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Economic Impacts of Fusarium Head Blight in Wheat and Barley: 1998-2000

William E. Nganje, D. Demcey Johnson, William W. Wilson,

F. Larry Leistritz, Dean A. Bangsund, and Napoleon M. Tiapo

Department of Agribusiness and Applied Economics ● Agricultural Experiment Station
North Dakota State University ● Fargo, ND 58105-5636

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Abstract

Fusarium Head Blight (FHB), commonly known as scab, has been a severe problem for wheat and barley producers since 1993. This study provides an update of economic losses suffered by wheat and barley producers in scab-affected regions in the United States. Emphasis is placed on estimating direct and secondary economic impacts of yield and price losses suffered by wheat and barley producers from 1998 to 2000. Nine states are included in the analysis for three wheat classes. Three of the nine states were also used for the analysis of malting and feed barley. The cumulative direct economic losses from FHB in hard red spring (HRS) wheat, soft red winter (SRW) wheat, durum wheat, and barley is estimated at $870 million from 1998 through 2000. The combined direct and secondary economic losses for all the crops were estimated at $2.7 billion. Two states, North Dakota and Minnesota, account for about 55 percent of the total dollar losses.

Key Words: Fusarium Head Blight, scab, vomitoxin, crop losses, wheat, barley

Highlights

This study provides an update of economic losses suffered by wheat and barley producers in scab-affected regions in the United States from 1998 through 2000. Wheat and barley producers in several states have experienced significant yield losses due to Fusarium Head Blight (FHB), or scab, since 1993. Losses have been especially severe in the spring wheat and barley regions, but soft red winter (SRW) wheat producers have also experienced major outbreaks. Three wheat classes, malting and feed barley were included in the analysis for nine states in the United States.

Losses were calculated as the decline in producer revenue due to FHB in affected crop districts. This entails estimating production losses (bushels) as well as the impact of FHB on net prices ($/bushel) received by producers. In principle, the price impact of FHB can be either positive or negative, as a production shortfall puts upward pressure on market prices while, on the other hand, a larger share of production may be discounted for poor quality. The average price received by producers in a given region can, therefore, be lower than normal despite favorable quoted prices for benchmark grades.

Production losses were estimated for each Crop Reporting District (CRD) by comparing actual yields to regression forecasts. Adjustments (based on input from extension specialists) were made to account for the contribution of other factors to yield shortfalls. The analysis also considered the impact of FHB on the ratio of harvested to planted acres. Price impacts were estimated for both futures and basis. Regression models were used to quantify the (positive) impact of FHB-related supply reductions on futures prices. Impacts on basis (either positive or negative) were measured by comparing actual basis values in a scab year to historical averages.

The direct combined effects of price discounts and yield reductions from FHB in hard red spring (HRS) wheat, SRW wheat, durum wheat, and barley were estimated at $870 million from 1998 through 2000. Direct economic losses over the period were greatest for SRW wheat ($333 million), followed closely by HRS wheat ($330 million). Losses for barley and durum wheat were estimated at $136 million and $70 million, respectively. Combined losses with the four crops were greatest in 1998 and decreased through 2000. Losses in 1998 accounted for over 50 percent of the three-year total.

Despite a substantial decrease in direct economic losses from FHB in 2000, cumulative economic effects over the period 1998 to 2000 were substantial. The commutative direct losses of $870 million represent a substantial loss in crop revenue for small grain producers in the affected areas. To put the losses in perspective, the three-year combined losses of $870 million would exceed the annual value of all barley and oats production in the United States in both 1999 and 2000–total value of barley and oats production in the United States was $766 million and $797 million in 1999 and 2000, respectively. The average value of all winter wheat production in the United States from 1998 through 2000 was about $4.2 billion. The average losses from FHB over the same period for all crops in this study was estimated at $290 million. Thus, annual losses from FHB represented, on average, 6.9 percent of the total value of all U.S. winter wheat production. When compared to the annual value of all wheat (spring, winter, durum, and other) production in the United States over the same period, annual losses from FHB represented 4.7 percent of the U.S. total.

The combined direct and secondary economic losses for all crops were estimated at $2.7 billion. North Dakota had $1 billion or about 41 percent of those losses during the 1998 to 2000 period. Losses in the other states were not as large, but substantial losses still occurred in Minnesota ($375 million), Ohio ($315 million), Illinois ($204 million), South Dakota ($183 million), and over $150 million each in Missouri and Michigan.

Scab is still a major economic problem, whether measured in relative terms to other crop sales or measured by overall direct and secondary economic impact. The scab problem is not limited to a narrow geographic region, hurting producers in both the northern Great Plains and central states. Scab continues to affect several classes of wheat and barley, constituting a serious economic problem in several regions of the United States.

Impacts from scab affect not only producers, but other areas of the economy as well. A substantial portion of the impacts affect the businesses that are dependent upon revenues from crop sales (for every $1 dollar of scab losses incurred by the producer, $2 in losses are incurred in other areas of rural and state economies). Depressed farm economies are further affected by scab. Scab occurs in many regions of the northern Great Plains that are not only reliant on agriculture, but are predominately dependent upon small grain production. Thus, scab is having an extenuating effect in those areas. Furthermore, income losses from scab are occurring during periods of depressed farm prices and low net farm income. (Net farm income has decreased significantly since 1996.)

The level of impacts (magnitude), the relative impact (comparisons to wheat/other small grain sales), and the geographic size of the problem all suggest that continued research into developing scab resistant varieties of wheat and barley is warranted. Clearly, several million dollars spent on scab research would be easily offset by future benefits of a reduction in scab losses.

Economic Impacts of Fusarium Head Blight in Wheat and Barley: 1998-2000

William E. Nganje, D. Demcey Johnson, William W. Wilson, F. Larry Leistritz, Dean A. Bangsund, and Napoleon M. Tiapo*

1. Introduction

Fusarium Head Blight (FHB), commonly known as scab, has been a severe problem for U.S. wheat and barley producers since 1993 (Johnson et al. 1998). Yield losses due to FHB have been widely reported.[1] Johnson et al. (1998) and the U.S. General Accounting Office (U.S. GAO 1999) quantified the economic losses suffered by producers in scab affected regions, from1993-1997 for wheat and barley, respectively. The objective of this study is to update the work of Johnson et al. and the U.S. GAO (1999) for 1998-2000 and, in addition, assess the secondary impact of losses incurred in other sectors of the economy.

The study focused on nine states where substantial FHB outbreaks have occurred during the 1990s, involving three wheat classes and barley. The affected states for hard red spring (HRS) wheat, durum wheat, and barley include Minnesota, North Dakota, and South Dakota. For soft red winter (SRW) wheat, the affected states include Illinois, Indiana, Kentucky, Michigan,[2] Missouri, and Ohio. In these states, major yield losses began in 1993 and continued through 2000.

Direct and secondary losses due to FHB per Crop Reporting District (CRD) for each wheat class and barley were estimated. Estimation of the direct impact (first-round effects) entails two quantities: first, the production (bushels) that might have been expected under normal conditions, and second, the price ($/bushel) that might have been expected under normal conditions. The 'price effects' of FHB are an important component of the analysis, as these can either magnify or reduce the value of economic losses in individual regions. Secondary impacts (sometimes further categorized into indirect and induced effects, also known as multiplier effects) result from subsequent rounds of spending and re-spending within an economy. An input-output model developed by Coon and Leistritz 2000 was used to estimate the secondary (multiplier) and total economic effects of FHB in the affected states.

The paper is organized into five sections including the introduction. Section 2 provides a brief explanation of the conceptual approach and delineates the 'price' and 'quantity' effects of FHB. Methodology and data sources are described in Section 3. Estimates of direct and

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*Nganje is an assistant professor, Johnson is the Director for the Small Grains Division at the USDA-ERS, Wilson and Leistritz are professors, Bangsund is research scientist, and Tiapo is research assistant in the Department of Agribusiness and Applied Economics, North Dakota State University, Fargo.

[1]See McMullen, Jones, and Gallenberg (1997) for an overview of FHB in small grains.

[2]Michigan also produces white wheat; however, this is not differentiated from SRW wheat in state-level price data.

secondary economic loss by state, year, wheat class, and barley are presented in Section 4. The paper concludes with a short summary and discussion of implications.

2. Illustration of Price and Quantity Effects

The following illustration of price and quantity effects is based on Johnson et al. (1998). To estimate the change in producer revenue due to FHB, it is not sufficient to know the size of a production shortfall; the impact on prices received must also be estimated. In principle, scab can either raise or lower the net price received by producers. This depends on two conflicting factors. On the one hand, a production shortfall puts upward pressure on futures prices and can lead to higher premiums for protein and other quality factors. On the other hand, in scab-affected areas, a larger share of production is discounted for poor quality. As a result, the price received by producers in a given region can be lower than normal despite favorable quoted prices for benchmark grades.

Figures 1 and 2 provide an illustration of the potential impacts of FHB on producer revenue. In Figure 1, it is assumed that the price received by producers is higher than normal as a result of FHB-related production shortfalls. Thus, ps > pn, where ps and pn are prices in 'scab' and 'normal' years. The production shortfall is measured by (qn − qs), where qn is normal production, based on planted acreage and trend yields, and qs is the actual production in a scab year. The change in producer revenue due to scab is given by

$$\Delta R = (ps \times qs) - (pn \times qn) \tag{1}$$

Producer revenue in a scab year is given by areas A + C, while producer revenue in a normal year is given by areas C + D. The change in revenue is A − D. Thus, producers would gain revenue if a positive price impact more than offset the value of lost production (i.e., if A > D).

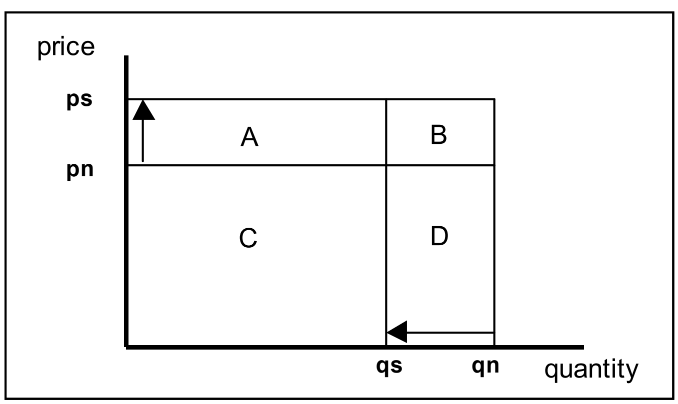

Figure 1. Change in Crop Value When Net Price Impact Is Positive

In Figure 2, it is assumed that the net price received by producers is lower than normal because of scab-related quality problems. Producer revenue in a scab year is given by area G, while producer revenue in a normal year is given by the area (E + F + G + H). The change in revenue is − (E + F + H), a negative amount. Producers lose two ways in this instance, from production shortfalls and lower prices.

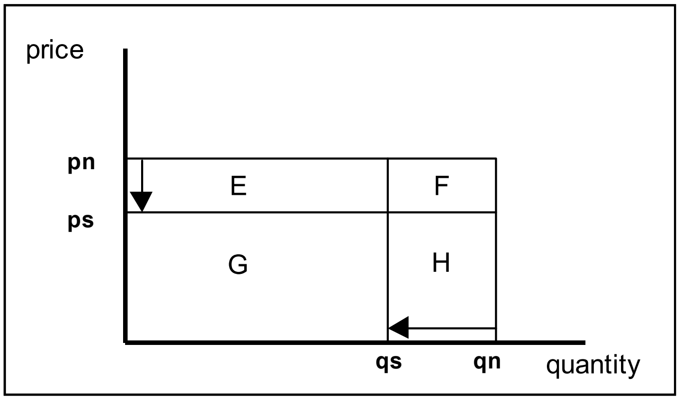

Figure 2. Change in Crop Value When Net Price Impact Is Negative

The revenue impact can be divided into separate price and quantity effects. Estimates of these effects vary, depending on whether actual prices (ps) or normal prices (pn) are used to value production shortfalls; the choice is somewhat arbitrary. In this study, we value production shortfalls as the average of the two prices. That is the area F in Figure 2 divided equally between price and quantity effects. Thus, the price effect equals − (E + ½F) while the quantity effect equals − (½F + H). Similarly, when the net price effect is positive as in Figure 1, it is measured as (A + ½B), while the quantity effect is − (½B + D).

3. Methodology and Data

Crop Reporting Districts (CRDs) where substantial FHB outbreaks occurred during the 1990s were identified with the help of researchers and extension specialists. The study area for SRW wheat, spring wheat, durum wheat, and barley are shown in Figures 3 and 4.

To estimate the economic losses due to FHB in a given CRD, the value of production under 'normal' conditions were estimated (i.e., if there had been no outbreak). Normal crop value is the product of two variables: pn, the price that farmers would have received, and qn, their expected production in absence of scab. For years of scab outbreak, both variables are unobserved and must be estimated. The lost crop value is then calculated as the difference between actual and normal crop value.

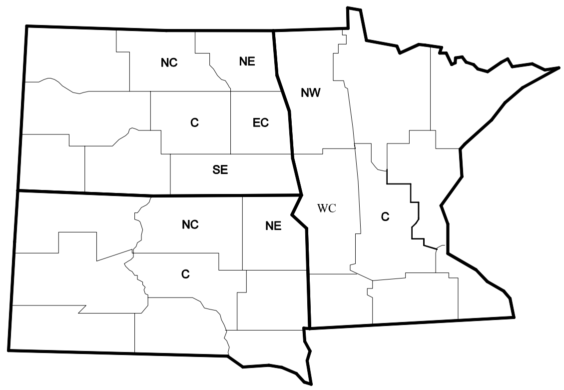

Figure 3. Crop Reporting Districts Included in HRS Wheat, Durum Wheat, and Barley Study Area

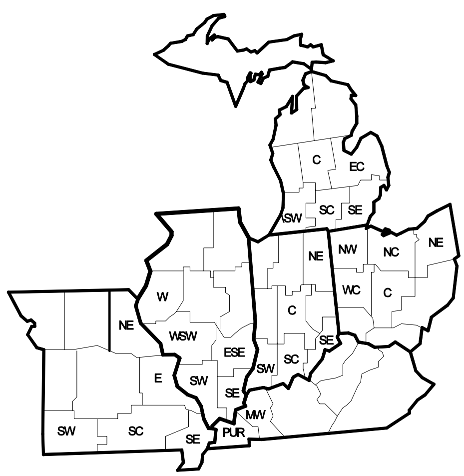

Figure 4. Crop Reporting Districts Included in Soft Red Winter Wheat Study Area

Estimating 'Normal' Production

The estimate of normal production has two components: yield and harvested acres. To derive yield in the absence of FHB, the following regression model was used:

$$y_{it} = \beta_0 + \beta_1 R_{it} + \beta_2 T_{it} + \beta_3 t \qquad (2)$$

where y_{it} is harvested yield in region i, R_{it} is rainfall inches received during the growing season,[3] T_{it} is average temperature during the growing season, and t is the year. The last parameter (β_3) is a measure of trend yield growth caused by changes in technology, input use, and farm size. Separate equations were estimated for each CRD, using data for years preceding severe FHB outbreak.[4] Results of estimated coefficients–βs and model fitness are shown in Appendix Tables A1 to A4. Regression models were then used to derive estimates of the yields that would have occurred in later years (given growing conditions) in the absence of FHB.

A complicating factor was that, in some producing regions, FHB occurred simultaneously with other wheat diseases or in conjunction with other factors reducing yields (e.g., floods). It would be misleading to attribute all of the estimated yield shortfall in these regions to FHB. For that reason, researchers and extension specialists provided input about the relative contribution of scab to yield shortfalls.[5] Their judgments were incorporated as follows. Let yn_{it} denote the normal yield in absence of FHB in production region i and year t. Let yf_{it} denote the forecast value from the regression equation and ys_{it} the actual yield in a scab-affected year. The fraction of a yield shortfall attributable to scab is denoted α_{it} $(0 \leq \alpha_{it} \leq 1)$. Normal yields (i.e., the estimated yields that would have occurred in the absence of FHB) are given by

$$yn_{it} = \alpha_{it} yf_{it} + (1 - \alpha_{it}) ys_{it} \qquad (3)$$

Normal yield is a weighted average of the regression forecast and actual yield. If $\alpha_{it} = 1$ for a given region and crop year, then normal yield equals the forecast value, and any estimated yield

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[3]For HRS and durum wheat growing areas, rainfall and temperature data are for April through July. For SRW wheat growing areas, these data are for March through June.

[4]Data from 1970-92 were used to estimate yield models for HRS, durum wheat, and barley. Data for 1970-90 were used for SRW yield models. A restricted and an unrestricted model were estimated for Equation 2. The unrestricted model incorporated a square precipitation term because there is an optimal level of precipitation, beyond which yields may decrease. However, only the barley model was unrestricted, Equation 2 was the robust model for HRS, durum, and SRW (Appendix Table A4).

[5]Input from extension experts for all CRDs were requested to obtain data on the difference between normal and actual production that was due to scab. For barley, this data is collected annually for North Dakota, Minnesota, and South Dakota by Dr. Paul Schwarz of the NDSU Cereal Science Department.

shortfall ($yf_{it} - ys_{it}$) is attributed entirely to FHB. If $\alpha_{it} < 1$, then normal yield lies between the regression forecast and actual yield, and part of the estimated yield shortfall is attributed to other factors. For example, suppose the yield forecast (yf_{it}) is 40 bu/acre, actual production (ys_{it}) is 28 bu/acre, but only 80 percent of the shortfall is attributed to FHB. The (adjusted) normal yield is then calculated as $yn_{it} = 0.8 \times (40) + (1 - 0.8) \times (28) = 37.6$ bu/acre.

Figure 5 shows actual yield, forecasted yield, and the (adjusted) normal yield for four CRDs included in the study. The lower right-hand and upper left-hand panels show durum yields in northeastern North Dakota (ND - NE) and SRW wheat yields in western Illinois (IL - W), respectively. In 1998 and 1999 in these CRDs, the 'predicted' and 'adjusted' yields coincide, hence, the estimated yield shortfalls are attributable to FHB ($\alpha_{it} = 1$). The upper right-hand panel shows HRS yields in northeastern North Dakota (ND - NE) where FHB accounted for a minuscule fraction of the shortfall in 1999 ($\alpha_{it} = .037$). Adjustment factors for all producing regions are provided in Appendix Table A5.

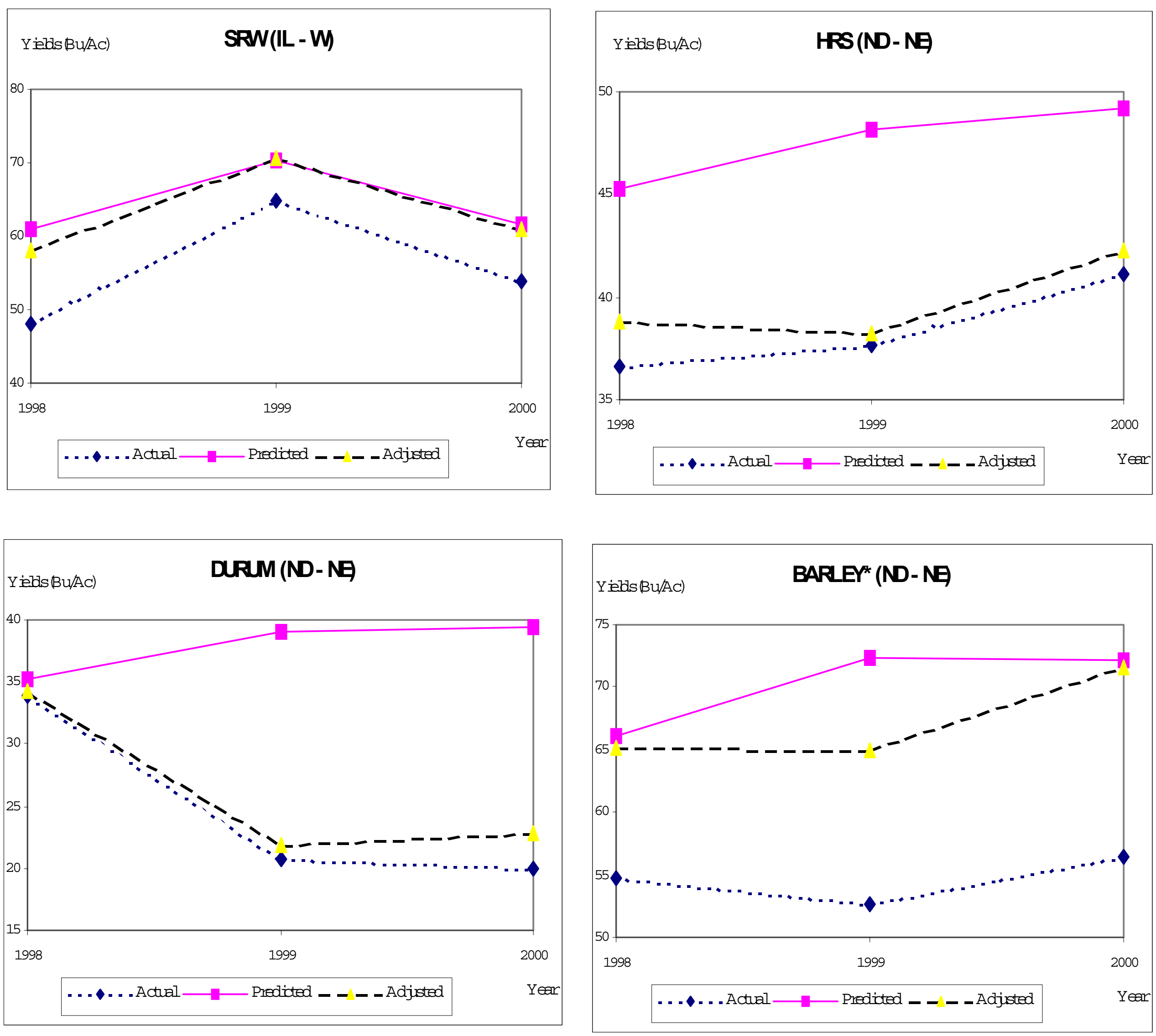

Figure 5. Predicted, Actual, and Adjusted Yields in Selected Crop Reporting Districts

FHB outbreaks can induce a higher-than-average rate of acreage abandonment. To account for this, a 'normal' ratio of harvested to planted acres was incorporated in the estimate of normal production. R_i represents the olympic average[6] of the ratio (ah_{it} / ap_{it}), where ah_{it} denotes harvested acres and ap_{it} planted acres, using data from seven years preceding the FHB outbreak. The 'normal' ratio (for region i, year t) is calculated as:

$$Rn_{it} = \alpha_{it} R_i + (1 - \alpha_{it}) \frac{ah_{it}}{ap_{it}} \tag{4}$$

Equation 4 uses the same adjustment factor as was used to calculate normal yield. If $\alpha_{it} = 1$ for a given region and year, then the 'normal' ratio of harvested to planted acres is equal to the olympic average. Otherwise, if $\alpha_{it} < 1$, the supposition is that factors other than FHB contributed to an abnormal ratio, and Rn_{it} is adjusted accordingly. Normal production, denoted qn_{it}, is given by the following formula:

$$qn_{it} = [\max(yn_{it}, ys_{it})] \cdot [\max(Rn_{it}, \frac{ah_{it}}{ap_{it}})] \cdot ap_{it} \tag{5}$$

The first bracketed term represents harvested yield. The second bracketed term is the ratio of harvested-to-planted acres. The product of the second term and acres planted (ap_{it}) equals normal harvested acres. The max function is used to correct for two types of data anomalies. If the estimated normal yield falls below actual yield in a scab year, (i.e., $yn_{it} < ys_{it}$), the latter value is selected. Similarly, if the normal ratio falls below the actual ratio of harvested-to-planted acres, (i.e., $Rn_{it} < [ah_{it} / ap_{it}]$), the latter value is used. Thus, in the unlikely event that production is higher than normal during a scab year, the analysis will not (falsely) attribute a positive impact to the disease.

Estimating Price Impacts for HRS, SRW, and Durum Wheat

In estimating the impact of FHB on the net price received by producers, two factors were considered. First, the impact of a production shortfall on market prices was estimated. Second, the effects of crop quality on prices were considered. To capture these effects, the average price received was divided into futures and basis.[7] While an FHB outbreak is expected to have a positive impact on futures (by reducing wheat supply), the impact on local basis (averaged over all wheat sold) can be either positive or negative, depending on crop quality and the premiums and discounts assessed by elevators in a given region.

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[6]An olympic average omits the maximum and minimum values contained in a given sample. Olympic averages are advantageous when the sample is small and select observations (e.g., 1988, a drought year) are viewed as exceptional or unrepresentative.

[7]Basis is defined as the difference between a local cash price and the futures price, for the same commodity. As used here, basis refers to the difference between weighted average cash price received (net of premiums and discounts) and average futures price, during a marketing year.

SRW wheat is generally priced with respect to wheat futures on the Chicago Board of Trade (CBT). To derive the price impact of FHB on CBT wheat futures, a regression equation was used. The regression analysis explains the CBT futures price as a function of total wheat supply and the loan rate (a farm program parameter), using annual data from 1980 through 1999. The estimated equation follows, with t-ratios in parentheses:

LCBT =	13.250	− 1.004 LTWS	+ 0.211 LLR	R^2 = .67
	(8.996)*	(−4.004)*	(2.116)*	Obs. 20

* significant at 1% level

Variables are defined as:

LCBT	logarithm of average CBT wheat futures price (c/bu), nearby contracts
LTWS	logarithm of total U.S. wheat supply (million bu), all classes
LLR	logarithm of loan rate for wheat (c/bu) in given marketing year.

The coefficient of interest is a factor that associates future prices with total wheat supply (otherwise known as the 'flexibility' coefficient). For example, a 1 percent change in total wheat supply would change the CBT price by 1.004 percent (in the opposite direction).

A similar equation was estimated for wheat futures on the Minneapolis Grain Exchange (MGE), which provides the standard reference for pricing of HRS wheat. In this case, HRS supply (in place of total wheat supply) was used as an explanatory variable. For MGE futures, the estimated equation follows, with t-ratios in parentheses:

LMGE =	9.115	− 0.836 LHRS	+ 0.112 LLR	R^2 = .59
	(7.121)*	(−4.055)*	(2.334)**	Obs. 20

* significant at 1% level
** significant at 5%

Variables are defined as:

LMGE	logarithm of average MGE wheat futures price (c/bu), nearby contracts
LHRS	logarithm of HRS wheat supply (million bu)
LLR	logarithm of loan rate for wheat (c/bu) in given marketing year.

The 'flexibility' coefficient is −0.836, indicating that a 1 percent change in the supply of HRS wheat is expected to change the MGE futures price by 0.836 percent in the opposite direction.

Adjustment for Imports

If U.S. wheat supplies were determined solely by domestic production and beginning stocks, the change in supplies due to scab would be equal to the sum of estimated production shortfalls in affected CRDs. However, imports of wheat from Canada represent another component of U.S. supply. Canada is a large surplus producer of spring wheat (HRS[8] and durum), and the surge in U.S. imports since 1993 is partly explained by disease problems in the U.S. spring wheat region (Johnson et al. 1998). Higher imports offset part of U.S. production shortfalls, thereby changing U.S. supply and reducing the positive impact of U.S. production shortfalls on futures prices.

To account for the imports induced by scab, it was assumed that 20 million bushels of HRS wheat would be imported annually from Canada under ordinary conditions, which is the average level of HRS imports during the three marketing years preceding 1993. Imports of HRS and durum wheat were larger than estimated production shortfalls due to scab in all three years–1988-2000 (Table 1). Of the imports exceeding 20 million bushels, the part that is attributed to scab is reflected in the following formula for expected HRS supply in absence of a scab outbreak:

$$Qn_t^{HRS} = Qs_t^{HRS} + \delta_t^{HRS} - \min[\theta_t^{HRS}(M_t^{HRS} - 20)\ ,\ \theta_t^{HRS}\delta_t^{HRS}] \qquad (6)$$

where variables are defined

Qn_t^{HRS}	hypothetical supply (million bushels) of HRS wheat in absence of scab outbreak
Qs_t^{HRS}	actual supply of HRS during year of scab outbreak
δ_t^{HRS}	estimated U.S. production shortfall of HRS wheat due to scab
θ_t^{HRS}	proportion of production losses due to scab, a weighted average of adjustment factors α_{it} in HRS regions[9]
M_t^{HRS}	actual imports of HRS wheat.

Table 1. Imports From Canada and Estimated U.S. Production Losses from Fusarium Head Blight, HRS and Durum

	Imports from Canada (million bu)		Estimated U.S. Production Losses (million bu)		Ratio of Imports to Losses	
Marketing Year	HRS Wheat	Durum Wheat	HRS Wheat	Durum Wheat	HRS Wheat	Durum Wheat
1998	58.2	25.9	8.4	0.7	6.9	36.0
1999	54.5	23.7	6.8	4.0	8.0	6.0
2000	52.0	25.1	12.4	4.6	4.2	5.5

[8]HRS is a U.S. classification; the comparable Canadian wheat classification is Canadian Western Red Spring (CWRS).

[9]For 1998-2000, values of θ_t^{HRS} are 0.5317, 0.112, and 0.2092.

The quantity selected by the min function (Equation 6) represents imports attributable to scab, partially offsetting the impact of a production loss on U.S. HRS supply. The hypothetical supply of all wheat in absence of scab, Qn_t^{ALL}, is calculated as:

$$Qn_t^{ALL} = Qs_t^{ALL} + (Qn_t^{HRS} - Qs_t^{HRS}) + \delta_t^{SRW} \tag{7}$$

where Qs_t^{ALL} is the actual U.S. supply of all wheat classes and δ_t^{SRW} is the estimated SRW production shortfall due to scab. Note that Qn_t^{ALL} reflects the production shortfall for SRW and supply reduction for HRS; it does not reflect reduced durum production. Based on recent history, any lost U.S. durum production was assumed to be entirely offset by imports from Canada.

Impacts on Wheat Futures and Basis

Given the flexibility coefficients and supply estimates, the futures prices that would have been observed in the absence of a scab outbreak are estimated as follows:[10]

$$Fn_t^j = \frac{Fs_t^j}{\gamma_j \left(\dfrac{Qs_t^j - Qn_t^j}{Qn_t^j} \right) + 1} \tag{8}$$

where j indicates the futures exchange (MGE or CBT) or appropriate supply category, and variables are defined:

γ_j price flexibility coefficient (for indicated futures supply category)
Qs_t^j actual wheat supply (HRS wheat for MGE futures, all wheat classes for CBT)
Qn_t^j estimated supply in absence of scab outbreak
Fs_t^j futures price (annual average, nearby contracts) in a scab year
Fn_t^j estimated futures price in absence of scab outbreak.

For SRW wheat growing regions, basis is defined as the difference between the average price received by producers and the average CBT futures. For HRS growing regions, basis is the difference between average price received and average MGE futures. Normal basis relationships for these wheat classes are represented by seven-year olympic averages, using data from years preceding the first scab outbreak.

Durum wheat was not traded on any futures exchange during the period under study. However, a long-term relationship has been observed between durum and spring wheat cash

[10]The price flexibility coefficient is defined: $\gamma = (\Delta P/P)/ (\Delta Q/Q)$. The formula is derived by substituting (Fs − Fn)/Fn for the numerator, (Qs − Qn)/Qn for the denominator, and re-arranging to solve for Fn.

prices–durum tends to trade at about 50 cents/bushel above the spring wheat price.[11] The long-term price relationship between durum and HRS was built into the estimate of the 'normal' cash price for durum.

Expected cash prices in absence of scab are calculated as follows:

$$\begin{aligned} \text{SRW:} \quad & pn_{it}^{SRW} = Fn_t^{C} + bn_i^{C} \\ \text{HRS:} \quad & pn_{it}^{HRS} = Fn_t^{M} + bn_i^{M} \\ \text{Durum:} \quad & pn_{it}^{D} = Fn_t^{M} + bn_i^{M} + 0.50 \end{aligned} \tag{9}$$

where variables are defined:

- pn_{it} normal (expected) cash price in absence of scab for indicated wheat class
- Fn_t^C Chicago wheat futures price (annual average)
- Fn_t^M Minneapolis spring wheat futures price (annual average)
- bn_i^C normal (olympic average) SRW basis relative to CBT futures
- bn_i^M normal (olympic average) HRS basis relative to MGE futures.

The analysis allows estimated basis effects to be either positive or negative in individual regions. Positive basis effects could arise because of large price premiums, induced by supply shortages, for wheat that meets milling specifications. Conversely, negative basis effects could result if quality-related price discounts apply to a larger-than-average portion of local production.

Estimating Price Impacts for Malting and Feed Barley

In estimating the impact of FHB on the net price received by barley producers, two factors were considered–the impact on malting premium price, and the impact on feed grain prices.[12] The procedure to estimate both malting barley premiums and feed grain prices for 1998 through 2000, had there been no FHB, uses two steps (U.S. GAO 1999)–step one involves estimating price equations for both malting barley premiums and feed prices in the absence of scab, while step two involves predicting the malting and feed barley prices that should have been obtained in the absence of the FHB epidemic.[13]

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[11]Approximately a 50 cents/bushel price premium is necessary to induce farmers to plant durum instead of HRS wheat, given differences in yield and risk factors.

[12] The U.S. GAO procedure was used to estimate the impact of FHB on malting premium price and feed barley price because it incorporates the proportion of malting and feed barley production in the absence of FHB. These proportions were necessary to estimate the shift of malting barley to feed barley due to FHB.

[13]Appendix Tables A6 and A7 provide regression equations for the CRDs in North Dakota.

In step one, regression analysis and historical data on price and production from 1959 through 1992 was used. Since the proportion of malting barley in the entire crop was fairly stable in the years prior to the FHB epidemic, increases in total barley production translate into increases in the quantities of malting barley. Moreover, while there are differences in premiums from region to region, prices are generally transmitted from the malting and brewing industries at a more aggregate market level. Therefore, in Equation 10, the historical association between malting premiums, Pj^m, and total U. S. barley production, Q_j, for each CRD analyzed were estimated.

$$P_j^m = \alpha_0 + \alpha_1 Q_j \tag{10}$$

A negative and statistically significant association exists between malting premiums and total barley production at the national level for all CRDs (Appendix Table A1). Other variations of this regression model, including those using combinations of stocks as well as barley yields for independent variables, did not perform as well as the total barley production variable. Because of the presence of positive serial correlation in all CRDS, the Yule-Walker[14] regression technique is used to derive the parameter estimates. In general, serial correlation causes standard errors to be biased downward, thus indicating that parameter estimates are more precise than indicated. Therefore, correcting this problem leads to more efficient parameter estimates.

In the feed grain market, corn is the primary feed grain product accounting for more than 80 percent of total feed grain consumption (U.S. GAO 1999). Because barley feed grain prices, P_i^f, are driven primarily by corn prices, in Equation 11, the historical association between feed grain barley prices, the price of corn, P_C, and total U.S. barley production, Q_j, was specified as:

$$P_j^f = \alpha_0 + \alpha_1 P_c + \alpha_2 Q_j \tag{11}$$

To correct for first-order serial correlation, as in the malting premium regression models, the Yule-Walker regression technique was used for the feed grain models. The total barley production variable for North Dakota was negative and significant at the 0.10 percent level in all CRDS except 6 (Appendix Table A6). In all CRDS, the price of corn was positively related to barley feed grain prices and statistically significant (Appendix Table A7).

The second step involved substituting actual values of barley production and corn prices for years 1998 through 2000, in Equations 10 and 11, to predict what malting barley and feed grain barley prices would have been in the absence of FHB. Malting barley prices were assumed to be the sum of estimated feed grain prices plus estimated malting premiums. The malting barley and feed grain barley price effects as a result of FHB were obtained by subtracting the actual prices from the estimated prices in the absence of scab.

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[14]The Yule-Walker regression technique starts by forming the ordinary least-square estimate of parameters. Next, given the vector of auto-regressive parameters (using the Yule-Walker equations) and the variance matrix of the error vector, efficient estimates of the regression parameters are computed using generalized least squares.

Estimating Direct and Secondary Revenue Losses Due to FHB

Economic activity from a project, program, policy, or event can be categorized into direct and secondary impacts. Direct impacts are those changes in output, employment, or income that represent the initial or first-round effects of the activity. Secondary impacts (sometimes further categorized into indirect and induced effects, also known as multiplier effects) result from subsequent rounds of spending and re-spending within an economy.

In estimating the direct economic losses, production shortfalls were multiplied by the average of the actual and estimated price (price that would have been observed in the absence of scab) to obtain the production losses due to FHB for each CRD and for each year (1998-2000). To obtain the revenue shortfall from price effect, the price difference (estimated price if there were no FHB, less actual price) was multiplied by the average of the actual production and the estimated production if there were no FHB.

The secondary economic effects were estimated using input-output (I-O) analysis. I-O analysis is a mathematical tool that traces linkages among sectors[15] of an economy and calculates the total business activity resulting from a direct impact in a basic sector (Coon et al. 1985). The North Dakota I-O Model was used to estimate the secondary (multiplier) and total economic effects in the affected states. Empirical testing has shown the North Dakota I-O Model is sufficiently accurate in estimating economic impacts in neighboring states (Coon and Leistritz 1994; Coon et al. 1984; Leistritz et al. 1990). The model was assumed to also be sufficiently accurate to estimate regional economic losses stemming from FHB in the central United States.

The North Dakota I-O Model has 17 economic sectors, is closed with respect to households (households are included within the model), and was developed from primary (survey) data from firms and households in North Dakota (Coon and Leistritz 2000). The model's transactions table (and the resulting technical coefficients and interdependence coefficients) reflect purchases made by firms in each sector from other sectors within North Dakota. Thus, imports of goods and services are not included in the transactions table and resultant coefficients.

The North Dakota I-O Model has two features which merit special comment. First, the model is closed with respect to households; households are included in the model as both a producing and a consuming sector. Second, the total gross business volume (gross receipts) of trade sectors was used (for both expenditures and receipts) in the transactions tables rather than the value added (margins) by those sectors. This procedure results in larger activity levels for those sectors than would be obtained if the margins were used, but this is offset by correspondingly larger levels of expenditures outside the region (state) by those sectors for goods purchased for resale. The advantage of this procedure is that the results of the analysis are expressed in terms of the gross business volumes of the respective sectors, which is generally more meaningful to most users.

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[15]An economic sector is a group of similar economic units (e.g., communications and public utilities, retail trade, construction).

Data Sources

Data on temperature and precipitation by region were obtained from the National Climatic Data Center (U.S. Department of Commerce). Data on planted and harvested acres, harvested yield, production, and average prices received by producers were obtained from the National Agricultural Statistics Service (U.S. Department of Agriculture). Average CBT and MGE futures prices were derived from a database of weekly quotes collected from *Grain Market News* (U.S. Department of Agriculture) and the *Wall Street Journal*. Basis was calculated as the difference between average price received in a region and the average futures price. For North Dakota, prices received were available by crop reporting district; in other states, prices are based on state averages.[16] Prices for the 2000 marketing year were based on data available through February, 2001. Data on national wheat and barley supplies were from the *Wheat Yearbook* published by the Economic Research Service of the U.S. Department of Agriculture.

4. Results

Production Losses Due to FHB

Production losses due to FHB, by state, wheat class, and barley were estimated (Table 2). Aggregate losses for wheat and barley were largest in 2000, followed by 1998 and 1999. Of the total estimated losses, for all wheat classes (47.8 million bushels), HRS wheat accounted for 27.6 million bushels. During the entire period (1998-2000), HRS wheat growers incurred the greatest loss, 57.6 percent; followed by SRW wheat, 23.1 percent; and durum, 20.2 percent. North Dakota and Minnesota incurred the largest losses for all wheat classes combined, 76.2 percent.

Of the total estimated losses, for malting and feed barley (42.8 million bushels), North Dakota incurred 70.1 percent, Minnesota incurred 29.3 percent, and South Dakota incurred less than one percent (0.6%) of the losses.

Price impacts, future and basis effects also account for significant losses due to FHB. Price impacts must be incorporated in an effective economic impact study. The proceeding section on price effects presents the results of the economic losses due to futures or market price and price discounts.

Price Effect Due to FHB

Table 3 presents the estimated price effects, on future and basis for all wheat classes and malting/feed barley. Although FHB caused futures price to increase for wheat (decrease losses), the basis effects are negative for all wheat classes and years except for SRW in Illinois and Kentucky in year 2000. However, the aggregate price effects for all wheat classes were negative. The positive price effect for SRW wheat estimated for 2000 draws attention to what

[16]State average prices were used for North Dakota CRDs in 2000, as more detailed information was not yet available.

may be termed an 'aggregation problem.' The analysis used CRD-level production data and CRD or state-level price data to derive the economic losses suffered by producers. Data at this level of aggregation do not convey the severity of losses for individual producers whose yields and prices were lower than average. Moreover, in some CRDs where producers benefitted (on average) from higher prices, scab-related production losses were fairly small or localized.

Table 2. Production Losses Due to Fusarium Head Blight by State, Crop, and Year

State/Crop	Year			
	1998	1999	2000	Total
	-- 000 bu --			
	HRS			
ND	4,767.44	2,664.79	8,549.01	15,981.26
MN	3,381.36	4,119.48	3,719.16	11,220
SD	244.08	0.00	108.18	352.26
Total HRS	8,392.88	6,784.27	12,376.37	27,553.52
	Durum			
ND	706.56	3,942.64	4,556.92	9,206.12
MN	12.14	15.84	1.42	29.40
SD	-	-	-	-
Total Durum	718.70	3,958.48	4,558.34	9,235.52
	SRW			
IL	2,111.89	226.99	449.78	2,788.65
IN	583.10	189.92	204.49	977.51
KY	306.52	352.03	725.39	1,383.93
MI	2,302.22	496.13	656.71	3,455.07
MO	286.64	138.78	599.27	1,024.67
OH	1,307.47	109.13	0	1,416.60
Total SRW	6,897.84	1,512.98	2,635.64	11,046.45
	All Classes of Wheat			
Total	16,009.42	12,255.72	19,570.35	47,835.48
	Barley			
ND	8,134.51	7,975.05	13,886.81	29,996.37
MN	7,679.00	2,373.04	2,490.10	12,542.14
SD	180.29	62.07	22,39	264.75
Total Barley	15,993.80	10,410.16	16,399.30	42,803.26

Table 3. Price Effect for Wheat and Barley in Fusarium Head Blight Affected Regions

Price Effect for HRS							
	ND-NC	ND-NE	ND-C	ND-EC	ND-SE	MN	SD
Year	Futures Price Effect (cents/bu) (Actual futures less estimated normal price)						
1998	1.97	5.28	2.60	4.53	3.33	5.23	2.38
1999	1.04	4.97	2.14	3.80	2.83	5.13	2.16
2000	2.13	6.37	2.73	4.78	3.65	6.81	2.34
	Basis Effect (cents/bu) (Actual futures less estimated normal price)						
1998	-61.03	-43.72	-43.40	-42.47	-70.67	-42.77	-55.62
1999	-53.95	-40.03	-37.86	-38.20	-55.17	-40.87	-56.84
2000	-21.87	-17.63	-21.27	-19.22	-20.35	-7.19	-21.66
	Total Price Effect (cents/bu) (Actual futures less estimated normal price)						
1998	-59.07	-38.45	-40.8	-37.95	-67.34	-37.54	-53.24
1999	-52.91	-35.07	-35.72	-34.41	-52.34	-35.74	-54.68
2000	-19.75	-11.26	-18.54	-14.43	-16.7	-0.38	-19.33
Price Effect for Durum							
	ND-NC	ND-NE	ND-C	ND-EC	ND-SE	MN	
Year	Futures Price Effect (cents/bu) (Actual futures less estimated normal price)						
1998	1.51	1.37	0.60	0.32	0.32	0.26	
1999	0.67	1.43	0.61	0.52	0.29	0.12	
2000	1.20	1.26	0.41	0.30	0.30	0.27	
	Basis Effect (cents/bu) (Actual futures less estimated normal price)						
1998	-89.49	-69.63	-55.40	-52.68	-52.68	-56.74	
1999	-70.33	-106.57	-15.39	-86.48	-48.71	-95.89	
2000	-42.80	-42.74	-43.59	-43.70	-43.70	-18.73	
	Total Price Effect (cents/bu)						
1998	-87.99	-68.23	-54.80	-52.36	-52.36	-56.48	
1999	-69.65	-105.14	-14.79	-85.97	-48.43	-95.78	
2000	-41.60	-41.47	-43.18	-43.40	-43.39	-18.47	

Table 3. Continued

Price Effect for SRW							
	IL	IN	KY	MI	MO	OH	
Year	Futures Price Effect (cents/bu) (Actual futures less estimated normal price)						
1998	1.67	1.79	1.60	1.16	1.63	2.36	
1999	1.74	0.93	1.45	1.36	1.83	2.17	
2000	1.66	1.12	1.52	1.35	2.00	2.52	
	Basis Effect (cents/bu) (Actual futures less estimated normal price)						
1998	-89.88	-91.79	-101.35	-94.77	-110.37	-100.59	
1999	-33.70	-32.51	-26.00	-33.08	-28.21	-43.27	
2000	-0.30	-9.85	-0.44	-9.61	-10.00	-9.44	
	Total Price Effect (cents/bu)						
1998	-88.22	-90.79	-99.74	-93.62	-108.74	-98.23	
1999	-31.97	-31.58	-24.54	-31.72	-26.39	-41.10	
2000	1.37	-8.75	1.08	-8.26	-8.00	-6.92	
Price Effect for Barley							
Malting Premium Price Effects							
	ND-NC	ND-NE	ND-C	ND-EC	ND-SE	MN	SD
1998	-20.60	-30.46	-14.88	-26.86	-5.60	-29.00	-25.75
1999	-13.24	-20.91	-15.00	-22.89	-20.31	-13.00	*
2000	-27.19	-35.30	-25.38	-31.43	-15.36	-22.00	*
Feed Barley Price Effects							
1998	-41.00	-41.00	*	-41.00	*	-41.00	*
1999	*	-50.00	*	-50.00	*	-50.00	*
2000	*	-45.00	-45.00	45.00	*	-45.00	*
Total Price Effect (cents/bu)							
1998	-41.60	-71.46	-14.88	-67.86	-5.60	-70.00	-25.75
1999	-13.24	-70.91	-15.00	-72.89	-20.31	-63.00	*
2000	-27.19	-80.30	-70.38	-76.43	-15.36	-67.00	*

*implies insignificant price effect

Estimates of economic loss are affected, unavoidably, by the inclusion of positive price effects for all crops sold in a CRD–even crops sold by producers who suffered no yield losses. Low impact on futures price may be due partly to imports from Canada that exceed the yield shortfall.

Price impacts on malting barley premiums and feed barley are negative and substantial. Aggregate price effects for barley range from 0 to 80.3 cents/bushel for some CRDs and years. Quality shortfall due to FHB remains a major source of loss for barley producers.

<u>Revenue Losses: Direct and Secondary Impact Due to FHB</u>

FHB affects small grain producers through price discounts and yield reductions on HRS wheat, SRW wheat, durum wheat, and barley. The combined effects of price discounts and yield reductions represent a loss of revenue to small grain producers and also represent direct economic losses to regional economies. The direct revenue losses for each crop and state are discussed in this section.

Hard Red Spring Wheat

Yield reductions and price discounts from FHB in HRS wheat were estimated at $330 million in North Dakota, Minnesota, and South Dakota from 1998 through 2000 (Table 4). In North Dakota, Minnesota, and South Dakota, reductions in price accounted for about 75 percent of the direct losses associated with FHB in HRS wheat. Total direct losses were greatest in North Dakota ($182 million), followed by Minnesota ($89 million) and South Dakota ($59 million). Direct losses in the three states decreased annually from 1998 to 2000. Of the total losses over the period, about 44 percent ($144 million) occurred in 1998, with only 21 percent ($97 million) occurring in 2000.

Table 4. Direct Economic Impacts from Fusarium Head Blight in Hard Red Spring Wheat in the Northern Great Plains, 1998 through 2000

State	Economic Effect	1998	1999	2000	Total 1998-2000
		----------------------- 000s $	----------------------------		
ND	Production Loss	14,442	7,657	25,220	47,319
	Price Effect	66,315	45,662	23,558	135,535
	Total	80,757	53,319	48,778	182,854
MN	Production Loss	10,448	11,864	11,343	33,655
	Price Effect	28,156	26,598	343	55,097
	Total	38,604	38,462	11,686	88,752
SD	Production Loss	730	0	319	1,049
	Price Effect	24,046	24,927	8,830	57,803
	Total	24,776	24,927	9,149	58,852
All States	Production Loss	25,620	19,521	36,882	82,023
	Price Effect	118,517	97,187	32,731	248,435
	Total	144,137	116,708	69,613	330,458

Durum Wheat

Yield reductions and price discounts from FHB in durum wheat were estimated at $70 million in North Dakota and Minnesota from 1998 through 2000 (Table 5). Price reductions accounted for 65 percent of the direct losses. The economic losses from FHB in durum wheat were limited primarily to North Dakota. Losses in North Dakota represented 99 percent of the two-state total. Annual direct losses in North Dakota were similar across the period.

Table 5. Direct Economic Impacts from Fusarium Head Blight in Durum Wheat in the Northern Great Plains, 1998 through 2000

State	Economic Effect	1998	1999	2000	Total 1998-2000
		------------------------------- 000s $ -------------------------- -			
ND	Production Loss	1,979	10,059	12,532	24,570
	Price Effect	18,396	18,685	8,352	45,433
	Total	20,375	28,744	20,884	70,003
MN	Production Loss	36	38	5	79
	Price Effect	104	153	13	270
	Total	140	191	18	349
All States	Production Loss	2,015	10,097	12,537	24,649
	Price Effect	18,500	18,838	8,365	45,703
	Total	20,515	28,935	20,902	70,352

Soft Red Winter Wheat

Yield reductions and price discounts from FHB in SRW wheat were estimated at $333 million in Illinois, Indiana, Kentucky, Michigan, Missouri, and Ohio from 1998 through 2000 (Table 6). In the affected states, reductions in price accounted for 93 percent of the direct losses. Total direct losses over the period were greatest in Ohio ($102 million), followed by Illinois ($66 million), Kentucky, Michigan, and Missouri ($51 million each), and Indiana ($34 million). Direct losses in the SRW wheat producing states decreased annually from 1998 to 2000. Of the total losses over the period, about 70 percent ($235 million) occurred in 1998, with only 5 percent ($17 million) occurring in 2000.

Table 6. Direct Economic Impacts from Fusarium Head Blight on Soft Red Winter Wheat in Central United States, 1998 through 2000

State	Economic Effect	1998	1999	2000	Total 1998-2000
		------------------------------ 000s $ ------------------------------			
IL	Production Loss	4,963	479	945	6,387
	Price Effect	43,655	16,979	(638)	59,996
	Total	48,618	17,458	307	66,383
IN	Production Loss	1,376	405	411	2,192
	Price Effect	22,395	7,576	2,182	32,153
	Total	23,771	7,981	2,593	34,345
KY	Production Loss	693	771	1,523	2,987
	Price Effect	19,999	4,834	(203)	24,630
	Total	20,692	5,605	1,320	27,617
MI	Production Loss	5,364	1,052	1,320	7,736
	Price Effect	27,707	12,701	2,879	43,287
	Total	33,071	13,753	4,199	51,023
MO	Production Loss	662	291	1,348	2,301
	Price Effect	38,150	8,439	2,649	49,287
	Total	38,812	8,730	3,997	51,588
OH	Production Loss	2,955	219	0	3,174
	Price Effect	67,091	27,155	5,068	99,314
	Total	70,046	27,374	5,068	102,488
All States	Production Loss	16,013	3,217	5,547	24,777
	Price Effect	218,997	77,684	11,937	308,618
	Total	235,010	80,901	17,484	333,395

Note: FHB had a positive economic effect through higher overall prices for SRW wheat in some states in 2000. Negative numbers represent a positive economic effect.

Barley

Yield reductions and price discounts from FHB in barley were estimated at $136 million in North Dakota, Minnesota, and South Dakota from 1998 through 2000 (Table 7). In North Dakota, Minnesota, and South Dakota, yield reductions accounted for over 50 percent of the direct losses. Total direct losses over the period were greatest in North Dakota ($103 million), followed by Minnesota ($33 million) and South Dakota ($0.7 million). Direct losses in the three states were greatest in 1998 ($58 million), decreased in 1999 ($27 million), and then increased to $52 million in 2000. Of the total losses over the period, about 80 percent occurred in 1998 and 2000.

Table 7. Direct Economic Impacts from Fusarium Head Blight in Barley in the Northern Great Plains, 1998 through 2000

State	Economic Effect	1998	1999	2000	Total 1998- 2000
		------------------------------ 000s $ ---------------------------- -			
ND	Production Loss	15,944	13,318	23,191	52,453
	Price Effect	21,111	8,390	21,022	50,523
	Total	37,055	21,708	44,213	102,976
MN	Production Loss	12,440	3,654	3,860	19,954
	Price Effect	7,494	1,432	3,771	12,697
	Total	19,934	5,086	7,631	32,651
SD	Production Loss	328	137	43	508
	Price Effect	227	0	0	227
	Total	555	137	43	735
All States	Production Loss	28,712	17,109	27,094	72,915
	Price Effect	28,832	9,822	24,793	63,447
	Total	57,544	26,931	51,887	136,362

Aggregate Direct Impacts

The combined effects of price discounts and yield reductions from FHB in HRS wheat, SRW wheat, durum wheat, and barley were estimated at $870 million from 1998 through 2000 (Table 8). Direct economic losses over the period were greatest for SRW wheat ($333 million), followed closely by HRS wheat ($330 million). Losses for barley and durum were estimated at $136 million and $70 million, respectively. Combined losses with the four crops were greatest in 1998 and decreased through 2000. Losses in 1998 accounted for over 50 percent of the three-year total.

Losses from all crops were summed by state (Table 9). North Dakota, with economic losses from FHB in HRS wheat, barley, and durum wheat incurred the greatest impacts ($356 million) of all affected states from 1998 through 2000. Other states with considerable economic losses over the period included Minnesota ($122 million), Ohio ($102 million), Illinois ($66 million), and South Dakota ($60 million). The remaining four states, with large impacts from FHB in SRW wheat, accounted for about 19 percent of economic losses. Losses in North Dakota exceeded $100 million annually over the period; whereas, losses in the other states were largely concentrated in 1998 and to a lesser extent in 1999. Direct economic losses in the tri-state region of North Dakota, Minnesota, and South Dakota accounted for nearly 62 percent of all FHB impacts over the period 1998 to 2000.

Table 8. Aggregate Direct Economic Impacts from Fusarium Head Blight, by Crop, in the Northern Great Plains and Central United States, 1998 through 2000

Crop	State	1998	1999	2000	Total	By crop
		---------------------- 000s $			------------------------	--- % ---
HRS	North Dakota	80,757	53,319	48,778	182,854	--
	Minnesota	38,604	38,462	11,686	88,752	--
	South Dakota	24,776	24,927	9,149	58,852	--
	Total	144,137	116,708	69,613	330,458	38.0
Durum	North Dakota	20,375	28,744	20,884	70,003	--
	Minnesota	140	191	18	349	--
	Total	20,515	28,935	20,902	70,352	8.1
SRW	Illinois	48,618	17,458	307	66,383	--
	Indiana	23,771	7,981	2,593	34,345	--
	Kentucky	20,692	5,605	1,320	27,617	--
	Michigan	33,071	13,753	4,199	51,023	--
	Missouri	38,812	8,730	3,997	51,539	--
	Ohio	70,046	27,374	5,068	102,488	--
	Total	235,010	80,901	17,484	333,395	38.3
Barley	North Dakota	37,055	21,708	44,213	102,976	--
	Minnesota	19,934	5,086	7,631	32,651	--
	South Dakota	555	137	43	735	--
	Total	57,544	26,931	51,887	136,362	15.7
All Crops	All States	457,206	253,475	159,886	870,567	--
	% by Year	52.5	29.1	18.4	--	--

Despite a substantial decrease in direct economic losses from FHB in 2000, cumulative economic effects over the period 1998 to 2000 were substantial. The cumulative direct losses of $870 million represent a substantial loss in crop revenue for small grain producers in the affected areas. To put the losses in perspective, the three-year combined losses of $870 million would exceed the annual value of all barley and oats production in the United States in both 1999 and 2000. Total value of barley and oats production in the United States was $766 million and $797 million in 1999 and 2000, respectively (U.S. Department of Agriculture, National Agricultural Statistics Service 2001). The average value of all winter wheat production in the United States from 1998 through 2000 was about $4.2 billion. The average losses from FHB over the same period for all crops in this study was estimated at $290 million. Thus, annual losses from FHB represented, on average, 6.9 percent of the total value of all U.S. winter wheat production. When compared to the annual value of all wheat (spring, winter, durum, and other) production in the United States over the same period, annual losses from FHB represented 4.7 percent of the U.S. total.

Table 9. Aggregate Direct Economic Impacts from Fusarium Head Blight, by State, in the Northern Great Plains and Central United States, 1998 through 2000

State	Crop	1998	1999	2000	Total	By Crop
		---------------------------- 000s $			-------------------	-- % --
ND	HRS	80,757	53,319	48,778	182,854	
	Durum	20,375	28,744	20,884	70,003	
	Barley	37,055	21,708	44,213	102,976	
	Total	138,187	103,771	113,875	355,833	40.9
MN	HRS	38,604	38,462	11,686	88,752	
	Durum	140	191	18	349	
	Barley	19,934	5,086	7,631	32,651	
	Total	58,678	43,739	19,335	121,752	14.0
SD	HRS	24,776	24,927	9,149	58,852	
	Barley	555	137	43	735	
	Total	25,331	25,064	9,192	59,587	6.8
IL	SRW	48,618	17,458	307	66,383	7.6
IN	SRW	23,771	7,981	2,593	34,345	3.9
KY	SRW	20,692	5,605	1,320	27,617	3.2
MI	SRW	33,071	13,753	4,199	51,023	5.9
MO	SRW	38,812	8,730	3,997	51,539	5.9
OH	SRW	70,046	27,374	5,068	102,488	11.8

When losses from FHB in North Dakota, the most affected state, were compared to crop revenues over the period, the effects were more substantial. North Dakota averaged $118.6 million in annual losses from FHB from 1998 through 2000. The losses represent 14.2, 19.8, and 52 percent of the average value of all wheat, spring wheat, and durum wheat production over the period, respectively. The average annual losses from FHB represent 5 percent of the annual average value of all crop production in North Dakota over the period. The losses in North Dakota over the period were substantial, both in terms of overall size and in terms of relative perspective to the value of crop activities in the state.

Secondary Economic Impacts

FHB affects small grain producers in the northern Great Plains and central United States through price discounts and yield reductions on HRS wheat, durum wheat, barley, and SRW wheat. The effects of FHB were assumed to reduce producer net revenues, as the economic linkages and activities associated with crop production (e.g., planting, harvesting) are largely covered through the dispersal of revenues that producers are currently receiving from crop sales.

Reductions in producer net revenues were treated as direct economic impacts and allocated to the **Households** sector of the North Dakota I-O Model to estimate the secondary and total economic impacts.

Hard Red Spring Wheat

Direct economic impacts (reductions in producer net revenues) from FHB on HRS wheat totaled $330 million in North Dakota, Minnesota, and South Dakota from 1998 to 2000. Total direct and secondary economic impacts (total economy-wide losses) from FHB on HRS wheat in the three-state region were estimated at $1 billion over the period (Table 10). In the case of HRS wheat, North Dakota sustained the greatest level of overall economic loss ($563 million) over the period. Economy-wide losses in Minnesota and South Dakota were estimated at $273 million and $181 million, respectively (Table10).

Durum Wheat

Direct economic impacts of FHB in durum wheat totaled about $70 million in North Dakota and Minnesota from 1998 to 2000. Total direct and secondary economic impacts (total economy-wide losses) from FHB in durum wheat in the two-state region were estimated at $217 million over the period (Table 10). Nearly all (over 99 percent) of the economic losses from FHB in durum wheat occurred in North Dakota. Unlike losses due to FHB with HRS or SRW wheat, the annual effects for durum wheat were nearly equal during the period.

Soft Red Winter Wheat

Direct economic impacts of FHB in SRW wheat were estimated at $333 million in Illinois, Indiana, Kentucky, Michigan, Missouri, and Ohio from 1998 through 2000. Total regional losses (direct and secondary economic impacts) in the affected states were estimated at $1 billion over the period (Table 10). Over 60 percent of the regional losses occurred in Ohio, Illinois, and Indiana. Of the $1 billion in regional economic losses, $315 million occurred in Ohio. Unlike durum and barley, the economic losses from FHB in SRW wheat largely occurred in 1998, and subsequently decreased in 1999 and 2000.

Barley

Direct economic impacts of FHB in barley were estimated at $136 million in North Dakota, Minnesota, and South Dakota from 1998 through 2000. Total direct and secondary economic impacts in the tri-state region were estimated at $420 million over the period (Table 10). About 75 percent or $317 million of those losses occurred in North Dakota. Over the period, overall economic losses in the three states were greatest in 1998, followed closely by losses in 2000.

Total Direct and Secondary Economic Impacts

Total direct and secondary economic losses from FHB in HRS wheat, barley, durum wheat, and SRW wheat from 1998 to 2000 were estimated at $2.7 billion (Table10). About 53 percent of those losses occurred in 1998, with overall losses decreasing in 1999 and 2000. Total economic impacts were greatest for SRW and HRS wheat, which accounted for over three-quarters of all losses.

Table 10. Total (Direct and Secondary) Economic Impacts from Fusarium Head Blight, by Crop and State, in the Northern Great Plains and Central United States, 1998 through 2000

Crop	State	1998	1999	2000	Total	By crop
		------------------------ 000s $ ------------------------				---- % ---
HRS	North Dakota	248,594	164,131	150,150	562,875	--
	Minnesota	118,835	118,397	35,977	273,209	--
	South Dakota	76,268	76,732	28,166	181,166	--
	Total	443,697	359,260	214,293	1,017,250	38.0
Durum	North Dakota	62,721	88,483	64,287	215,491	--
	Minnesota	436	589	55	1,080	--
	Total	63,157	89,072	64,342	216,571	8.1
SRW	Illinois	149,660	53,741	947	204,348	--
	Indiana	73,172	24,568	7,983	105,723	--
	Kentucky	63,695	17,253	4,067	85,015	--
	Michigan	101,807	42,337	12,926	157,070	--
	Missouri	119,474	26,872	12,306	158,652	--
	Ohio	215,620	84,269	15,602	315,491	--
	Total	723,428	249,040	53,831	1,026,299	38.3
Barley	North Dakota	114,067	66,826	136,100	316,993	--
	Minnesota	61,364	16,659	23,489	100,512	--
	South Dakota	1,709	421	133	2,263	--
	Total	177,140	83,906	159,722	419,768	15.7
Totals	All Crops	1,407,422	781,278	492,188	2,679,888	--
	% by Year	52.5	29.1	18.4	--	--

Direct and secondary economic losses for all crops were summed by state (Table 11). Of the $2.7 billion in economic losses associated with FHB, North Dakota had $1 billion or about 41 percent of those losses during the 1998 to 2000 period. Losses in the other states were not as large, but substantial losses still occurred in Minnesota ($375 million), Ohio ($315 million), Illinois ($204 million), South Dakota ($183 million), and over $150 million each in Missouri and Michigan.

Table 11. Total (Direct and Secondary) Economic Impacts from Fusarium Head Blight, All Crops, by State, in the Northern Great Plains and Central United States, 1998 through 2000

State	1998	1999	2000	Total	By State
	--------------------------- 000s $			-----------------------------	--- % ---
ND	425,382	319,440	350,537	1,095,359	40.9
MN	180,635	134,645	59,521	374,801	14.0
OH	215,620	84,269	15,602	315,491	11.8
IL	149,660	53,741	947	204,348	7.6
SD	77,977	77,153	28,299	183,429	6.8
MO	119,474	26,872	12,306	158,652	6.8
MI	101,807	42,337	12,926	157,070	5.9
IN	73,172	24,568	7,983	105,723	3.9
KY	63,695	17,253	4,067	85,015	3.2
Total	1,407,422	780,278	492,188	2,679,888	- - -

<u>Economic Impacts by Sector</u>

Input-output analysis provides for estimates of the lost business activity by economic sector. The combined effects (direct and secondary) of FHB by economic sector for all affected crops was summed by year for the 1998 to 2000 period (Table 12). The economic sectors of the individual state and regional economies with the greatest loss of business activity during the period were **Households** (which represents economy-wide personal income) ($1.4 billion) and **Retail Trade** ($648 million). Other sectors which incurred substantial loss of economic activity as a result of FHB in small grains included **Finance, Insurance, and Real Estate** ($146 million), **Government** ($94 million), **Communication and Public Utilities** ($92 million), and **Agriculture** ($82 million). Since all effects (direct economic losses) of FHB were allocated to the **Households** sector for each crop and each state, lost business activity by sector within individual states would be in proportion to the aggregate totals for each year (i.e., state-level effects by economic sector would be largely in the same ratio as found in Table 12).

Based on the North Dakota I-O Model, each dollar of direct economic loss or each dollar of lost producer net revenues would result in an additional $2.08 of lost business activity in the state and regional economies. Thus, not only are producers affected by FHB through lost revenues, but numerous sectors of the state and regional economies also are affected.

Table 12. Total (Direct and Secondary) Economic Impacts for Fusarium Head Blight in All Crops, by Economic Sector and Year, Northern Great Plains and Central United States, 1998 through 2000

Economic Sector	HRS and SRW Wheat, Durum, and Barley			
	1998	1999	2000	Total 1998-2000
	------------------------------ 000s $ ------------------------------			
Agriculture	42,978	23,825	15,030	81,833
Construction	41,239	22,863	14,423	78,525
Communication & Public Utilities	48,237	26,741	16,868	91,846
Retail Trade	340,482	188,765	119,068	648,315
Finance, Insurance, & Real Estate	76,856	42,610	26,878	146,344
Households	709,769	393,499	248,210	1,351,478
Government	49,380	27,375	17,267	94,022
Other Sectors[1]	98,481	54,600	34,444	187,525
Total Direct Impacts	457,206	253,475	159,886	870,567
Total Secondary Impacts	950,216	526,803	332,302	1,809,321
Total	1,407,422	780,278	492,188	2,679,888

[1] Includes sectors such as business, professional, personal, social services, transportation, and manufacturing.

Secondary Employment

Secondary employment estimates represent the number of full-time jobs generated based on the volume of business activity created by an industry. Productivity ratios[17] were used with estimates of business activity to obtain secondary employment. The loss of producer revenues from FHB in small grains in the northern Great Plains and central United States had substantial effects on secondary employment in the state and regional economies (Table 13). In 1998, the loss of gross business volume (direct and secondary economic activity) would have supported about 14,000 full-time equivalent (FTE) jobs. In 1999, the loss of economic activity due to FHB would have supported about 7,700 FTE jobs in the affected states. The loss of business activity in 2000 would have supported 4,800 FTE jobs.

[17] A measure of the amount of economic activity needed in an economic sector to support one full-time job within that sector.

Table 13. Secondary Employment Losses from Fusarium Head Blight, All Crops, by State, in the Northern Great Plains and Central United States, 1998 through 2000

State	1998	1999	2000
	-------------------- full-time equivalent jobs ----------------		
ND	4,254	3,177	3,476
MN	1,800	1,333	583
OH	2,161	837	149
IL	1,497	531	0
SD	770	761	274
MO	1,193	261	116
MI	1,016	418	124
IN	729	239	75
KY	635	168	34
Total	14,055	7,725	4,831

5. Summary and Discussion

This study provides an update of economic losses suffered by wheat and barley producers in scab-affected regions in the United States from 1998 to 2000. Wheat and barley producers in several states have experienced significant yield and price losses due to Fusarium Head Blight (FHB), or scab, since 1993. Yield and price effects of FHB are estimated in this study using change in crop value after accounting for reduced yields, higher abandoned acres, and price impacts on futures and basis, and malting and feed barley prices.

One of the main difficulties in measuring economic losses due to FHB is estimating the price effects. While supply reductions tend to increase the futures price, the effects on average basis (difference between local cash price and futures) are less certain. Shortages of milling-quality grains can induce large price premiums, which favor producers who have high quality wheat or barley to sell. However, many producers in scab-affected regions face quality discounts due to damaged kernels, low test weight, or vomitoxin. The average basis in a region depends on the quality of crop sold by all producers and the premiums and discounts applied by local elevators.

To measure the impact of FHB on basis, deviations from olympic-average basis values were used in years preceding the scab outbreak in the case of wheat. In the case of barley, the malting and feed barley prices were estimated. The actual prices were deducted from the estimated prices to obtain the price effects. An input-output model was used to estimate secondary and total economic impacts of FHB on state economies, individual economic sectors, and secondary employment.

The direct combined effects of price discounts and yield reductions from FHB in HRS wheat, SRW wheat, durum wheat, and barley were estimated at $870 million from 1998 through 2000. Direct economic losses over the period were greatest for SRW wheat ($333 million), followed closely by HRS wheat ($330 million). Losses for barley and durum wheat were estimated at $136 million and $70 million, respectively. Combined losses for the four crops were greatest in 1998 and decreased through 2000. Losses in 1998 accounted for over 50 percent of the three-year total.

Despite a substantial decrease in direct economic losses from FHB in 2000, cumulative economic effects over the period 1998 to 2000 were substantial. The commutative direct losses of $870 million represent a substantial loss in crop revenue for small grain producers in the affected areas. To put the losses in perspective, the three-year combined losses of $870 million would exceed the annual value of all barley and oats production in the United States in both 1999 and 2000–total value of barley and oats production in the United States was $766 million and $797 million in 1999 and 2000, respectively. The annual losses from FHB over the three years represent on average 6.9 percent of the total value of all U.S. winter wheat production. When compared to the annual value of all wheat (spring, winter, durum, and other) production in the United States over the same period, annual losses from FHB represented 4.7 percent of the U.S. total.

The combined direct and secondary economic losses for all crops were estimated at $2.7 billion. North Dakota had $1 billion or about 41 percent of those losses during the period 1998 to 2000. Losses in the other states were not as large, but substantial losses still occurred in Minnesota ($375 million), Ohio ($315 million), Illinois ($204 million), South Dakota ($183 million), and over $150 million each in Missouri and Michigan.

When compared with estimates from 1993 to 1997 reported by Johnson et al. (1998), revenue loss due to FHB decreased substantially for wheat in 1998-2000. The most likely reason for the decrease was the introduction of FHB resistant varieties in North Dakota and Minnesota and low precipitation recorded during these periods (Figures A1 and A2) . However, barley producers continue to suffer significant losses. North Dakota and Minnesota had the largest cumulative yield losses for all wheat classes and barley, followed by Michigan and Illinois.

Scab is still a major economic problem, whether measured in relative terms to other crop sales or measured by overall direct and secondary economic impact. The scab problem is not limited to a narrow geographic region, hurting producers in both the northern Great Plains and central states. Scab continues to effect several classes of wheat and barley, constituting a serious economic problem in several regions of the United States.

Impacts from scab affect not only producers, but other areas of the economy as well. A substantial portion of the impacts affect the businesses that are dependent upon revenues from crop sales (for every $1 dollar of scab losses incurred by the producer, $2 in losses are incurred in other areas of rural and state economies). Depressed farm economies are further affected by scab. Scab occurs in many regions of the northern Great Plains that are not only reliant on agriculture, but are predominately dependent upon small grain production. Thus, scab is having an extenuating effect in those areas. Furthermore, income losses from scab are occurring during periods of depressed farm prices and low net farm income. (Net farm income has decreased significantly since 1996.)

The level of impacts (magnitude), the relative impact (comparisons to wheat/other small grain sales), and the geographic size of the problem all suggest that continued research into developing scab resistant varieties of wheat and barley is warranted. Clearly, several million dollars spent on scab research would be easily offset by future benefits of a reduction in scab losses.

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Appendix Tables

Table A1. HRS Wheat Yield Equation Parameter Estimates, by State

State / CRD	Intercept	Trend	Temperature	Precipitation	R2	Adj. R2	Sample Size
ND - NC	94.227	0.32133	-1.4173	0.64874	0.4029	0.2976	21
	(3.305)	(1.685)	(-2.890)	(1.297)			
ND - NE	85.402	0.5673	-1.0613	0.47697	0.3101	0.1883	21
	(2.285)	(2.337)	(-1.698)	(0.7834)			
ND - C	75.725	0.33886	-1.0997	1.0742	0.4323	0.3321	21
	(2.423)	(1.669)	(-2.103)	(2.110)			
ND - EC	93.574	0.63324	-1.2613	0.60845	0.3619	0.2493	21
	(2.415)	(2.590)	(-1.922)	(1.138)			
ND - SE	78.095	0.40425	-1.0025	0.26589	0.2333	0.098	21
	(1.935)	(1.803)	(-1.511)	(0.5233)			
MN - NW	70.111	0.72676	-0.88439	1.0175	0.4083	0.3039	21
	(1.522)	(2.842)	(-1.157)	(1.528)			
MN - WC **	46.37	0.61307	-0.54676	1.2211	0.3581	0.2448	21
	(0.9857)	(2.788)	(-0.7331)	(2.189)			
MN - C **	-26.752	0.20103	0.91152	0.46975	0.1508	0.001	21
	(-0.4797)	(0.6544)	(1.017)	(0.9343)			
SD - NC	79.998	0.36576	-1.134	0.58488	0.3396	0.223	21
	(1.714)	(1.710)	(-1.571)	(0.8920)			
SD - NE **	36.78	0.47997	-0.47984	1.2704	0.3232	0.2037	21
	(0.8842)	(2.576)	(-0.7205)	(2.563)			
SD - C	84.557	0.32151	-1.1035	-0.047464	0.291	0.1659	21
	(-1.702)	(-1.289)	(-1.452)	(-0.079)			

Numbers in the parentheses are t-values.

** Indicates error structure corrected for first order auto-correlation.

Table A2. Durum Wheat Yield Equation Parameter Estimates, by State

State / CRD	Intercept	Trend	Temperature	Precipitation	R2	Adj. R2	Sample Size
ND - NC	98.817	0.32251	-1.4729	0.70589	0.4058	0.3009	21
	(3.332)	(1.625)	(-2.887)	(1.356)			
ND - NE	84.35	0.36631	-1.1761	0.82275	0.3616	0.2489	21
	(2.798)	(1.829)	(-2.275)	(1.475)			
ND - C	82.668	0.46442	-1.2943	1.3865	0.5387	0.4573	21
	(2.616)	(2.263)	(-2.449)	(2.693)			
ND - EC	94.682	0.85496	-1.3889	0.87211	0.4673	0.3733	21
	(2.348)	(3.360)	(-2.033)	(1.567)			
ND - SE	65.407	0.5025	-0.89617	0.83324	0.3908	0.2832	21
	(1.750)	(2.420)	(-1.459)	(1.771)			
MN - NW	61.129	0.6421	-0.82059	1.4907	0.4763	0.3838	21
	(1.416)	(2.678)	(-1.145)	(2.387)			
MN - WC **	35.806	0.42769	-0.39002	1.2589	0.4217	0.3197	21
	(1.044)	(2.674)	(-0.7170)	(3.084)			

Numbers in the parentheses are t-values.

** Indicates error structures corrected for first order auto-correlation.

Table A3. SRW Wheat Yield Equation Parameter Estimates, by State							
State / CRD	Intercept	Trend	Temperature	Precipitation	R2	Adj. R2	Sample Size
IL - W	56.233	1.2241	-0.24502	-0.58471	0.6816	0.6179	19
	(1.279)	(4.483)	(-0.3298)	(-1.742)			
IL - WSW	75.505	0.93293	-0.4845	-0.61913	0.6284	0.5541	19
	(1.783)	(3.799)	(-0.6918)	(-1.884)			
IL - ESE	35.662	0.85432	0.21217	-0.73802	0.6479	0.5775	19
	(0.8517)	(3.77)	(0.3069)	(-2.286)			
IL - SW	80.715	0.80986	-0.55467	-0.83165	0.6176	0.5412	19
	(1.86)	(3.643)	(-0.7916)	(-2.814)			
IL - SE	-2.2713	0.79954	0.7623	-0.62178	0.5553	0.4664	19
	(-0.04404)	(3.272)	(0.9269)	(-1.910)			
IN - NE **	70.906	0.89601	-0.57457	-0.17975	0.6339	0.5606	19
	(2.351)	(6.03)	(-1.111)	(-0.4213)			
IN - C **	90.46	1.0548	-0.7959	-0.36563	0.7873	0.7447	19
	(3.339)	(9.376)	(-1.763)	(-1.292)			
IN - SW	29.112	0.76875	0.22551	-0.39652	0.4521	0.3426	19
	(0.5295)	(3.081)	(0.2547)	(-1.101)			
IN - SC **	42.918	0.66552	-0.16107	-0.073021	0.4488	0.3386	19
	(1.015)	(3.651)	(-0.2327)	(-0.2520)			
IN - SE	33.704	0.90967	0.013917	-0.25987	0.6554	0.5864	19
	(0.7634)	(4.818)	(0.01932)	(-0.8592)			
KY - PUR **	4.975	0.74822	0.46648	-0.27356	0.5624	0.4749	19
	(0.0909)	(2.577)	(0.5423)	(-1.060)			
KY - MW	63.983	0.6774	-0.40115	-0.37702	0.4075	0.2889	19
	(0.8769)	(2.169)	(-0.3477)	(-0.8993)			
MI - C	46.362	0.7124	-0.33776	0.51998	0.3094	0.1713	19
	(1.105)	(2.529)	(-0.4099)	(0.9605)			
MI - EC	33.645	1.3381	-0.087447	0.79063	0.6995	0.6394	19
	(0.9666)	(5.78)	(-0.1301)	(1.771)			
MI - SW	57.557	0.88435	-0.52123	0.093666	0.4865	0.3838	19
	(1.543)	(3.208)	(-0.7884)	(0.1458)			
MI - SC	76.68	0.88382	-0.8258	0.013682	0.4688	0.3626	19
	(1.805)	(3.181)	(-1.081)	(0.02038)			
MI - SE	54.808	0.99427	-0.46167	0.36915	0.6047	0.5257	19
	(1.64)	(4.657)	(-0.7414)	(0.6588)			
MO - NE **	76.348	0.74045	-0.58409	-0.51745	0.3678	0.2414	19
	(1.543)	(2.953)	(-0.7318)	(-1.294)			

State / CRD	Intercept	Trend	Temperature	Precipitation	R2	Adj. R2	Sample Size
MO - E	42.048	0.54152	-0.005345	-0.47311	0.4246	0.3095	19
	(0.9438)	(2.516)	(-0.007128)	(-1.783)			
MO - SW	95.491	0.48229	-0.96776	-0.43828	0.4027	0.2832	19
	(2.16)	(2.27)	(-1.333)	(-1.645)			
MO - SC	38.84	0.58563	-0.10129	-0.38543	0.4907	0.3888	19
	(1.002)	(3.128)	(-0.1553)	(-1.670)			
MO - SE **	53.13	0.18257	0.0076974	-0.89689	0.3791	0.255	19
	(1.803)	(0.8101)	(0.01441)	(-2.865)			
OH - NW **	11.227	0.88812	0.42239	0.55772	0.5406	0.4487	19
	(0.258)	(4.883)	(0.5589)	(0.899)			
OH - NC **	14.405	0.95953	0.41396	0.0062829	0.6824	0.6188	19
	(0.4492)	(6.564)	(0.7199)	(0.01602)			
OH - NE **	0.68114	0.88102	0.60395	-0.077001	0.7398	0.6877	19
	(0.0267)	(8.242)	(1.282)	(-0.2230)			
OH - WC **	30.901	0.92016	0.24147	-0.29203	0.6805	0.6166	19
	(0.9204)	(6.548)	(0.4161)	(-0.9234)			
OH - C **	17.405	1.0137	0.4663	-0.5433	0.8358	0.803	19
	(0.6465)	(11.11)	(1.031)	(-2.278)			
Numbers in the parentheses are t-values.							
**Indicates error structures corrected for first order auto-correlation.							

Table A4. Barley Yield Equation Parameter Estimates, by State

State / CRD	Intercept	Trend	Temperature Deviation	Precipitation Deviation	Precipitation Deviation squared	R2	Adj. R2	Number of Observations
ND - NC**	25.87*	0.72*	-3.89*	4.1*	-2.65*	0.71	0.68	34
	(9.06)	(5.64)	(-3.31)	(3.72)	(-2.47)			
ND - NE	24.43*	1.15*	-3.41*	3.26*	-2.31	0.75	0.72	34
	(8.48)	(9)	(-2.47)	(2.72)	(-1.65)			
ND - C	21.28*	0.93*	-4.56*	5.37*	-1.27	0.69	0.64	34
	(7.73)	(7.02)	(-3.44)	(4.25)	(-1.34)			
ND - EC	27.2*	1.17*	-3.57*	2.96*	-2.27	0.76	0.72	34
	(10.01)	(9.09)	(-2.67)	(2.33)	(-2.14)			
ND - SE	26.43*	0.92*	-2.87*	5.49*	-3.6	0.7	0.66	34
	(9.66)	(7.01)	(-2.07)	(3.56)	(-3.83)			
MN - NW	12.51	0.94	5.15	0.65	-0.44	0.66	0.62	34
	(1.59)	(1.03)	(2.92)	(2.28)	(-5.62)			
MN - WC	19.93	0.76	3.49	1.78	-0.4	0.69	0.65	34
	(2.73)	(3.83)	(4.71)	(1.79)	(-5.3)			
MN - C	21.45	0.37	2.94	1.52	-0.08	0.48	0.4	34
	(3.17)	(3.5)	(3.45)	(1.67)	(-2.79)			
SD - NC	22.5	0.31	1.19	2.03	0.06	0.45	0.37	34
	(2.76)	(2.3)	(0.62)	(0.59)	(2.32)			
SD - NE	11.18	0.68	4.09	0.63	-0.25	0.56	0.5	34
	(1.27)	(1.01)	(2.39)	(1.77)	(-4.23)			
SD - C	18.28	0.5	1.47	0.52	0	0.27	0.17	34
	(1.81)	(0.6)	(0.03)	(0.61)	(2.94)			

Numbers in the parentheses are t-values.

** Indicates error structure corrected for first order auto-correlation.

Table A5. Fraction of HRS, Durum, SRW, and Barley Yield and Area Loss Attributable to Fusarium Head Blight (α_{it}), by Crop Reporting District and Year											
Year	ND-NC	ND-EC	ND-C	ND-EC	ND-SE	MN-NW	MN-WC	MN-C	SD-NC	SD-EC	SD-C
1998 1999 2000	1.00 0.04 0.67	0.26 0.05 0.15	0.81 0.07 0.41	0.19 0.04 0.15	1.00 0.37 *	0.13 0.11 0.39	1.00 0.63 *	* 1.00 *	* * *	0.16 * *	* * *

Fraction of Durum Yield and Area Loss Attributable to FHB (α_{it}), by CRD and Year

Year	ND-NC	ND-EC	ND-C	ND-EC	ND-SE	MN-NW	MN-WC
1998 1999 2000	1.00 0.04 0.67	0.26 0.05 0.15	0.81 0.07 0.41	0.19 0.04 0.15	1.00 0.37 *	0.13 0.11 0.39	1.00 0.63 *

Fraction of SRW Yield and Area Loss Attributable to FHB (α_{it}), by CRD and Year

Year	IL	IN	KY	MI	MO	OH
1998 1999 2000	0.22 0.06 0.15	0.13 0.02 *	0.06 0.01 *	0.24 0.12 *	0.05 0.09 0.08	0.08 * *

Fraction of Barley Yield and Area Loss Attributable to FHB (α_{it}), by CRD and Year

Year	ND-NC	ND-EC	ND-C	ND-EC	ND-SE	MN-NW	MN-WC	MN-C	SD-NC	SD-EC	SD-C
1998 1999 2000	0.73 0.35 0.75	0.90 0.63 0.96	0.47 0.40 0.81	0.80 0.60 0.86	0.93 0.56 0.43	1.00 0.69 0.90	0.83 * 0.50	* * *	* * *	0.75 * *	* * *

*Insignificant proportion.
Source: Extension Specialists.

Table A6. Malting Barley Premium Parameter Estimates by Crop Reporting District					
Crop Reporting District	Independent Variable				
	Intercept	Total production (Q_T)	Reg R^2	DW	Observations
ND-NC	0.88** (3.68)	-0.0015** (2.78)	0.20	1.66	34
ND-NE	1.42** (6.16)	-0.0026** (-5.29)	0.47	1.77	34
ND-C	1.07** (4.48)	-0.0018** (3.54)	0.29	1.81	34
ND-EC	2.05** (6.85)	-0.0039** (-6.07)	0.54	1.84	34
ND-SE	1.07** (4.23)	-0.0018** (-3.18)	0.25	2.00	34

Note: Numbers in the parentheses are t-values.
**Indicates parameter is statistically significant at the 0.05 level or higher.

Table A7. Feed Grain Barley Parameter Estimates by Crop Reporting District						
Crop Reporting District	Independent Variable					
	Intercept	Corn price (P_C)	Total production (Q_T)	Reg R^2	DW	Observations
ND-NC	0.24 (1.19)	0.78* (17.75)	-0.0009* (-2.07)	0.91	1.94	34
ND-NE	0.28 (1.48)	0.75* (18.18)	-0.0008* (-2.10)	0.92	1.93	34
ND-C	0.21 (1.19)	077* (19.81)	-0.0007** (2.00)	0.93	1.91	34
ND-EC	0.22 (1.13)	0.75* (17.42)	-0.0006 (-1.39)	0.91	1.87	34
ND-SE	0.21	0.78* (17.49)	-0.0007** (-1.76)	0.91	1.91	34

Note: Numbers in the parentheses are t-values.
*Indicates parameter is statistically significant at the 0.05 level or higher.
**Indicates parameter is statistically significant at the 0.10 level.

Appendix Figures

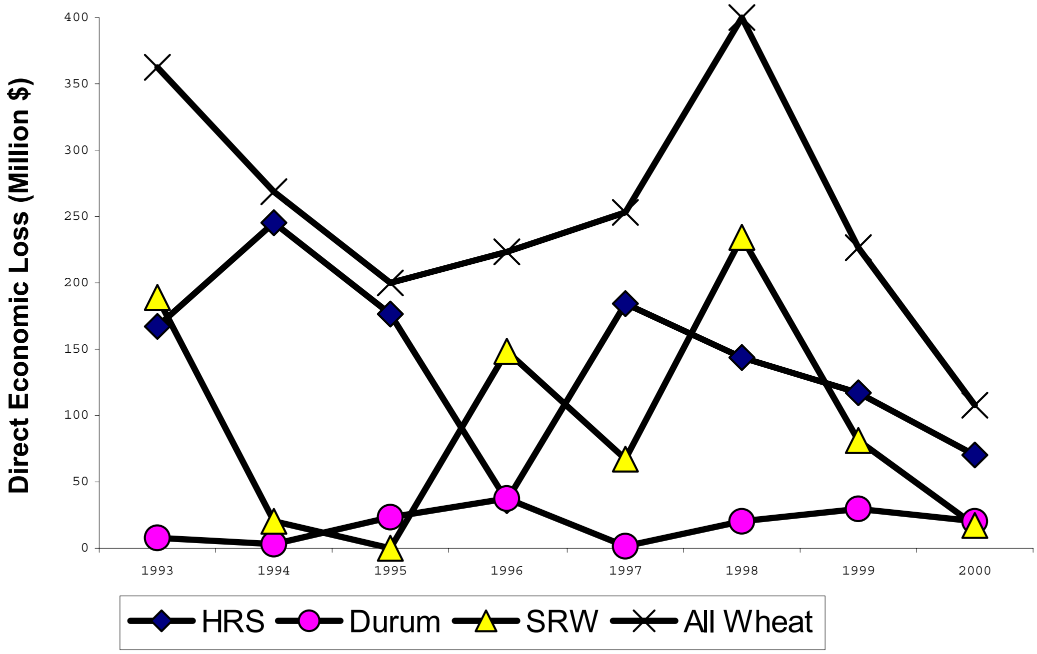

Figure A1. Direct Economic Revenue Losses due to Fusarium Head Blight in Wheat from 1993 -2000 (All States)

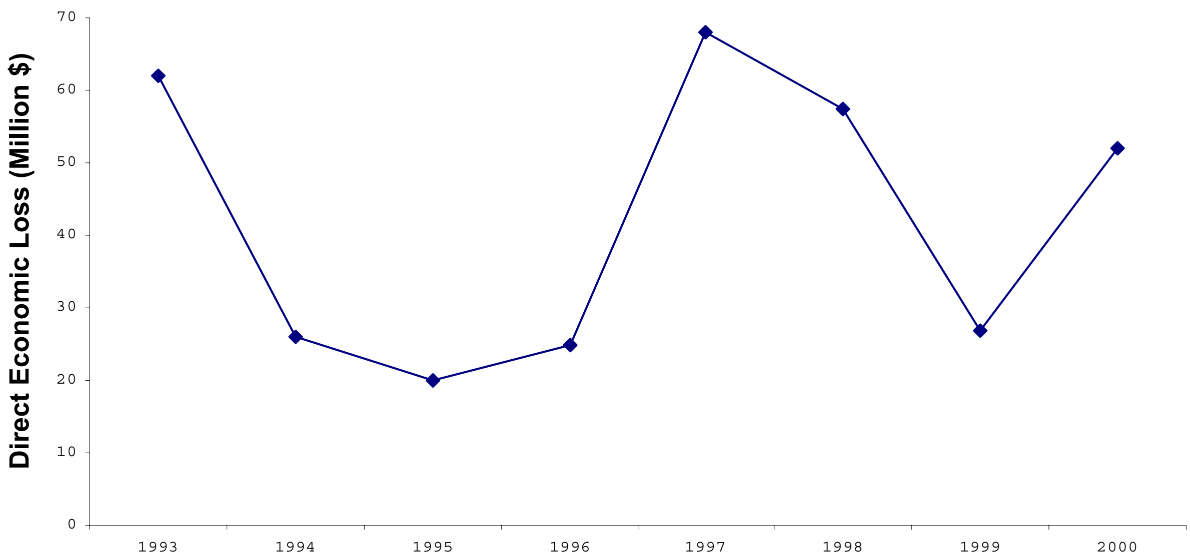

Figure A 2. Revenue Losses due to Fusarium Head Blight in Barley from 1993 - 2000 in North Dakota