United States General Accounting Office

GAO

Report to the Honorable
Byron L. Dorgan, U.S. Senate

March 1999

U.S. AGRICULTURE

Grain Fungus Creates Financial Distress for North Dakota Barley Producers

GAO/RCED-99-59

GAO

United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

B-281798

March 22, 1999

The Honorable Byron L. Dorgan
United States Senate

Dear Senator Dorgan:

Barley has traditionally been a major source of farm income in North Dakota, second only to wheat in total acreage planted and crop income. However, since 1993, substantial portions of North Dakota's barley crop have been damaged by a fungal disease—known as scab—that frequently produces a toxin called vomitoxin. The scab and vomitoxin epidemic has reduced the amount of barley produced and sold in North Dakota and the prices paid for barley. Specifically, scab causes barley kernels to become discolored and shriveled, reduces crop yield, depresses grain weight, and ultimately forces farmers to sell fewer bushels of barley at reduced prices. Furthermore, barley (in the form of barley malt) is a key ingredient in beer, and vomitoxin in barley can cause beer to produce too much foam, either during the fermentation process, thereby reducing the amount of beer produced, or when beer cans or bottles are opened, thus creating a less desirable product. In response, the malting and brewing industries will pay only a discounted price for barley that tests positive for vomitoxin; conversely, the industries offer top, or premium, prices for barley that is vomitoxin-free. Barley that is not of malting quality is sold primarily for animal feed and commands a much lower price. Discounted prices for vomitoxin-contaminated barley cover a narrow range of concentrations, beginning at 0.6 parts per million (ppm)—the approximate level at which field tests can begin quantifying the amount of vomitoxin—to about 3 ppm.[1] Beyond 3 ppm, barley is usually sold as animal feed.

Concerned about the effect of these losses on North Dakota barley farmers, you asked us to (1) determine the financial impact from scab and vomitoxin on these farmers,[2] (2) assess the performance of vomitoxin test methods, and (3) identify short- and long-term actions that could help reduce the impact of scab and vomitoxin on North Dakota barley farmers.

[1]To put these concentrations in context, 1 ppm is approximately equivalent to 1 kernel of contaminated barley in almost two bushels of barley.

[2]To estimate losses because of scab and vomitoxin, we first estimated what barley revenues would have been for 1993 through 1997 had there been no scab and vomitoxin outbreak. We then compared our estimate of barley revenues with actual barley revenues for these years to determine losses. In estimating losses, we controlled for other variables, such as weather, that can affect barley production.

Results in Brief

North Dakota barley farmers have experienced extensive revenue losses from scab and vomitoxin damage. From 1993 through 1997, these farmers suffered estimated cumulative losses of about $200 million from scab and vomitoxin—equal to about 17 percent of the $1.2 billion in total barley revenues they received during this period.[3] While most of the revenue losses resulted from decreases in barley production, losses also resulted from severe price discounts. Maltsters and brewers, the traditional buyers of North Dakota's malting barley, have reacted to the scab and vomitoxin damage by purchasing less barley from North Dakota farmers and more from Canadian and other western U.S. sources.

Three tests are generally used to measure vomitoxin concentrations in barley produced in North Dakota. One is a field kit, called Veratox, which is commonly used by grain elevators and commercial testing facilities and is the test that most directly affects the prices farmers receive for their barley. The Veratox test can produce results that vary at concentrations critical to pricing decisions. Testing experts attribute variations in test results to several sources, including the skill of the technician conducting the test. They stress the importance of quality assurance measures and training to help reduce this variation. The other two tests—high pressure liquid chromatography and gas chromatography—are reference methods that are used primarily in research laboratories for such purposes as checking the performance of the Veratox kit. According to analytical chemists and other testing experts, these tests provide accurate and consistent test results. However, because of the complexity and the cost of the equipment for these two tests, they are not practical for use at commercial testing facilities and other locations that serve barley farmers.

Short-term actions, such as rotating crops and spraying with fungicides, may help reduce scab and vomitoxin's impact under conditions of light infestation. However, according to North Dakota agriculture experts, the benefits of these actions are negligible during periods of moderate to severe infestation. From 1993 through 1997, several counties in the Red River Valley of North Dakota experienced moderate or severe scab and vomitoxin infestation. Furthermore, many of these actions have tradeoffs, such as causing environmental problems (like soil erosion), that barley farmers must take into account. The longer-term action of developing more scab-resistant barley may also help reduce the disease's impact under conditions of light infestation. But many scientists say that more resistant barley may not be commercially available for at least 6 years.

[3]All measures of farm revenues and losses are stated in 1997 constant dollars. Crop insurance payments for scab and vomitoxin-damaged barley covered only a very small portion (less than 2 percent) of cumulative revenue losses from the epidemic.

They also emphasize that developing a variety that is 100-percent resistant to scab is unlikely anytime soon.

Background

Vomitoxin, a toxin associated with a fungal disease called scab, only occurs when scab is present. Since 1993, scab and vomitoxin have affected wheat and barley crops in the Northern Great Plains, which includes North Dakota; Minnesota; South Dakota; and Manitoba, Canada. Crops in the Red River Valley region (the eastern part of North Dakota, the western part of Minnesota, and a corner of northeast South Dakota) have been the most severely affected. The mold that produces vomitoxin grows primarily on grains, particularly on wheat and barley, and can cause vomiting in farm animals that ingest vomitoxin-contaminated feed grains. The Food and Drug Administration (FDA), which is responsible for ensuring food safety in certain foods—including grains—has not issued any guidance on vomitoxin in barley or barley products. However, it has issued advisory levels[4] for vomitoxin in wheat and wheat products and feed grains for animals.

The scab and vomitoxin epidemic has added to the financial stress of farmers in North Dakota and the rest of the Northern Great Plains. North Dakota suffered a drought in 1988 and floods in 1993 and 1997. The U.S. Department of Agriculture's (USDA) Farm Service Agency (FSA) estimates that in the barley-producing regions of North Dakota most affected by scab and vomitoxin, 768 (or about 14 percent) of the farmers stopped farming between 1996 and 1998. Although this figure includes farms that failed because of flood, drought, and other reasons, FSA officials stated that scab and vomitoxin were the primary reasons for leaving farming.

Barley is economically important to North Dakota agriculture. Traditionally, it is second only to wheat in acreage planted and total crop income. For example, in 1992, the last year before the scab and vomitoxin epidemic, North Dakota's farm income from all crops totaled $2.2 billion, of which $1.2 billion (about 54 percent) was from wheat and $237 million (about 11 percent) was from barley. Furthermore, for the last 50 years, North Dakota has been the leading barley producer in the United States; in 1997, it accounted for 27 percent of the nation's total barley production.[5]

[4]Advisory levels are FDA's initial guidance on the amount of toxin allowed in food before public health is threatened.

[5]In 1997, other leading U.S. barley producers were Montana, Idaho, Washington State, and Minnesota.

Most farmers sell their barley to grain dealers, who then resell it to maltsters and brewers. To determine the price they will offer farmers for their barley, including the need for discounts, grain dealers have the barley tested for vomitoxin. Most testers of vomitoxin in North Dakota use a test kit called Veratox because it is relatively quick, inexpensive, and practical for commercial use. The high pressure liquid chromatography (HPLC) and gas chromatography (GC) tests, which are used by researchers for purposes such as advancing research on vomitoxin, are also used by maltsters and USDA's Grain Inspection, Packers and Stockyards Administration (GIPSA) to check Veratox test results. These two reference methods are generally not used by commercial testing facilities and grain dealers because they are more costly, time-consuming, and complex to operate.

GIPSA is the USDA agency that oversees federal grain inspections and has several key associated responsibilities. It authorizes certain commercial testing facilities to perform tests following its official procedures and standards. It also approves various testing methods, such as the Veratox kit, for use by these authorized facilities. Approved test methods, for which GIPSA provides training, must meet the agency's performance criteria. GIPSA also monitors the consistency of test results across its authorized facilities. For example, GIPSA conducts quarterly reviews of the test results from its authorized testing facilities. For these reviews, GIPSA uses the HPLC test method as a reference for, or check on, test results from these facilities. GIPSA considers the scab and vomitoxin epidemic to be a serious problem and has taken actions to address vomitoxin testing issues, such as conducting a study in 1998 to assess the extent to which sampling methods can affect vomitoxin test results.

However, GIPSA oversees only a portion of commercial grain testing nationwide.[6] Commercial testing facilities unaffiliated with GIPSA and large grain elevators where in-house testing with the Veratox kit is cost-effective also perform vomitoxin testing. The North Dakota Barley Council estimates that 40 percent of commercial vomitoxin testing in North Dakota occurs at GIPSA's authorized facilities; the remaining 60 percent occurs at either the unaffiliated testing facilities or large grain elevators. GIPSA has no oversight responsibility for vomitoxin tests performed by these other entities. Currently, GIPSA has four authorized agents in North Dakota that operate six commercial testing facilities. In addition, North Dakota has

[6]Only exports of U.S. grains are required to have a GIPSA grain inspection. However, unless requested, these inspections do not include vomitoxin testing. In addition, domestic grain elevators can request GIPSA to inspect grain, including testing for vomitoxin.

about nine commercial testing facilities that are not affiliated with GIPSA and between 12 and 20 grain elevators that test for vomitoxin.

North Dakota Barley Farmers Have Experienced Large Revenue, Yield, and Acreage Losses Because of Scab and Vomitoxin

From 1993 through 1997, we estimate that North Dakota barley farmers suffered cumulative revenue losses from scab and vomitoxin of about $200 million (in 1997 dollars)[7] —equal to almost 17 percent of the $1.2 billion in total barley revenues farmers received during this period.[8] The losses from these diseases varied significantly, both over the years and across the regions of the state, with the Red River Valley suffering the greatest losses. However, crop insurance payments for scab- and vomitoxin-damaged barley covered only a very small portion, less than 2 percent, of these cumulative losses. U.S. maltsters and brewers, the traditional buyers of North Dakota's malting barley, have reacted to scab and vomitoxin by expanding their imports of malting barley from Canada by about 380 percent.

Large Revenue Losses Resulting From Scab and Vomitoxin Are Caused by Production Declines and Price Discounts

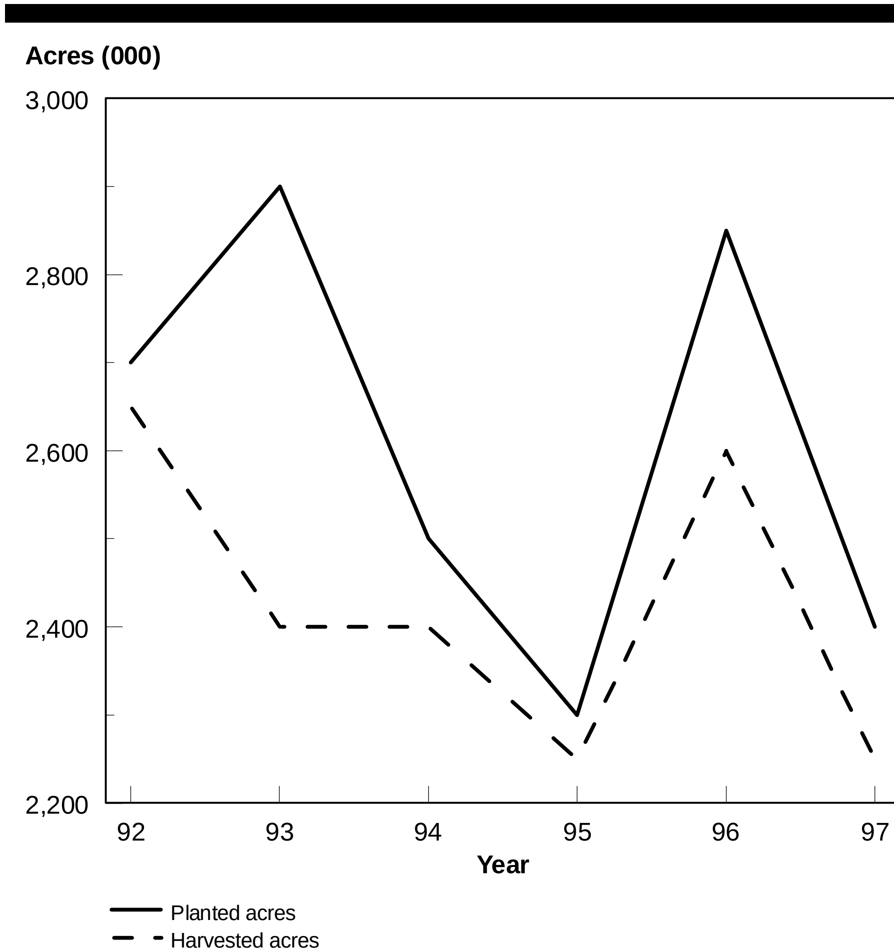
From 1993 through 1997, we estimate that North Dakota farmers lost about $200 million (in 1997 dollars) in revenues as a result of declines in both production and price discounts. These losses were equal to almost 17 percent of the $1.2 billion in total revenues barley farmers received during these years. About 70 percent of these losses, or $139 million, were from reduced barley yields (in bushels per acre) and from farmers' leaving more barley unharvested. For example, between 1992 and 1997, average North Dakota barley yields dropped from a pre-disease level of 65 bushels an acre to 45 bushels an acre. Also, as shown in figure 1, from 1993 through 1997 (the years of the epidemic), the number of acres planted with barley fell from 2.9 million to 2.4 million and the number of harvested acres of barley fell from 2.4 million to 2.25 million.[9] Differences between the amount of acres planted and actually harvested were the largest in 1993 and 1996. For instance, in 1993, North Dakota farmers harvested about 500,000 fewer barley acres than they had planted.

[7]Technically, using a range of assumptions, we estimated losses of $177 million to $224 million. For the purpose of this report, we are stating this as approximately $200 million in revenue losses.

[8]See app. I for a detailed description of our data sources, methodology, and the results of our analysis.

[9]In 1996, the amount of barley planted and harvested temporarily increased. Planted acres increased because of farmers' response to record high barley prices in 1995; harvested acres increased because of favorable weather conditions that were less conducive to the development of scab and vomitoxin.

Figure 1: North Dakota Barley Acreage—Gap Between Planted Acres and Harvested Acres, 1992-97



Source: GAO's analysis of USDA's data.

Price discounts for barley contaminated with vomitoxin also played a key role in reducing farmers' revenues. From 1993 through 1997, price discounts because of vomitoxin accounted for about 30 percent, or $61 million, of total revenue losses. The relationship between vomitoxin and price discounts is complex. Discounting in the marketplace stems from the U.S. brewing industry's desire to use little or no vomitoxin-contaminated barley. In general, U.S. brewers send price signals that reflect their specific quality and quantity requirements to merchandisers and maltsters. These price signals are subsequently incorporated into price discount schedules that reflect buyers' reluctance to purchase barley with vomitoxin unless they receive a highly discounted price. Grain elevators use these schedules, in conjunction with other quality premium or discount factors,[10] to determine an overall price quote to farmers. Price discount schedules for barley vomitoxin can change over time, sometimes on a daily basis, depending on market conditions. Price signals for malting barley come largely from the four large firms that dominate the U.S. brewing industry. One of these firms represents nearly half of the market.[11] A limited number of buyers in a given industry, such as the brewing industry, can influence the market price for a given commodity.

According to industry experts, although vomitoxin can cause excessive foaming during the malting process and in finished beer products, brewers require discounts for malting barley primarily because they are concerned about the potential for a negative public perception of beer containing vomitoxin. The industry is concerned that consumers will switch brands or purchase other alcoholic beverages if it is reported that beer contains vomitoxin. As a result, brewers are willing to pay top prices for vomitoxin-free barley, but only highly discounted prices for barley contaminated with vomitoxin.

Table 1 shows an example of a price schedule for barley, incorporating discounts for different levels of vomitoxin. Although discounting strategies vary, grain dealers generally begin discounting the price of vomitoxin-contaminated barley at 0.6 ppm. This first discount, usually the largest of several, ranges from about 40 cents to 60 cents a bushel. As shown in table 1, this first discount would result in a price of about $2 per bushel. Grain dealers apply subsequent discounts of about 5 cents to 15 cents for concentrations of vomitoxin that range from 1.1 ppm to 3.0 ppm. At vomitoxin concentrations above 3.0 ppm, dealers generally purchase barley as feed grain, which receives the lowest price, about $1.75 per bushel. The American Malting Barley Council reported that for 1997 only 9 percent of all midwestern malting barley had a vomitoxin level that fell into the premium price category of 0.5 ppm or less.

[10]Other quality factors that can affect malting barley premiums and discounts include moisture, color, test weight, protein, foreign material, and damage.

[11]These top four firms are Anheuser-Busch, Inc., the Miller Brewing Company, the Coors Brewing Company, and the Stroh Brewery Company. In 1998, these firms constituted 45 percent, 22 percent, 10 percent, and 9 percent, respectively, of the U.S. beer market.

Table 1: Example of a Price Schedule for Barley, Discounted for Different Concentrations of Vomitoxin

Concentration of vomitoxin	Price per bushel
0-0.5 ppm	$2.55 (premium malting barley price— no discount)
0.6-1.0 ppm	$2.00
1.1-2.0 ppm	$1.85
2.1-3.0 ppm	$1.80
3.1-3.5 ppm	$1.75 (feed grain price)

Source: GAO's analysis of May 1998 barley price schedules from two grain dealers in Bottineau County, North Dakota.

Along with steep price discounts, vomitoxin has had the effect of shifting the amount of malting versus feed grain barley produced in North Dakota. In the years before the scab and vomitoxin epidemic, the largest part of the state's barley production, and hence barley revenues, came from premium-priced malting barley—60 to 70 percent of all North Dakota barley sales. However, since the scab and vomitoxin epidemic, this trend has changed. Specifically, in several years during 1993 through 1997, many regions of North Dakota sold over 50 percent of the barley produced to the lower-valued feed grain market.[12]

Revenue Losses Because of Scab and Vomitoxin Varied by Location and Year

While scab and vomitoxin have reduced North Dakota barley farmers' revenues, the amount of loss has varied by region and year. As seen in table 2, the most severely affected area in North Dakota in terms of total revenue losses has been in the upper Red River Valley—the East Central and Northeast regions of the state—while the Southeast region has been least affected. Barley farmers suffered their greatest losses overall from vomitoxin in 1993 and in 1997, with losses of $62 million and $68 million, respectively. However, as the table shows, some regions—because they were less affected by vomitoxin and thus had more premium quality malting barley to sell—had a small increase in revenues in certain years.

[12]Other than its use in beer production, barley produced for human consumption represents a very small part, less than 5 percent, of North Dakota barley production.

Table 2: Changes in North Dakota Barley Farmers' Revenues as a Result of Scab and Vomitoxin, by Region, 1993-97

Dollar in millions

	Changes in barley revenues by crop reporting districts					
Year	North Central	Northeast	Central	East Central	Southeast	Total by year
1993	($11)	($21)	($8)	($16)	($6)	($62)
1994	$4	($14)	($1)	($13)	($1)	($26)
1995	$3	($10)	($2)	($10)	($1)	($20)
1996	($3)	($21)	$1	($3)	$1	($25)
1997	($12)	($36)	($7)	($11)	($2)	($68)
Total by region	**($19)**	**($102)**	**($17)**	**($53)**	**($10)**	**($201)**

Note: Dollars are stated in 1997 constant dollars. Losses are in parenthesis and represent revenue declines from barley contaminated by scab and vomitoxin. For example, farmers in the North Central District received $11 million less for their barley in 1993 because of this contamination. Losses were determined by comparing actual barley revenues with predicted revenues in the absence of vomitoxin for each year. Predicted revenues were developed using historical data from the pre-vomitoxin years of 1959 through 1992. (See app. I for details on our methodology.)

Source: GAO's analysis of data from various organizations.

Imports of Malting Barley From Canada Increased as a Result of Scab and Vomitoxin

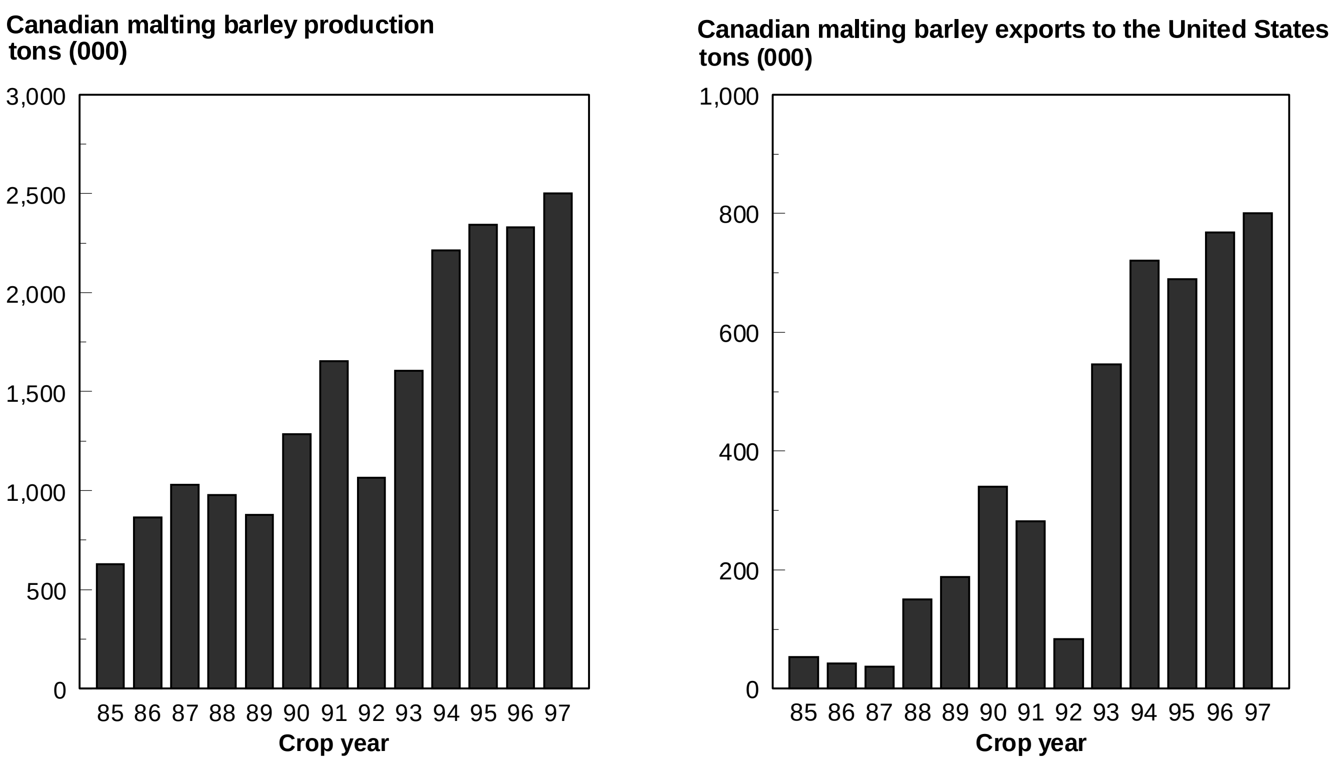
Because the scab and vomitoxin outbreak has reduced the supply of high-quality malting barley in the Northern Great Plains, the traditional purchasers of North Dakota malting barley—U.S. brewers and maltsters—have increasingly turned to Canadian and other U.S. sources. Figure 2 illustrates the increase in Canadian barley production and the increase in exports of malting barley to the United States. During the years of the scab and vomitoxin epidemic, average annual Canadian exports of malting barley to the United States increased by about 380 percent.[13] From 1993 through 1997, average annual barley exports from Canada reached 705,000 metric tons, compared to 147,125 metric tons from the pre-epidemic years of 1985 through 1992. In addition, to meet the increased U.S. demand for premium quality malting barley, Canadian production of malting barley grew from 1 million metric tons in 1993 to 2.2 million metric tons in 1997. Agriculture Canada[14] reported in 1997 that the United States has been Canada's largest market for malting barley over the past 4 years because of the shortage of quality U.S. malting barley. And, in 1997, malting barley imports from Canada represented over

[13]While we did not consider them central to discussing Canadian barley imports, we recognize that other factors influence these imports, such as exchange rates and the North American Free Trade Agreement.

[14]Agriculture Canada is the Canadian government's department of agriculture.

25 percent of all malting barley consumed by the U.S. brewing industry. In comparison, from 1988 through 1992, malting barley imports from Canada represented about 5 percent of all malting barley consumed by the industry.

Figure 2: Canadian Malting Barley Production and Exports to the United States, 1985-97



Note: Canadian production of malting barley is estimated by Agriculture Canada as including that country's domestic barley consumption and its exports of barley and barley malt.

Source: GAO's analysis of Agriculture Canada's data.

Although scab and vomitoxin have decreased North Dakota barley farmers' revenues, Canadian imports have somewhat moderated the blight's impact on U.S. brewers and maltsters. Shortages of malting barley in the United States as a result of these diseases would normally tend to increase U.S. malting premiums and prices, but these increases have been tempered by the large imports of Canadian malting barley. That is, even with a smaller domestic supply of malting quality barley, larger Canadian imports produce competitive pressures to keep prices below the levels they would be if imports were not part of the U.S. malting barley market.

Veratox Test Results Have Increased Variabilty at Levels Critical to Pricing Decisions

According to testing experts,[15] while the Veratox test kit serves the market's need for a relatively fast and cost-effective method for measuring vomitoxin in barley, it can produce test results that vary, particularly at concentrations critical to pricing decisions. Testing experts state that this variability can be reduced to some extent through quality assurance measures and training. Testing experts believe the HPLC and GC tests produce more accurate and consistent results, in part because they are conducted under controlled laboratory conditions. However, because of their complexity and cost, these tests are not practical for commercial use.

Barley Prices Are Set at Levels Where Veratox Test Results Vary the Most

Testing experts state that all tests for vomitoxin, including Veratox, experience variability in test results, particularly at the upper and lower limits of the test's ability to measure vomitoxin. This variability at the Veratox kit's lower limits of measuring vomitoxin can affect whether barley farmers receive a price discount. According to the manufacturer of the Veratox kit, the kit's lower limit of measurement is 0.5 ppm. At this concentration, Veratox test results can range from 0 ppm (where barley receives no discount) to 1.1 ppm (where barley would incur a substantial price discount). The market, therefore, is making crucial pricing decisions at concentration levels where the Veratox kit has substantial variability.

Our analysis of selected test data results supports expert opinion regarding Veratox's variability. To conduct this analysis, we compared 1,068 Veratox test results between (1) Neogen (the manufacturer of Veratox) and a North Dakota commercial grain testing facility and (2) these two facilities and GIPSA's in-house HPLC reference method.[16] We found that Veratox test results on the same samples of barley varied

[15]Testing experts we interviewed included officials from the Association of Official Analytical Chemists. See the scope and methodology section of this report for a listing of the organizations of the testing experts that we contacted.

[16]The test data were drawn from GIPSA's 1998 Sampling Variability Study. The purpose of the study was to determine how sample size affects variability in vomitoxin test results, but was not intended to represent all vomitoxin sampling efforts across North Dakota. Similarly, our analysis is not intended to represent all vomitoxin testing that occurs in North Dakota, but rather to address testing results from the two study participants that use the Veratox kit—the manufacturer and a North Dakota commercial grain testing facility. See app. II for a technical discussion of our analysis.

between Neogen and the commercial grain testing facility. Specifically, assuming that the HPLC test results represent the true concentration of vomitoxin, we found that at concentrations between 0.7 and 4 ppm, Neogen's estimate of vomitoxin levels was, on average, higher than the testing facility's. Consequently, farmers could have received different prices from each testing location, had the test results been the basis for a commercial sale. For example, we found instances in which, at a HPLC vomitoxin concentration of 1 ppm, the manufacturer's test results measured 1.1 ppm vomitoxin or greater, while the testing facility's measured 0.4 ppm. Had these results been the basis for a sale, a producer would have received $1.85 per bushel or less from the manufacturer but $2.55 per bushel from the testing facility. (See table 1 for an example of a price schedule for barley.)

Testing experts said that test methods have two types of variability—inherent and systemic. Inherent variability exists in all vomitoxin test methods and increases at the higher and lower limits of a given test method's ability to measure vomitoxin levels. Experts state that this variability cannot be controlled, which is why it is called inherent. The inherent variability of the Veratox test may affect barley buyers and farmers differently. According to GIPSA officials, grain elevators, which purchase barley from farmers and sell it to maltsters and brewers, may be less affected because they handle larger volumes of barley, with a correspondingly greater number of test results. Thus, the prices based on test results that were too high or too low—because of the inherent variability associated with the test kit—could counterbalance each other. As a result, grain elevators may be less affected by variable test results than barley farmers, who receive prices based on fewer test results. Because farmers may be more affected, some testing experts believe that if price discounts were started at 1 ppm, rather than at 0.5 ppm (the lower testing limit of the kit), farmers could receive more equitable test results. Some cereal scientists told us that no appreciable increases in beer production problems occur when brewing with barley having vomitoxin concentrations of 1 ppm versus 0.5 ppm. However, U.S. brewers and maltsters we talked to had varying opinions on whether beer production problems would increase at concentrations of 1 ppm.

Systemic variability, which refers to differences in how testers obtain and process grain samples and conduct tests, can also affect test results—for Veratox as well as for other testing methods. For example, a Veratox test involves many actions—selecting and processing the grain sample, extracting the vomitoxin from the grain, and measuring the vomitoxin.

Furthermore, the test equipment must be maintained and cleaned in order to achieve optimal results. Experts said that, because the potential exists for mistakes at each stage of the process, the accuracy of the kit's results is affected by the skill of the technician using it.

For all testing methods, a number of actions—including training and quality assurance[17] efforts—can be used to reduce systemic variability. First, test results from grain samples known to have vomitoxin can be compared across various testing facilities. This method, often referred to as a "check-sample program," helps ensure that testing facilities will achieve consistent test results. GIPSA's offices and its authorized testing facilities use this approach. Specifically, GIPSA sends samples of barley or wheat with known concentrations of vomitoxin to its authorized facilities for testing. GIPSA then compares the test results to determine if all the facilities are measuring about the same amount of vomitoxin. GIPSA officials believe that their check-sample program helps keep vomitoxin test results consistent among its testing facilities.

Second, testing experts stress the importance of using "quality assurance (QA) pools" to reduce systemic variability. QA pools consist of samples of naturally contaminated barley that a testing facility has tested many times in order to identify the true amount of vomitoxin in the sample. Testing facilities that practice quality assurance using QA pools will run tests on a pool in conjunction with daily vomitoxin tests. If a test on the QA pool detects an amount of vomitoxin that differs significantly from the known amount of vomitoxin in the pool, technicians are alerted that the tests on other samples also may be incorrect.

Finally, testing experts said that the training of the technicians who conduct the tests is critical for obtaining optimal test results. GIPSA, for instance, provides Veratox training to all personnel who work at GIPSA-authorized testing facilities in North Dakota.[18] However, GIPSA does not oversee the training given to other commercial grain testing facilities. Neogen, the Veratox kit's manufacturer, also provides training to new customers.[19]

[17]Quality assurance efforts are defined as any policy, procedure, or program whose purpose is to identify and address errors and inconsistencies in test results.

[18]GIPSA facilitates 1 day of training with the Veratox kit in coordination with the manufacturer—4 hours of lecture on the nature of mycotoxins and how the kit works and 4 hours of demonstration and practice led by a Neogen representative.

[19]Neogen's training consists of hands-on practice with the test kit. A Neogen official said that training normally lasts from 4 to 8 hours, but Neogen trainers will work with customers as long as necessary to ensure that they can use the kit.

Reference Methods Produce Accurate Results, but Are Not Practical for Commercial Use

According to testing experts, the HPLC and GC testing methods are widely accepted among analytical chemists for providing accurate and consistent results. For example, the Association of Official Analytical Chemists[20] has approved a GC method and reviewed an HPLC method; and the American Society of Brewing Chemists[21] has approved a GC method for industry use. In addition, the HPLC and GC methods are sometimes used to assess the performance of commercial test kits, including Veratox, because these chromatographic methods, according to testing experts, have less variability in their test results. For instance, GIPSA evaluates the performance of any new commercial test kit against its HPLC reference method before permitting its use by GIPSA employees and GIPSA-authorized testing facilities. Furthermore, GIPSA uses the HPLC method in its check-sample program.

While these reference methods have less variability than Veratox, they are not practical for use at commercial testing facilities and grain elevators for several reasons, according to experts we spoke with. First, the procedures for preparing and testing the vomitoxin samples for these methods take several hours to complete. However, during the barley harvest, farmers typically deliver their barley to grain elevators by trucks that must unload and return to the fields for other loads. Because of the need for quick turnaround, the farmers, elevators, and truck drivers cannot wait several hours for a vomitoxin test to be conducted. In comparison, the Veratox test takes about 30 minutes to conduct. Second, the HPLC and GC methods require thousands of dollars in equipment investments. For example, HPLC and GC test equipment cost between $40,000 to $60,000 to purchase, while the Veratox test equipment costs about $3,200.

[20]The Association of Official Analytical Chemists (International) is an independent association devoted to promoting methods validation and quality of measurements in the analytical sciences through, among other things, studying, validating, and approving methods of analysis.

[21]The American Society of Brewing Chemists was founded to improve and bring uniformity to the brewing industry on a technical level by resolving technical problems on an industrywide basis, keeping current on the technical needs of the brewing industry, and anticipating the industry's future concerns.

Under Conditions of Light Infestation, Short- and Longer-Term Actions May Reduce the Impact of Scab and Vomitoxin

In barley, scab, and the vomitoxin resulting from scab, can be reduced somewhat through the use of fungicides and certain farming practices, such as crop rotation and deeper tillage of the soil.[22] However, costs and other factors limit the usefulness of these actions, and their impact is minimal when the infestation is severe.[23] In addition, varieties of barley that are more resistant to scab and vomitoxin will not be commercially available for at least 6 years. According to cereal scientists, improved barley varieties combined with short-term actions may eventually help some farmers to better manage scab and vomitoxin infestations, thereby reducing farmers' financial losses. However, it is unlikely that vomitoxin will be completely eliminated in the foreseeable future.

Short-Term Actions May Be Helpful, but Have Limitations

According to North Dakota extension agents[24] and cereal scientists, a number of short-term actions can help farmers reduce scab, and thus vomitoxin concentrations, in barley. First, crop rotation—changing the type of crop planted each growing season—enriches the nutrients in the soil and decreases the incidence of crop disease. Although most farmers rotate crops routinely, the inclusion of more broadleaf crops in a rotation is likely to help decrease the levels of scab in the soil. Broadleaf crops, such as sunflowers, canola, and sugarbeets, are not as susceptible to scab as cereal grains, such as barley and wheat. However, even if rotation initially helps reduce scab levels, infestation could occur from airborne spores from other locations. Furthermore, other problems could discourage the use of crop rotations: (1) some broadleaf crops (such as sugarbeets) require costly equipment and costly contractual agreements and (2) many broadleaf crops cannot be grown in certain parts of North Dakota, thereby limiting the number of crops that can be included in rotations. For example, some farmers in north central North Dakota cannot easily grow beans because the climate is generally too cold and the growing season is too short. As a result, these farmers have shorter rotation cycles and are forced to more quickly return to crops (such as barley and wheat) that are highly susceptible to scab.

[22]As mentioned previously, vomitoxin is caused by the scab disease. Thus, all efforts to reduce vomitoxin must begin with reducing the occurrence of scab.

[23]Although a formal definition does not exist, one North Dakota extension agent described a year of light infestation as one in which 5 to 10 percent of the barley crop acres in one county are contaminated with scab and vomitoxin; a year of moderate infestation as one in which about 50 percent of the barley acres in one county are contaminated; and a year of severe infestation as one in which 75 percent or more of the barley acres in one county are contaminated.

[24]University-based extension specialists interact with scientists and relay scientific and other knowledge to farmers and other research customers.

Second, deep tilling to completely overturn the soil—which does not occur with conventional tilling—could reduce scab levels. Since scab stays through the winter in infected crop stubble, tilling deeper into the soil buries any infected residue and can help prevent scab from spreading to the next year's crop. However, deep-till practices result in less moisture in the soil, causing farmland to become more prone to wind and water erosion, and are therefore not practical for farmers in the drier portions of North Dakota (such as the western portion of the state). Deep tilling also requires farmers to purchase more expensive tilling equipment. Furthermore, as with crop rotation, infestation can occur from airborne spores if even one scab-infected farm in an area does not use deep tilling. Thus, for optimal effectiveness, deep tilling has to be conducted across many farms.

Third, applying fungicides can help reduce vomitoxin. However, fungicides are not always reliable because of weather conditions and the difficulties associated with applying them. North Dakota farmers primarily use two types of fungicides, protectant and systemic. Protectant fungicides (which cover the plant externally) have been used for a number of years and are easily washed off by rain and degraded by sunlight. Systemic fungicides, which are newer, get absorbed into the barley plant within 4 to 8 hours of application and are not affected by sunlight or water. However, the timing of the application of both systemic and protectant fungicides is critical. They must be applied immediately after the barley flower blossoms because a new flower can become infected with airborne scab spores within 3 to 4 days. Once the barley flower is infected with the scab fungus, the fungus has the potential to produce vomitoxin. In addition, a farmer can expect to spend between about $90,000 and $138,000 to spray a 3,000-acre barley crop with a fungicide.[25] Thus, in deciding whether to use fungicides, farmers must compare the costs they will incur in applying them with the higher price they could receive if their barley is less contaminated with vomitoxin.

North Dakota extension agents told us that using the deep-till and rotation farming practices with fungicides increases the overall effectiveness of these short-term actions in reducing scab and lowering vomitoxin levels. However, they also noted that if airborne scab spores are widespread and weather conditions are favorable to fungal growth, barley crops would still become contaminated. Thus, they believe that these short-term actions will be effective only in years of light infestation.

[25]The range of costs for fungicides is due primarily to whether a crop is sprayed from the ground or from the air. If a farmer chooses to spray a field from the ground, a large capital investment in equipment is required.

More Resistant Barley Varieties Are Expected to Be Commercially Available in Several Years

North Dakota State University, the University of Minnesota, South Dakota State University, and Busch Agricultural Resource, Inc.,[26] began a cooperative breeding effort to develop more scab-resistant barley in 1994. The four institutions exchange and test potential new varieties of barley. They also share information about new barley varieties that show resistance to scab and vomitoxin.

In March 1997, a U.S. Wheat and Barley Scab Initiative was formed by scientists, members of the wheat and barley industries, commodity groups, and others to call national attention to the scab problem and to set national priorities for scab research. In fiscal year 1998, the Congress appropriated $500,000 to USDA to fund the scab research plan established by the leaders of the initiative; in fiscal year 1999, an additional $3 million was appropriated for the effort. Several of the research areas focus on developing more resistant varieties and assessing the effectiveness of fungicides in combating scab. Although USDA's Agricultural Research Service (ARS) is funding the initiative, scientists at state land grant universities, including North Dakota State University, will perform most of the research.

According to barley breeders and farming experts, because of many scientific and commercial requirements, it takes about 8 to 10 years to breed, test, and release a new variety of barley. The breeding process includes several steps. First, a breeder must identify the genetic characteristics that could make the barley more resistant to vomitoxin. Second, these characteristics need to be combined and strengthened through successive new generations of barley varieties. Third, new varieties must be tested under multiple environmental conditions to ensure that they are truly resistant. During the breeding process, new varieties may sometimes appear to be resistant to scab when, in fact, they are not. For example, if a greenhouse containing a new variety being tested for resistance is kept cool and limited moisture is allowed to accumulate on the barley, little scab will grow. This may lead the breeder to believe that the variety is scab-resistant, while, in fact, the greenhouse environment suppressed scab growth.

Fourth, after a breeder is confident that new varieties are truly resistant, they must be tested and screened for necessary malting and brewing qualities. For example, a new variety of barley must be uniform in size and have plump kernels (necessary for successful beer brewing) or maltsters

[26]Busch Agricultural Resource, Inc., is an agricultural research and operations subsidiary providing brewing raw materials to Anheuser-Busch, Inc.

and brewers will not be interested in buying it.[27] According to scientists, while some more resistant barley varieties are currently undergoing commercial trials by maltsters and brewers, none contain all of the characteristics that the industry requires.

Lastly, new barley varieties must be tested for commercial viability. Any new variety of barley that meets the malting and brewing industry's requirements would also have to be high-yielding in order for it to be commercially attractive to farmers. Scientists estimate that a commercially acceptable, more scab-resistant barley variety is at least 6 years away.

Breeders expect that, over time, new, more resistant barley, combined with short-term actions may help farmers to better manage scab and vomitoxin infestations and reduce their financial losses. However, these experts state that a more resistant barley variety will not completely eliminate the incidence of scab and vomitoxin, particularly during periods of moderate or severe infestation.

Agency Comments

We provided a draft of this report to USDA for its review and comment. We met with the Deputy Administrator, Grain Inspection, Packers and Stockyards Administration, and with other officials from that organization and USDA's Agricultural Research Service. The officials generally agreed with the information presented in the report and provided several technical changes and clarifications. We have incorporated these changes as appropriate.

Scope and Methodology

You asked us to (1) determine the financial impact of scab and vomitoxin on North Dakota barley farmers, (2) assess the performance of vomitoxin test methods, and (3) identify short- and long-term actions that could help reduce the impact of scab and vomitoxin on North Dakota barley farmers.

To address the first question, we collected and developed historical data on North Dakota barley prices and production for 1959 through 1992—the period before the scab and vomitoxin epidemic—and on key weather factors affecting production for both that period and the blighted years. We used these data to estimate (1) what barley prices and production would have been in 1993 through 1997 in the absence of scab and

[27] A University of Minnesota plant pathologist estimates that breeders must consider at least 30 different barley traits in order to develop barley that meets the brewing industry's needs.

vomitoxin and (2) what revenues would have been in the absence of scab and vomitoxin. We then compared this estimate of revenues with actual barley revenues to determine farmers' losses by year and by crop reporting district. We also developed information on how prices are transmitted from the maltsters and brewers down to the farmers, and collected data on Canadian production and exports of malting barley to the United States during this time period.[28] To conduct these tasks, we used data from the North Dakota State University, GIPSA, the North Dakota Department of Agriculture, USDA's National Agricultural Statistics Service and its Economic Research Service, the North Dakota Barley Council, and Agriculture Canada. We also conducted interviews with officials from these organizations and with North Dakota grain dealers. (See app. I for a detailed description of our data sources, methodology and the results of our analysis.)

To address the second question, we reviewed GIPSA, industry, and academic studies on the test methods; interviewed testing experts; and analyzed Veratox test data on vomitoxin from GIPSA's 1998 Sampling Variability Study. Using data from the study, we assessed the performance of vomitoxin test results on the basis of the variability of test results between testing facilities. Testing experts we spoke with included officials at GIPSA, FDA, and major U.S. malting and brewing companies; academic researchers; and representatives of the Association of Official Analytical Chemists, the American Society of Brewing Chemists, the American Malting Barley Association, the North Dakota Barley Council, and the North Dakota Grain Dealers Association. (See app. II for a detailed description of our methodology and the results of our analysis.)

To address the third question, we (1) obtained information on academic, public, and private research on actions to reduce the impact of scab and vomitoxin and on progress in developing more scab-resistant barley and (2) interviewed scientists at North Dakota State University and the University of Minnesota and officials at USDA's Economic Research Service and Agricultural Research Service.

Finally, we had a draft of this report reviewed for accuracy and objectivity by several economists and agricultural experts from academia.

[28]To convert the revenue losses to 1997 constant dollars, we used the Department of Commerce's chain-type price index for gross domestic product.

We did not independently verify the data obtained from our sources. Our work was conducted from April 1998 through February 1999 in accordance with generally accepted government auditing standards.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days from the date of this letter. At that time, we will provide copies of this report to Chairman Richard Lugar and Ranking Minority Member Tom Harkin of the Senate Committee on Agriculture, Nutrition, and Forestry; Chairman Larry Combest and Ranking Minority Member Charles Stenholm of the House Committee on Agriculture; other interested congressional committees; and the Honorable Dan Glickman, the Secretary of Agriculture. We will also make copies available to others upon request.

If you or your staff have any questions about this report, please contact me at (202) 512-5138. Major contributors to this report are listed in appendix III.

Sincerely yours,

Robert E. Robertson
Associate Director, Food and
Agriculture Issues

Contents

Figures

Abbreviations

ARS	Agricultural Research Service
CRD	Crop Reporting District
ERS	Economic Research Service
FDA	Food and Drug Administration
FSA	Farm Service Agency
GC	gas chromatography
GIPSA	Grain Inspection, Packers and Stockyards Administration
HPLC	high pressure liquid chromatography
NASS	National Agricultural Statistics Service
QA	Quality Assurance
USDA	United States Department of Agriculture

Estimation of Revenue Losses to North Dakota Barley Farmers as a Result of Scab and Vomitoxin

This appendix explains the methods and data we used to estimate the revenue losses for North Dakota barley as a result of the scab and vomitoxin epidemic for 1993 through 1997.[29] To develop this estimate, we first estimated what barley revenues would have been in the absence of the vomitoxin epidemic in North Dakota.[30] This required estimating what production levels and prices would have been in each district in each year. In turn, estimating production levels required estimating both yields and the ratios of harvested-to-planted acres in the absence of the disease. We then compared estimated barley revenues without the disease to actual barley revenues received, which we calculated from price and production data, to obtain estimated losses. We then totaled all the crop reporting districts and all the years to obtain an estimate of total losses during this period.

Estimating Revenue Losses in the Absence of Scab and Vomitoxin

To estimate losses resulting from scab and vomitoxin, we first estimated what barley revenues would have been during this time period if the epidemic had not occurred, but all other relevant factors (such as weather) had been unchanged. We estimated both production levels and prices and multiplied them to obtain estimated revenues.

Estimating Production in the Absence of Scab and Vomitoxin

As a first step in estimating production, we used a regression analysis to estimate barley yields from 1959 through 1992 (before the scab and vomitoxin epidemic) for region i in time period t as a function of weather events and a time trend:

(1)

$$y_{it} = \beta_0 + \beta_1 P_{it} + \beta_2 P_{it}^2 + \beta_3 T_{it} + \beta_4 t$$

where

y_{it} = harvested yield in region i in year t

[29]The method used in this analysis is adapted from a report by D. Demcey Johnson, George K. Flaskerud, Richard D. Taylor, and Vidyashankara Satyanarayana, “Economic Impacts of Fusarium Head Blight in Wheat,” Agricultural Economics Report No. 396, June 1988, Department of Agricultural Economics, North Dakota State University, Fargo, North Dakota.

[30]North Dakota has nine major crop reporting districts (CRD). For this analysis, we focused on the five regions where substantial scab and vomitoxin outbreaks have occurred—the North Central, Northeast, Central, East Central, and Southeast CRDs of the state.

P_{it} = the difference between average total precipitation and total precipitation during the growing season divided by the standard deviation of total rainfall for region i and year t

P_{it}^2 = the squared value of P_{it}, the precipitation deviation variable

T_{it} = the difference between historical average temperature during the growing season and average temperature during the growing season divided by the standard deviation of average temperature for region i, year t

t = a time trend variable, t=1,...,34

In this regression, we transformed both average growing season temperature and total rainfall to measures of deviations by subtracting their historical average levels from their actual levels and dividing by their standard deviations.[31] As a result, these variables measure how close a particular year's average temperature or total rainfall is to its historical average. For example, values greater than +1 are associated with hot weather or wet months; values less than –1 are associated with dry or cool months; and values between +1 and –1 are near the average. We used these transformed weather variables in the regression rather than the actual values because they were more significantly related to yield and contained less multicollinearity. In addition, because there is an optimum level of precipitation, beyond which yields may decrease, we included a squared precipitation term in our equation. Other agricultural economists analyzing yield have also used squared precipitation terms. Finally, we inserted an annual time trend to represent yield changes because of changes in such things as technology, input use, or farm size.

Table I.1 displays our estimates of the parameters of these regression equations for each CRD analyzed. Except for P_{it}^2 in CRDS 3 and 5, all independent variables were significant at the 0.05 level and above and displayed the expected signs.

[31]Lloyd D. Teigen and Milton Thomas, Jr., Weather and Yield, 1950-1994: Relationships, Distributions, and Data, Economic Research Service Staff Paper, Commercial Agriculture Division, Number 9527.

Table I.1: Barley Yield Equation Parameter Estimates by Crop Reporting District

	Crop reporting district				
	CRD 2 North Central[a]	CRD 3 Northeast	CRD 5 Central	CRD 6 East Central	CRD 9 Southeast
Intercept	25.87[b] (9.06)	24.43[b] (8.48)	21.28[b] (7.73)	27.20[b] (10.01)	26.43[b] (9.66)
Precipitation deviation (P_{it})	4.10[b] (3.72)	3.26[b] (2.72)	5.37[b] (4.25)	2.96[b] (2.33)	5.49[b] (3.56)
Precipitation deviation squared (P_{it}^2)	–2.65[b] (–2.47)	–2.31 (–1.65)	–1.27 (–1.34)	–2.27[b] (–2.14)	–3.60[b] (–3.83)
Temperature deviation (T_{it})	–3.89[b] (–3.31)	–3.41[b] (–2.47)	–4.56[b] (–3.44)	–3.57[b] (–2.67)	–2.87[b] (–2.07)
Time trend (t)	0.72[b] (5.64)	1.15[b] (9.00)	0.93[b] (7.02)	1.17[b] (9.09)	0.92[b] (7.01)
R^2	0.71	0.75	0.69	0.76	0.70
Adjusted R^2	0.68	0.72	0.64	0.72	0.66
DW	1.74	1.79	1.62	1.91	1.79
Number of Observations	34	34	34	34	34

Note: Numbers in the parentheses are t-values.

[a]Indicates error structure corrected for first order autocorrelation.

[b]Indicates parameter is statistically significant at the 0.05 level or higher

We also performed a Chow test to determine whether barley yields were homogeneous across CRDs and, thus, if we could pool all of our data into one regression equation. This hypothesis, however, was rejected at the 0.05 level, and we therefore used our yield estimates from the regressions of the separate CRDs in our analysis.

In equation 2, we calculated yield in the absence of scab and vomitoxin as a weighted average of predicted yield from equation 1 and actual yield.

(2)

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

In equation 2, yn_{it} denotes yield in the absence of scab and vomitoxin, yf_{it} the predicted yield from equation 1, and ys_{it} the actual yield in a scab-infected year. The fraction of yield shortfall attributable to scab and vomitoxin is denoted α_{it}. If vomitoxin were the only factor accounting for a shortfall during the scab-infected years, then $\alpha = 1$ and $yn_{it} = yf_{it}$; that is, the yield that would have occurred in the absence of the disease equals the predicted yield from equation 1.

Since scab and vomitoxin occur simultaneously with other crop diseases or weather problems, such as flooding, in these regions, we needed to estimate the fraction of yield shortfall resulting only from the disease. In order to obtain these estimates, we first asked experts at the North Dakota State Extension Service as well as the North Dakota State Plant Pathology Department what yield losses (in percentages) were due only to scab and vomitoxin for each year and each district. We then multiplied these percentages for each CRD and each year by our predicted yields, or the yields in the absence of vomitoxin, to determine yield loss in bushels per acre. In order to estimate the percent of yield loss resulting only from the disease, we then divided these yield losses by the difference between predicted and actual yields (or total yield shortfall) in order to estimate the fraction of yield shortfall resulting only from the disease. These calculated percentages are shown in table I.2:

Vomitoxin

Table I.2: Fraction of Yield Shortfall Resulting From the Presence of Scab and Vomitoxin by CRD, 1993-97

	Crop reporting district				
Year	CRD 2 North Central	CRD 3 Northeast	CRD 5 Central	CRD 6 East Central	CRD 9 Southeast
1993	1.00	0.24	0.26 - 0.43	0.17 - 0.28	0.19 - 0.31
1994	1.00	0.32 - 0.65	1.00	0.18 - 0.30	0.19 - 0.32
1995	0.26 - 0.52	0.34	0.16 - 0.32	0.15 - 0.31	0.15 - 0.30
1996	0.84 - 1.00	0.69 - 0.93	1.00	0.66	0.75 - 1.00
1997	0.43 - 0.87	0.40 - 0.53	0.45 - 0.68	0.11 - 0.26	0.19 - 0.38

In addition to estimating yield in the absence of scab and vomitoxin, we needed to calculate the ratio of harvested-to-planted acres to estimate barley production. During the years of the epidemic, many acres that were planted to barley actually went unharvested. Because the ratio of actual harvested-to-planted acreage during the scab-infected years might have differed from the predicted ratio for reasons other than scab and vomitoxin, we again used a weighted average of the predicted and actual ratios to estimate the ratio in the absence of the disease. We used past values of the ratio of harvested-to-planted acreage as the predicted values, but we used the same α values to measure the fraction of yield shortfall resulting from scab and vomitoxin. Specifically, in equation 3, we calculated the ratio of harvested-to-planted acres to account for acreage that was left abandoned because of scab and vomitoxin for each region for each time period as:[32]

(3)

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

where

ah_{it} = actual harvested acres in time period t in CRD i

ap_{it} = actual planted acres in time period t in CRD i

R_i = the average[33] of the ratio of harvested-to-planted acres, 1983-92

Rn_{it} = the ratio of planted-to-harvested acres, in the absence of vomitoxin

α_{it} = the same adjustment factor used to calculate yield without vomitoxin

Finally, we combined our estimates of yield and the ratio of harvested-to-planted acreage in the absence of vomitoxin to estimate production in the absence of vomitoxin, qn_{it}:

(4)

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

In order to estimate production in the absence of scab and vomitoxin, without overestimating losses, we used the maximum of estimated yield in

[32]While this calculation is an adjustment for reductions in harvested-to-planted barley acres, we did not make an adjustment for the decrease in planted acres. Overall, however, we assumed that farmers who reduced planting barley acreage increased their acreage of other crops. Therefore, while revenue went down because of reduced barley acres, revenue for the whole farm may not have decreased because of the increased plantings of other crops.

[33]Here, we took an olympic average of the ratio of harvested-to-planted acres for the 10 years from 1983 through 1992. An olympic average omits the maximum and minimum values contained in a given sample. It is used when the sample is small and may have observations that are unrepresentative (such as a drought year).

the absence of vomitoxin and actual yield and the maximum of the calculated ratio of harvested-to-planted acres without vomitoxin and the actual ratio. For example, if the estimated yield falls below actual yield in a scab year, actual yield would be used instead of the estimated yield (without scab/vomitoxin) to estimate production. The product of the second term and acres planted, ap_{it}, equals harvested acres in a year without the presence of scab and vomitoxin.

Estimating Barley Malting Premiums and Feed Grain Prices in the Absence of Vomitoxin

As the next step in determining barley revenue in the absence of vomitoxin, we estimated both malting barley premiums and feed grain prices for 1993 through 1997 had there been no disease. To do this, we used regression analysis and historical data on price and production from 1959 through 1992 to estimate price equations for both malting barley premiums and feed grain prices. First, we explain malting premium price movements by total barley production or its relationship to the larger national barley market. Since the proportion of malting barley in the entire crop was fairly stable in the years prior to the vomitoxin 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 5 we specify the historical association between malting premiums, Pi^{m} and total U.S. barley production, Q_T, for each CRD analyzed, i:

(5)

$$P_i^m = \alpha_0 + \alpha_1 Q_T$$

Table I.3 shows the results of this analysis.

Table I.3: Malting Barley Premium Parameter Estimates by Crop Reporting District

	Crop reporting district				
Independent variable	**CRD 2 North Central**	**CRD 3 Northeast**	**CRD 5 Central**	**CRD 6 East Central**	**CRD 9 Southeast**
Intercept	0.88[a] (3.68)	1.42[a] (6.16)	1.07[a] (4.48)	2.05[a] (6.85)	1.07[a] (4.23)
Total production (Q_T)	–0.0015[a] (–2.78)	–0.0026[a] (–5.29)	–0.0018[a] (–3.54)	–0.0039[a] (–6.07)	–0.0018[a] (–3.18)
Reg R^2	0.20	0.47	0.29	0.54	0.25
DW	1.66	1.77	1.81	1.84	2.00
Observations	34	34	34	34	34

Note: Numbers in the parentheses are t-values.

[a]Indicates the parameter is statistically significant at the 0.05 level or higher.

As table I.3 shows, we found a negative and highly significant association between malting premiums and total barley production at the national level for all CRDs. We also tried other variations of this regression model, including ones using combinations of stocks as well as barley yields for independent variables. However, these variables did not perform as well as the total barley production variable. Because of the presence of positive serial correlation in all CRDs, we used the Yule-Walker regression technique[34] to derive our estimates. In general, serial correlation causes standard errors to be biased downward, thus indicating that parameter estimates are more precise than they actually are. Therefore, correcting for 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. Because barley feed grain prices, P_i^f, are driven primarily by corn prices, in equation 6, we specify the historical association between feed grain barley prices, the price of corn, P_C, and total U.S. barley production, Q_T, as:

(6)

$$P_i^f = \alpha_0 + \alpha_1 P_C + \alpha_2 Q_T$$

[34]The Yule-Walker regression technique starts by forming the ordinary least-squares estimate of the parameters. Next, given the vector of autoregressive 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.

To correct for first-order serial correlation, as in the malting premium regression models, we used the Yule-Walker regression technique for the feed grain regressions. As table I.4 indicates, the total barley production variable displayed a negative sign and was significant at the 0.10 percent level and above in all CRDs except 6. In all CRDs, the price of corn was positively related to barley feed grain prices and highly statistically significant.

Table I.4: Feed Grain Barley Parameter Estimates by Crop Reporting District

	Crop Reporting District				
Independent variable	CRD 2 North Central	CRD 3 Northeast	CRD 5 Central	CRD 6 East Central	CRD 9 Southeast
Intercept	0.24 (1.19)	0.28 (1.48)	0.21 (1.19)	0.22 (1.13)	0.21 (1.04)
Corn price (P_C)	0.78[a] (17.75)	0.75[a] (18.18)	0.77[a] (19.81)	0.75[a] (17.42)	0.78[a] (17.49)
Total production (Q_T)	–0.0009[a] (–2.07)	–0.0008[a] (–2.10)	–0.0007[b] (–2.00)	–0.0006 (–1.39)	–0.0007[b] (–1.76)
Reg R^2	0.91	0.92	0.93	0.91	0.91
DW	1.94	1.93	1.91	1.87	1.91
Observations	34	34	34	34	34

Note: Numbers in parentheses are t-values.

[a]Indicates parameter is statistically significant at the 0.05 level or higher.

[b]Indicates parameter is statistically significant at the 0.10 level.

Substituting in actual values of barley production and corn prices for years 1993 through 1997, we used these regression parameters to predict what malting barley and feed grain barley prices would have been in the absence of the vomitoxin epidemic for these years. We assume that malting barley prices are the sum of estimated feed grain prices plus estimated malting premiums.

Estimation of Barley Revenue in the Absence of Scab and Vomitoxin

As the final step in estimating barley revenue in the absence of vomitoxin, we combined our previously obtained estimates of production and prices without the disease to obtain revenue as the product of production and price. However, since barley production data are only for total production, and are not separated out for the malting and the feed grain markets, we first needed to allocate total production to these markets. We derived the proportion of the crop sold as malting barley and feed grain barley by using actual data on the prices of malting barley, P_M, feed grain barley, P_F, and the total average barley price, P_B. Because the overall price of barley, P_B, is a weighted average of the malting and feed grain price, using[35] equations 7 and 8, we can obtain the proportion of barley that is sold to the malting market, $nbar_i^m$, and the proportion sold to the feed grain market ($1 - nbar_i^m$) as equation 7 shows:

(7)

$$P_B = nbar_i^m * P_M + (1 - nbar_i^m) * P_F$$

Rearranging terms, we can express the proportion of barley sold to the malting market as a function of observed prices as equation 8 shows:

(8)

$$nbar_i^m = (P_B - P_F)/(P_M - P_F)$$

Using historical malting and feed grain prices from 1959 through 1992, we obtained proportions for each year and took their average to derive malting barley and feed grain weights. These weights represent the proportions of malting and feed grain barley in the market in a year without the disease. Table I.5 shows, for each CRD, these estimated average weights:

Table I.5: Estimated Average Malting and Feed Grain Weights by Crop Reporting District, 1959-92

Barley market	CRD 2 North Central	CRD 3 Northeast	CRD 5 Central	CRD 6 East Central	CRD 9 Southeast
Malting ($nbar^m_i$)	0.71	0.68	0.62	0.79	0.60
Feed grain ($1-nbar^m_i$)	0.29	0.32	0.38	0.21	0.40

To estimate the amount of production that would have gone to the malting barley and feed grain markets for each district in each year from 1993 through 1997 in the absence of vomitoxin, we multiplied these weights by our estimate of total barley production (without vomitoxin). For instance, in order to account for the amount of barley that typically went into the

[35] In order to calculate average barley prices, the National Agricultural Statistics Service (NASS) surveys farm elevators for malt and feed grain prices as well as quantities sold in North Dakota counties. Typically, this covers about one-third of the barley farmers in a county. According to the Associate Administrator of NASS, three caveats are associated with this method. First, there may be some error because of sampling expansion factors; second, the measurement is taken at the elevator, not where the grain actually comes from; and third, there may be some discrepancy because of carryover stocks from one year to another.

malting side of the market for CRD i in year t, we multiplied $nbar_i^m$, the average proportion of malting barley for that CRD, by the estimated production in that district in year t in the absence of the disease, qn_{it} (from equation 4). Finally, to estimate malting barley revenue for years 1993 through 1997 in the absence of vomitoxin, we multiplied the estimated malting barley production for each district and year by the predicted malting barley price (in the absence of vomitoxin), nP_i^m, for that district and year. We used the same procedure to estimate the revenue for all CRDs for the feed barley market. Equation 9 summarizes how we estimated total barley revenue in a particular district and year in the absence of vomitoxin ($NREV_{it}$):

(9)

$$NREV_{it} = (nbar_i^m * qn_{it} * nP_{it}^m) + (nbar_i^f * qn_{it} * nP_{it}^f)$$

where

$nbar_i^m$ = proportion of malting barley production without vomitoxin for CRD i

$nbar_i^f$ = proportion of feed barley production without vomitoxin for CRD i

qn_{it} = total quantity of barley production for CRD i in year t, (from eq. 4)

nP_{it}^m = predicted malting barley price, without vomitoxin, for CRD i, time t

nP_{it}^f = predicted feed grain barley price, without vomitoxin, CRD i, time t

We used the chain-type price index for gross domestic product to express all revenues in 1997 dollars and then totaled over the years 1993 through 1997 to obtain an estimate for each district of what barley revenues would have been during this period in the absence of vomitoxin.

Calculating Actual Revenue From Malting Barley and Feed Grain Barley

Using equation 10, we calculate the actual amount of revenue from barley production, $AREV_{it}$, for CRD i, in time period t as:

(10)

$$AREV_{it} = (abar_{it}^m * qa_{it} * aP_{it}^m) + (abar_{it}^f * qa_{it} * aP_{it}^f)$$

The actual amount of production in each CRD in each year is denoted qa_{it}, while the actual market prices of malting barley and feed barley are represented by aP_{it}^{m} and aP_{it}^{f}, respectively. For each year between 1993 and 1997 and for each CRD, we calculated the proportion of barley sold to the malting market, $abar_{it}^{m}$ and the proportion sold as feed, $abar_{it}^{f}$, using the same method as we did in equation 8. Table I.6 displays these weights for each CRD.

Table I.6: Estimated Malting Barley and Feed Grain Barley Weights, by Crop Reporting District, 1993-97

Market	Year	CRD 2 North Central	CRD 3 Northeast	CRD 5 Central	CRD 6 East Central	CRD 9 Southeast
Malting barley	1993	0.22	0.28	0.61	0.42	0.18
	1994	0.78	0.53	0.67	0.32	0.53
	1995	0.85	0.72	0.70	0.55	0.67
	1996	0.58	0.43	0.91	0.77	0.43
	1997	0.58	0.20	0.68	0.28	0.84
Barley feed grain	1993	0.78	0.72	0.39	0.58	0.82
	1994	0.22	0.47	0.33	0.68	0.48
	1995	0.15	0.28	0.3	0.45	0.33
	1996	0.42	0.57	0.09	0.23	0.57
	1997	0.42	0.8	0.32	0.72	0.16

Calculating Changes in Farm Revenue Resulting From Scab and Vomitoxin

Using equation 11, we calculated total changes in revenue from barley production for North Dakota due to scab and vomitoxin, Δ_{it}, as:

(11)

$$\sum_{i=1}^{5}\sum_{t=93}^{97}\Delta_{it}=(NREV_{it}-AREV_{it})$$

This total represents the sum of the differences between the actual revenue, $AREV_{it}$, and the predicted revenue in each year, in the absence of vomitoxin, $NREV_{it}$, for each CRD i in each year, 1993 through 1997.

Data Used to Estimate Losses in Farm Revenues From Scab and Vomitoxin

We gathered data from several sources for our calculation of the revenue losses for North Dakota barley as a result of scab and vomitoxin. Our main source of data, the North Dakota Agricultural Statistics Service, provided information by CRD on planted and harvested barley acres, total barley production, malting barley prices, feed grain barley prices, and average barley yields for 1959 through 1997. We used weather data, average temperature and total precipitation by CRD from 1950 to 1997, supplied by USDA's Economic Research Service as well as by North Dakota State University. North Dakota State University area crop extensionists and plant pathologists familiar with vomitoxin provided estimates of the fraction of yield shortfall attributed to vomitoxin for 1993 through 1997. Finally, we used data on U.S. barley production and corn prices from 1959 to 1997 from NASS in our estimation of malting barley premiums and barley feed prices.

Analysis of the Veratox Test Kit's Performace

According to our analysis of the data from the Grain Inspection, Packers and Stockyards Administration's (GIPSA) 1998 Sampling Variability Study, the Veratox test results from Neogen (the kit's manufacturer) and Grand Forks Grain Inspection, Inc. (a GIPSA-authorized testing facility) differed significantly from each other and from GIPSA's high pressure liquid chromatography (HPLC) results. Our analysis is not projectable to all Veratox test results in North Dakota because the data from GIPSA's sampling study are not representative of all Veratox testing and barley sampling throughout the state.

GIPSA's 1998 Data From Its Sampling Variability Study

GIPSA's sampling study was designed to determine how sampling size and method affect variability in vomitoxin test results. In this study, GIPSA (1) obtained six bulk barley samples from various elevators to study the effect of sampling size on variability and (2) sampled 10 trucks using different sampling methods to determine the effect of sampling method on variability. All samples were cleaned, ground, and subdivided into portions for testing by the Grand Forks Grain Inspection's laboratory. Additional portions were provided to Neogen and Romer (another test kit manufacturer) for testing in their respective laboratories, and portions of the truck samples were tested by GIPSA in its Kansas City, Missouri, laboratory using the HPLC method. Neogen and Grand Forks Grain Inspection tested each subsample using Neogen's Veratox test kit.[36] Neogen performed two tests on each subsample it received, and Grand Forks Grain Inspection performed one test on each subsample it received.

GIPSA did not intend to have the results from its barley sampling study represent the variability that exists with all barley sampling in North Dakota. It selected its test lots to ensure that vomitoxin concentration levels in the samples would fall within the Veratox test kit's range of measurement ability—that is, from 0.5 parts per million (ppm) to 5 ppm. In addition, test data were from samples that differed in size and method of collection because GIPSA's purpose was to assess the effect of these variables (size and sampling method) on vomitoxin test results. However, because GIPSA found that sample size and sampling method did not significantly alter the variability of test results, we concluded that the lack of uniformity in sample size and sampling method is not a significant limitation to our analysis.

[36]The samples were also tested by North Dakota State University using gas chromatography and Romer Labs, Incorporated, using its FluoroQuant test kit and the HPLC method.

We analyzed 376 Veratox tests performed by Grand Forks Grain Inspection and 692 tests performed by Neogen.[37] According to GIPSA officials, greater variability occurs when results from multiple test facilities are analyzed. Thus, since our analysis is based on data from only two testing facilities, our results may not be representative of the true amount of variability in vomitoxin test results conducted in North Dakota.

GAO's Analysis

According to GIPSA officials, the variability of test results differs depending on the concentration of vomitoxin in the barley sample. At their recommendation, we used GIPSA's HPLC test result to represent the true concentration of vomitoxin in a sample and grouped the Veratox test results into four ranges. The first range contains results from barley samples with relatively low concentrations of vomitoxin—those with HPLC results of 0.7 ppm to 1 ppm. The last category contains results from samples with the highest concentrations of vomitoxin—those with HPLC results of 3.1 ppm to 4 ppm.

Our analysis of Veratox test results from Neogen and the Grand Forks testing facility showed differences in the amount of vomitoxin measured at each location (see table II.1). That is, testing identical samples of barley at the testing facility and at the manufacturer resulted in different measurements of vomitoxin. Specifically, using the HPLC test results to represent the true concentration of vomitoxin, we found that at concentrations between 0.7 and 4 ppm, Neogen's estimation of vomitoxin was, on average, higher than the testing facility's. Given these differences, and the fact that small differences in the amount of vomitoxin measured can affect barley prices, we concluded that producers could have received different prices from each testing location if the test results had been the basis for a commercial sale.

[37]We originally obtained 1,287 Veratox tests (which had corresponding HPLC test results of less than 5.1 ppm) from GIPSA's sampling study, but excluded 132 Veratox tests from our analysis because they either lacked comparative data or exceeded the calibration range of the Veratox method. We then excluded the remaining 87 records in the concentration category 4.1-5 parts per million (ppm) because the removal of records from the tests that exceeded the calibration range of the Veratox method greatly reduced the number of records within this category.

Table II.1: Difference in Veratox Results at Two Testing Facilities

In parts per million

At an HPLC result of	We estimate that average test results at Neogen will exceed those at Grand Forks by[a]
0.7 — 1.0	0.2 — 0.6
1.1 — 2.0	0.2 — 0.6
2.1 — 3.0	0.6 — 1.0
3.1 — 4.0	0.7 — 1.2

[a]Our estimates represent the 95-percent confidence intervals for the differences between the mean test results for Neogen and Grand Forks Grain Inspection.

Source: GAO's analysis of data from GIPSA's 1998 Sampling Variability Study.

We also found in some cases that the results from Neogen and Grand Forks Grain Inspection differed, on average, from GIPSA's HPLC reference method (see table II.2). Specifically, test results from the manufacturer were higher than test results from the HPLC reference method at three of the four concentration ranges we reviewed. For example, when HPLC results ranged from 0.7 to 1.0 ppm, we estimated that the average Neogen's results would be between 1.3 to 1.5 ppm, which is higher than the average HPLC results. In addition, average Veratox results from the Grand Forks facility were lower than the reference method at two of four concentration ranges. For instance, when HPLC results ranged from 2.1 to 3.0 ppm, we estimated that the average test result from the testing facility would be between 1.7 to 2.0 ppm, which is lower than the average for the reference method. The fact that in one case the manufacturer's test results were higher, on average, than the reference method's results, while the testing facility's results were lower, further demonstrates that variability can occur among testing facilities using the Veratox test kit.

Table II.2: Comparison of Average Veratox and HPLC Test Results

In parts per million

At an HPLC result of:	We estimate the average Veratox result from repeated tests will fall between:[a] Neogen	Grand Forks
0.7 — 1.0	1.3 — 1.5[b]	0.9 — 1.2
1.1 — 2.0	1.8 — 2.0[b]	1.4 — 1.7
2.1 — 3.0	2.5 — 2.8	1.7 — 2.0[b]
3.1 — 4.0	3.5 — 3.8[b]	2.5 — 3.0[b]

[a]Our estimates represent the 95-percent confidence intervals for the average Veratox result.

[b]Indicates a statistically significant difference between the average HPLC and Veratox result.

Source: GAO's analysis of data from GIPSA's 1998 Sampling Variability Study.

Major Contributors to This Report

Jerilynn B. Hoy, Assistant Director
Kurt W. Kershow, Project Manager
Patricia M. Crown
Barbara J. El-Osta
Leanne M. Flama
Jay R. Cherlow
Karen E. Bracey
Carol Herrnstadt Shulman

Related GAO Products

Wheat Pricing: Information on Transition to New Tests for Protein (GAO/RCED-95-28, Dec. 8, 1994).

Midwest Grain Quality (GAO/RCED-94-66R, Nov. 1, 1993).

Ordering Information

The first copy of each GAO report and testimony is free. Additional copies are $2 each. Orders should be sent to the following address, accompanied by a check or money order made out to the Superintendent of Documents, when necessary. VISA and MasterCard credit cards are accepted, also. Orders for 100 or more copies to be mailed to a single address are discounted 25 percent.

Orders by mail:

U.S. General Accounting Office
P.O. Box 37050
Washington, DC 20013

or visit:

Room 1100
700 4th St. NW (corner of 4th and G Sts. NW)
U.S. General Accounting Office
Washington, DC

Orders may also be placed by calling (202) 512-6000
or by using fax number (202) 512-6061, or TDD (202) 512-2537.

Each day, GAO issues a list of newly available reports and testimony. To receive facsimile copies of the daily list or any list from the past 30 days, please call (202) 512-6000 using a touchtone phone. A recorded menu will provide information on how to obtain these lists.

For information on how to access GAO reports on the INTERNET, send an e-mail message with "info" in the body to:

info@www.gao.gov

or visit GAO's World Wide Web Home Page at:

http://www.gao.gov