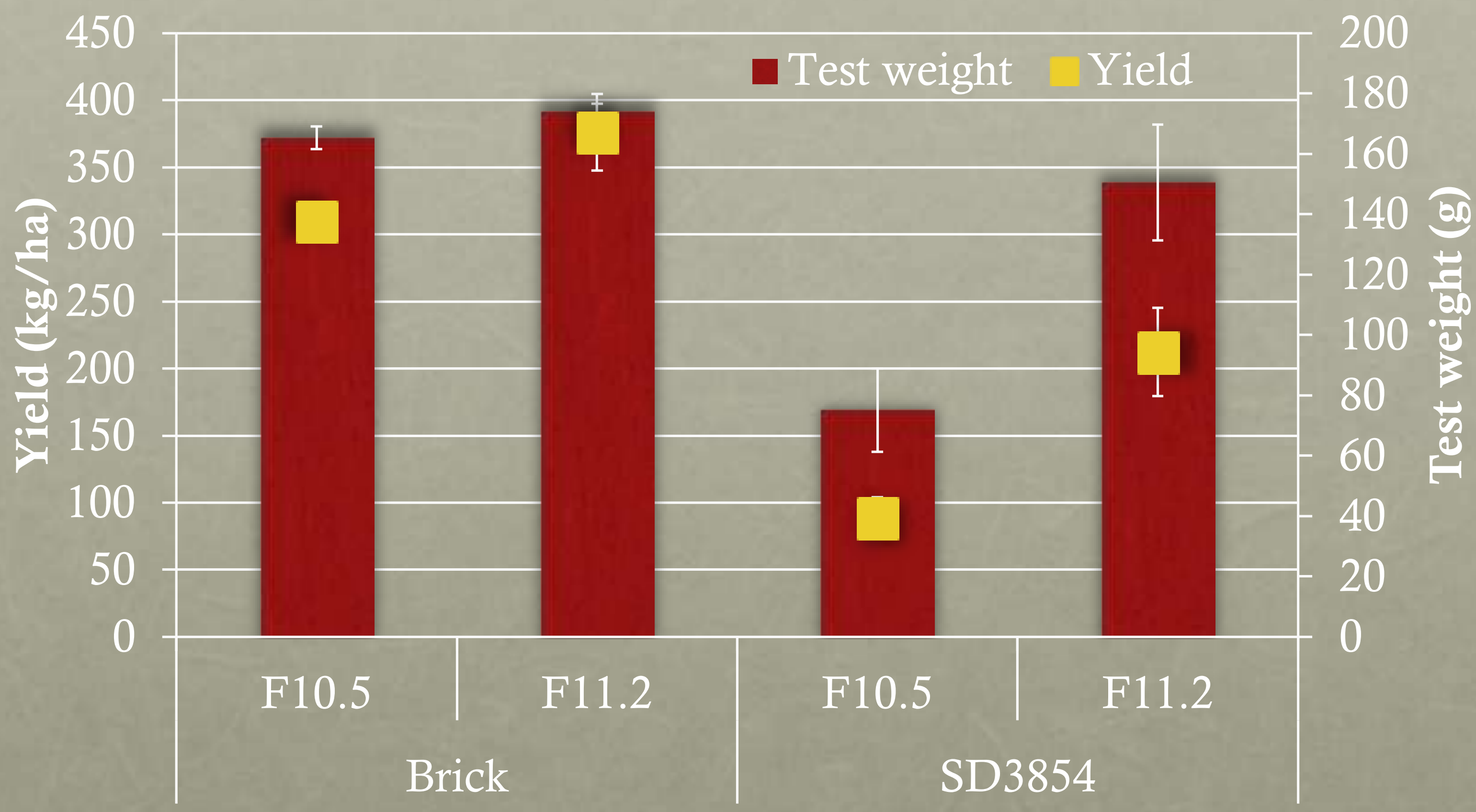


Receiver operating characteristic (ROC) curves for the logistic regression models 3, 4, and 6. Sensitivity (TPP) represents the proportion of true classification of positive eDON events and specificity (TNP) represents the proportion of true classification of negative eDON events.

Results
Barley grains – Test wt. & yield



Results
SW – Test wt. & yield



Results
WW – Test wt. & yield