Canadian
Barley
Symposium

PROCEEDINGS

of the
Canadian Barley Symposium

February 23-25, 1999
Winnipeg, Manitoba, Canada

Sponsorship

The Organizing Committee of the Canadian Barley Symposium ’99 greatly appreciates the sponsorship of the following organizations:

PLATINUM

Canadian Wheat Board	Alberta Barley Commission	Canadian Grain Commission	Prairie Malt Ltd.

GOLD

Canada Malting Ltd.	Agricore	XCAN Grain Pool	*DOMINION MALTING LIMITED* Dominion Malting

SILVER

Secan	WestCan Malting	James Richardson	Cargill Limited

BRONZE

Performance Seeds	United Grain Growers	Manitoba Agriculture

CONTRIBUTORS

CN Rail • Gustafson Seeds • Molson Breweries Ltd. • Labatt Brewing Co. • Bank of Nova Scotia Canadian International Grains Institute • Big Rock Brewery Ltd. • Busch Agricultural Resources Inc.

Organizing Committee

The Organizing Committee of the Canadian Barley Symposium '99 was comprised of staff from the Canadian Grain Commission's Grain Research Laboratory in Winnipeg, Manitoba.

- Sandy MacGregor, Program Chairman
- Michael Edney, Co-Chairman
- Sharon Bazin
- Carol Anne Carmichael
- Dennis Langrell
- Shirley Lowe
- Steve Schroeder
- John Walkof

Table of Contents

Table of Contents (continued)

Program Agenda

TUESDAY, FEBRUARY 23

07:30 - 10:00	OPENING RECEPTION AND REGISTRATION	Crowne Plaza, Campaign Room

Program Agenda

Wednesday, February 24, AM

07:30	Registration Opens	Winnipeg Convention Centre, Room 2E
08:00	Opening Remarks	Barry Senft, Canadian Grain Commission

Markets for Canadian Barley

CHAIR: Sandy MacGregor, Canadian Grain Commission

08:20	Changing Barley Situation in Canada – Implications for the Future	Brian Oleson / Darryl Kraft University of Manitoba
08:40	World Malt and Malting Barley Trade and Prospects for Canadian Malting Barley Exports	R.G. (Bob) Cuthbert Canadian Wheat Board
09:00	Export Markets for Canadian Malt: Past, Present, Future	Philip de Kemp Malting Industry Association of Canada
09:20	Developing Food Markets for Canadian Barley	R.J. (Dick) Klaffke Agricore
09:40	Discussion	
10:00	Coffee	

Biotechnology and Barley

CHAIR: Brian Rossnagel, University of Saskatchewan

10:20	Prospects For Barley Improvement Through Barley Genome Projects	Diane Mather McGill University
10:40	Barley Transformation in Canada	Ken Kasha University of Guelph
11:00	Marker Assisted Selection in Barley	Greg Penner Monsanto
11:20	Improving Malting Quality Through Biotechnology	A.W. (Sandy) MacGregor Canadian Grain Commission
11:40	Discussion	
NOON	Lunch	Winnipeg Convention Centre, Room 2F

Program Agenda

WEDNESDAY, FEBRUARY 24, PM

Quality Requirements for Canadian Barley

CHAIR: Michael Edney, Canadian Grain Commission

13:30	MALTING BARLEY QUALITY FOR DOMESTIC AND EXPORT MARKETS	Xiang Yin / Walter Fernets Prairie Malt Limited
13:50	FUTURE NEEDS OF THE CANADIAN BREWING INDUSTRY	Alan Griffiths John Labatt Breweries
14:10	A CUSTOMER'S PERSPECTIVE ON CANADIAN MALTING BARLEY	Alan Slater Busch Agricultural Resources Inc.
14:30	DOES THE FEED INDUSTRY HAVE BARLEY QUALITY NEEDS?	Dave Hickling Canadian International Grains Institute
14:50	DISCUSSION	
15:10	COFFEE	

Barley Research

CHAIR: Marta Izydorczyk, University of Manitoba

15:30	BARLEY RESEARCH IN EASTERN CANADA	T.M. (Alek) Choo Agriculture and Agri-Food Canada
15:50	FOOD QUALITY ASPECTS OF BARLEY	Thava Vasanthan University of Alberta
16:10	DISCUSSION	
16:30	ADJOURN	
18:30	COCKTAILS	Crowne Plaza, Victoria/Albert Room
19:00	DINNER	Crowne Plaza, Victoria/Albert Room

DINNER ADDRESS: "THE NEW CANADIAN WHEAT BOARD" — Greg Arason, Canadian Wheat Board President and CEO

Program Agenda

THURSDAY, FEBRUARY 25, AM

Fusarium and Other Pathological Concerns

CHAIR: Bryan Harvey, University of Saskatchewan

08:30	*FUSARIUM GRAMINEARUM* – A SPREADING PROBLEM	Randy Clear Canadian Grain Commission
08:50	FUSARIUM HEAD BLIGHT OF BARLEY: A PLANT PATHOLOGIST'S PERSPECTIVE	Andy Tekauz Agriculture and Agri-Food Canada
09:10	IS HARRINGTON SHOWING ITS AGE?	T. Kelly Turkington Agriculture and Agri-Food Canada
09:30	DISCUSSION	
09:50	COFFEE	

Future Uses of Barley

CHAIR: R.J. (Dick) Klaffke, Agricore

10:10	HULLESS BARLEY – THE BARLEY OF THE FUTURE?	Brian Rossnagel University of Saskatchewan
10:30	CHALLENGES IN BREEDING FEED BARLEY	James Helm Alberta Agriculture
10:50	CANADIAN MALTING BARLEY VARIETIES FOR THE FUTURE	Michael Edney Canadian Grain Commission
11:10	DISCUSSION	
11:30	LUNCH	Winnipeg Convention Centre, Room 2F

Program Agenda

THURSDAY, FEBRUARY 25, PM

Handling of Malting Barley

CHAIR: Michael Brophy, Canadian Wheat Board

13:00	MARKETING GENETICALLY ENHANCED BARLEY	Earl Geddes Canadian Wheat Board
13:20	METHODS FOR ASSURING VARIETAL PURITY IN BARLEY	Randal Giroux Canadian Grain Commission
13:40	STRENGTHS AND WEAKNESSES OF THE CURRENT HANDLING/TRANSPORTATION SYSTEM	Pat Rowan ConAgra Grain
14:00	HANDLING MALTING BARLEY – A PRODUCER'S PERSPECTIVE	Bob McCallister Producer
14:20	DISCUSSION	
14:40	COFFEE	

Forum on Barley Research Funding

CHAIR: Rob Hill, University of Manitoba

15:00	PANELLISTS:	
	Clifton Foster	Alberta Barley Commission
	Ken Campbell	Agriculture and Agri-Food Canada
	Cam Henry	Western Grains Research Foundation
16:00	CLOSING REMARKS	Bryan Harvey University of Saskatchewan

Opening Remarks

Barry Senft, President and Chief Commissioner
Canadian Grain Commission, Winnipeg, Manitoba, Canada

The barley industry in Canada is going through a time of rapid change, for example, industry concentration, the expansion of domestic feed barley markets, advancements in molecular biology, and pressure to ensure varietal integrity in the handling system. Producers, researchers, marketers, and grain handlers are compelled to anticipate and respond to change – and keep the barley industry strong.

Quality has always been Canada’s grain marketing strategy. Quality, consistency and meeting specific needs of customers will be critical to the success of the barley industry in Canada. Australia, Canada’s major competitor for barley markets, has its own quality strategy. To compete, barley producers and all sectors of the barley industry should be prepared to respond to challenges, be open to innovation and take advantage of opportunities. Three issues on the symposium agenda exemplify this endeavor: developing solutions to fusarium; looking at how biotechnology will change the industry; and creating new uses for barley.

The industry has made many achievements in the past. The Canadian Grain Commission supports the goal of the symposium to maintain the industry’s reputation as a leader in high quality food, feed and malting barley.

Changing Barley Situation in Canada – Implications for the Future

Brian T. Oleson / Darryl F. Kraft, University of Manitoba
Winnipeg, Manitoba, Canada

Abstract

The future for barley in Canada will be driven by global economic and political forces and their interaction with our own unique situation. The decade of the 1990’s was a decade of ongoing change, evolution and turmoil for global agriculture. The world added close to one billion people. Incomes grew rapidly in many regions of the globe. These growth rates were remarkable by any norm. So was the economic collapse in some of these countries at the end of the decade. Politically, the Soviet Union collapsed in the early 1990’s and a new group of economically weak countries emerged. The Cold War came to an end but regional wars became commonplace. All these factors directly or indirectly affected agriculture.

In the agriculture sector, a grain subsidy war raged for the first half of the decade. Hog prices collapsed toward the end of the decade in a fashion unseen since the depression. The latest round of the GATT included a significant agriculture component. This was heralded as a major breakthrough for agriculture. The world of biotechnology took hold. Every day there are new breakthroughs, new products, and new controversies.

This decade of change left its imprint on Canadian agriculture. The statutory rail rates, which lowered the cost of moving grain from Western Canada to export position, are gone. The CWB pooling system, which increased the profitability of export grain from the eastern prairies, has also disappeared. With CUSTA and NAFTA, agriculture exports to the United States have increased considerably as have trade tensions between the two countries. Large-scale hog production facilities are now commonplace in the prairie region. The grain collection system is undergoing a radical transformation. The cattle sector is expanding but continues to be influenced by the cycles inherent to this industry.

Barley production in Canada amidst all this change has remained relatively stable, perhaps surprisingly stable. There has been growth in the use of barley feed in Canada. There has been growth in the export of malt and malting barley. This growth has been offset by a decrease in the export of Canadian barley for feed. In the decade ahead, a similar profile is expected to emerge. However, the continuation of these trends will take place against a background of constant change and instability.

World Malt and Malting Barley Trade and Prospects for Canadian Malting Barley Exports

R.G. (Bob) Cuthbert, Canadian Wheat Board
Winnipeg, Manitoba, Canada

Introduction

Canada is the world's second largest exporter of malting barley after Australia and the second largest exporter of malt after the European Union (EU). Canadian Harrington has set the world standard for quality 2-row malting barley and is a favorite of our largest 2-row export markets, including China as bulk barley and Japan as malt.

Malting barley and malt trade expanded rapidly in the last ten years and Canada was well placed to capture a significant portion of this new demand. In coming years, as trade expands further, there are several factors which will influence how successful Canada will be in maintaining market share in world malt and malting barley trade.

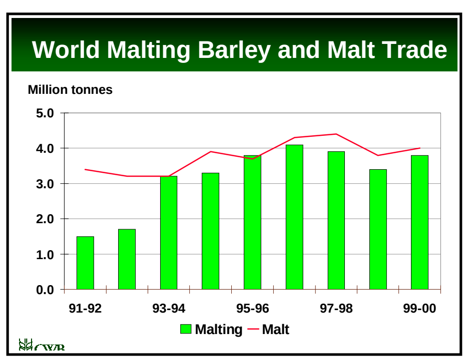
One of the major factors determining Canada's success in the future will be the development of new varieties which will meet increasingly tight customer specifications and which will compete successfully with Australian and European varieties.

Another important factor will be the relative strength of the world's malting barley markets compared to the domestic feed barley market in Canada. In 1998-99, poor returns on the world market for malting barley (and malt) have made the Canadian domestic feed barley market look very attractive. This could lead to a reduction in malting barley acres in Western Canada if the premiums do not improve. However, under current conditions, we expect malting barley premiums over feed will return to a more historical level next year.

This paper provides an overview of three areas: i. world malt and malting barley trade; ii. the challenge Canada faces with respect to developing new malting barley varieties; and iii. major markets for malting barley.

Section I: Review of World Malting Barley and Malt Trade

World malting barley and malt trade expanded rapidly between the late eighties and late nineties. Malting barley trade doubled between 1990 (1.7 MT) and 1995 (3.4 MT) and malt trade increased by over 25 per cent (3.1 MT to 3.9 MT) during the same period.



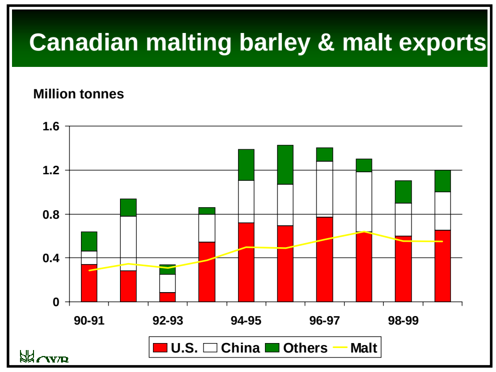
After peaking at around 4.1 MT in 1996-97, world malting barley trade is forecast to drop to 3.5 MT in the current year (1998-99). This is the result of reduced demand, particularly in China, but also in

E. Europe and Russia, in the wake of the current economic downturn. U.S. malting barley imports will also be lower this year. Meanwhile, malt trade is expected to fall from 4.3 MT in 1997-98 to around 3.8 MT in 1998-99.

Canadian Malt and Malting Barley Exports

Canada took advantage of the rapidly expanding markets for malting barley and malt through the nineties. In 1994-95, Canada exported over 1 MT of malting barley for the first time. In comparison, in the late eighties, malting barley exports averaged 300-400,000 T.

In 1993-94, the U.S. became Canada’s number one malting barley export market, whereas previously it had been China. The increase in U.S. demand corresponded to the growing incidence of fusarium in the U.S. 6-row crop which forced the American maltsters and brewers to look to Canada for supplies.

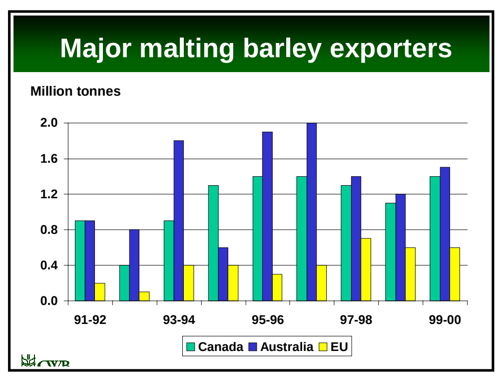


Meanwhile, Canadian maltsters also took advantage of expanding market opportunities. Malting capacity in Canada grew by nearly 50% between 1987 and 1997, increasing from 600,000 T (800,000 T gr. equiv.) to 900,000 T (1.2 MT gr. equiv.). Malt exports peaked in 1997-98 at 500,000 T (630,000 T gr. equiv.), more than double 1990-91 exports of 230,000 T (290,000 T gr. equiv.).

In total, Canadian malt and malting barley exports (combined) have grown from under 1 MT in the early nineties to over 2 MT in recent years. However, in 1998-99, Canadian malting barley exports will only be 1.0 MT, and malt exports are forecast at 425,000 T (550,000 T gr. equiv.).

Major World Malting Barley Exporters

Looking at the pattern of exports, it is clear that Canadian and Australian malting barley exports have fallen in the last two years (1997-98 and 1998-99) to the benefit of the EU who has expanded exports considerably, albeit with the use of heavy export subsidies. In 1997-98, the EU exported over 700,000 T of malting barley, a record export program. In the current year, the EU is once again active in global malting barley trade.

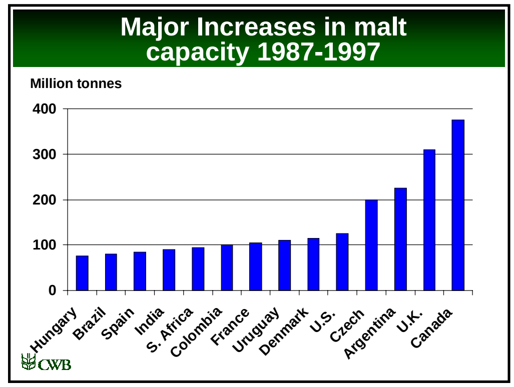


Whereas previously EU malting barley did not have a formidable reputation on the world market, their premier 2-row spring varieties of Alexis, Prisma and Scarlett appear to be gaining acceptance by international maltsters and will provide competition for Canada and Australia in coming years.

Australia’s malting barley exports peaked in 1996-97 at a record 2.0 MT. Australia’s premier varieties include Schooner and Stirling which compete with Canadian Harrington into China and Japan. In the last two years, Australian exports have fallen as a result of lower demand combined with smaller, poorer quality barley crops.

Major Increases in Malt Capacity 1987-1997

Between 1987 and 1997, world malt capacity expanded considerably. According to a Pollock and Pool study entitled *The Malting Industry*, world malt capacity grew by a substantial 30% from 15 MT to 19.5 MT over ten years.

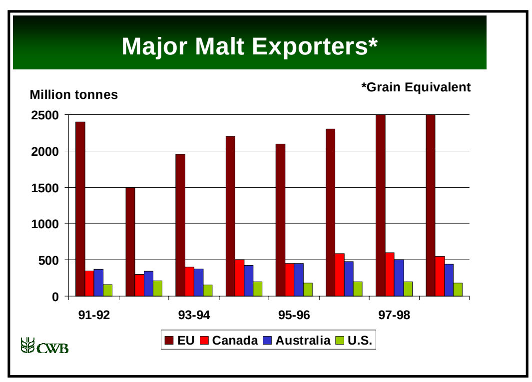


The largest single country expansion was in Canada at nearly 400,000 T, but collectively the EU countries of the UK, France, Denmark and Spain expanded capacity by over 600,000 T. Current EU malt capacity is approximately 7.5 MT compared to Canada’s 900,000 T.

The rapid expansion since 1985 has kept capacity well ahead of demand. In the current year, weaker demand coupled with oversupply have led to disastrous malt prices. Malt plants across Europe, as well as in the U.S. and Canada, have closed down capacity and reduced output as a result of the current downturn in the malt markets.

Major Malt Exporters

All three of the world’s major malt exporters have expanded their activities in recent years. In the EU, malt exports have been rising steadily over the years to current export levels of nearly 2.0 MT of malt (2.5 MT gr. equiv.) annually.

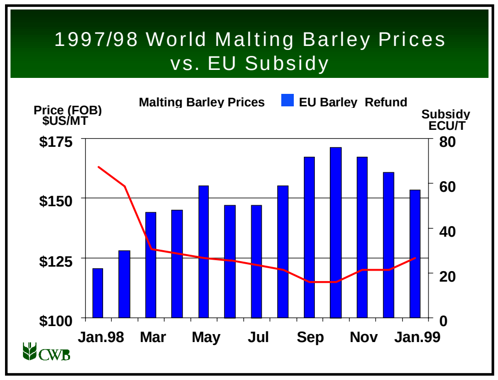


Canadian malt exports have grown from 250,000 T in 1991-92 to almost 500,000 T in 1997-98 (640,000 T gr. equiv.). In Australia, malt exports have increased much less dramatically, growing from 280,000 T to 350,000 T by 1997-98.

In the current year, Canadian malt exports will be lower than last year, forecast at around 425,000 T. In the EU, export licenses are a record 2.3 MT this year (3.0 MT grain equivalent). A portion of these licenses were “rolled over” from 1997-98 given the larger export subsidy in the current year (US $90 compared to US $36 the year previous). The current licenses are valid until December, 1999 which will pressure on the world malt market through to next fall and possibly beyond.

EU Barley Export Subsidies vs. 2-Row Prices

The expansion in EU malting barley exports recently has added considerable pressure to world malting barley values, not simply as a result of increased supplies. EU barley export subsidies have been substantial over the last 12 months, or at least since feed barley prices tumbled last winter in the wake of limited Saudi demand and heavy Baltic and Black Sea feed barley exports (Russia, Ukraine, Turkey).

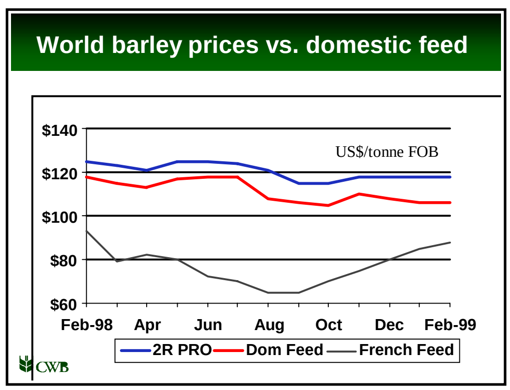


On March 12, 1998, the EU increased their barley export subsidy from US $35/T to US $55/T, applicable to both feed and malting barley exports. That level of export subsidy was maintained and even increased over the summer until it peaked at US $80/T in October. International top quality 2-row prices dropped from US $165/T in February 1998 to $115/T in September. Malting barley prices have since recovered by US $10/T. Global malt values were also hit hard, falling from US $300/T in the winter of 1998 to current lows of below US $180/T FOB for 2-row spring malt.

A major problem with the EU system is not only its aggressive use of export subsidies, but also the fact that those subsidies are based on global feed barley supply and demand fundamentals and yet apply malting barley. This artificially depresses malt barley and malt values in years when their S&D fundamentals are significantly different from feed barley.

World Prices vs. Domestic Feed Barley Prices

As a result of the poor returns for 2-row on the world market this year and relatively strong domestic feed barley prices, some Canadian producers are questioning the economics of malting barley production.

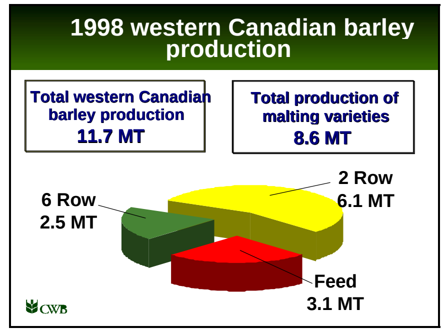


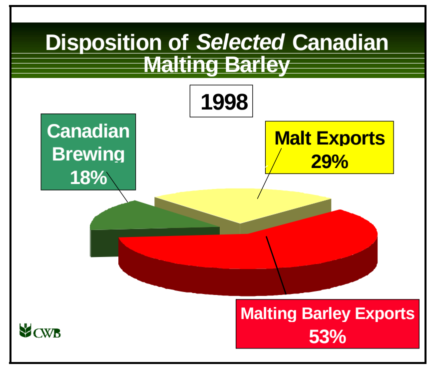
The graph on the right illustrates the limited premium producers are getting this year for 2-row malting barley over the domestic feed barley market (although the graph also shows that the premium to world feed barley prices is still considerable). It begs the question as to what kind of price spreads we will see in the future. Given the yield advantages of feed barley varieties, Canadian produces are liable to shift out of malting barley production if the premium doesn't improve.

However, the factors which led to this historically low spread are unlikely to repeat themselves next year. This year's high quality wheat crop left little feed wheat for the domestic market, helping to support feed prices. Secondly, EU barley export subsidies are expected to be lower next year due to reduced world barley stocks and stronger feed barley prices (which have already increased US $25/T since July 1998). Therefore, we expect the spread between the malting barley pool returns and the domestic feed barley market to return to a more historical level in 1999/2000.

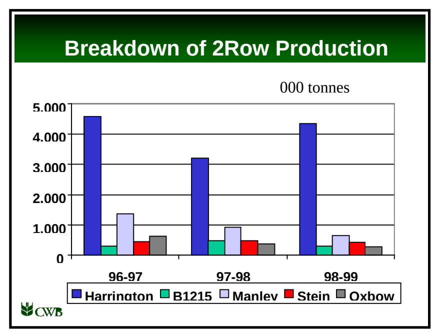
Section II: Canadian Malting Barley Production

Canadian barley production has averaged 13.3 MT over the last five years with about 1 MT of barley typically grown outside Western Canada. Approximately 70 to 75% of seeded barley acres in Western Canada are to sown malting varieties. Of that, 40 to 50% of acres are seeded to 2-row and 20 to 30% are seeded to 6-row malting barley varieties.





Selectable supplies of malting barley typically amount to 20 to 30% of malting barley production or 2.0-2.5 MT annually. In 1998, the malting barley pool is smaller than usual at around 1.9 MT. Of that, 350,000 T will be consumed domestically, 1 MT will be exported as malting barley, and another 550,000 T will be exported as malt.



Breakdown of 2-Row Production

Harrington remains the preferred variety of western Canadian malting barley producers. Harrington production actually dropped a little in 1997-98 and then regained some ground in 1998-99.

Manley has seen production fall in the last three years, as has Oxbow. Stein production has been relatively steady.

Typical Sales Quality Specifications

	2 Row	6 Row
Plump	Min. 80-85%	Min. 70-75%
Thin	Max. 4%	Max. 4%
Test wt.	Min. 65 kg/hl	Min. 63 kg/hl
1000 kernel wt.	Min. 40 g	
Protein	Max. 12.5- 13.5%	Max. 13-13.5%
Colour	Good	Good

CWB

Customer Requirements

Our customers around the world have become increasingly demanding with respect to quality specifications. Now more than ever, the need to produce a high quality product is essential. Some of the newly developed varieties, discussed below, will help Canada to meet the customer’s requirements.

Harrington – Too Successful?

Harrington is the variety that has set the industry standard worldwide for North American 2-row malting barley. Export markets for Canadian malting barley and malt were built on Harrington. In a sense, it has been too successful. Although the industry has had some success in marketing Manley, Stein, B1215 and Oxbow, these varieties that were registered before the mid-1990's did not show sufficient quality improvement benefits over Harrington to encourage a major customer shift away from Harrington. The variety is now almost 20 years old and it is falling behind newer malting and feed varieties in terms of yield and disease resistance. Producers will no longer opt to grow current acreage levels of Harrington unless they are assured a significant premium.

The move to new 2 Row varieties

Existing Varieties	*New Varieties*
Harrington	B1202
Stein	TR 118
Manley	TR 129
B1215	TR 139
Oxbow	TR 145
Metcalfe	TR 243
Lager	TR 970
Stratus	

CWB

Finding a Successor

The Canadian malting industry must work together to find one or more suitable varieties that can be a significant step forward from Harrington. We also need varieties with malting and brewing quality specifications to satisfy customers who have found Harrington unsatisfactory. We may well have those varieties now, but further market development work is required to get these varieties accepted by brewers in Canada and internationally.

The industry may have to narrow the portfolio of recommended 2-row varieties to perhaps three or four. We cannot be actively promoting and selling 11 registered varieties of 2-row; this will only cause confusion in markets and create logistics problems. The Malting Barley Industry Group Variety Recommended List is a step in this direction. Some of the older varieties will have to be dropped from this list so the seed industry and growers can increase production of a short list of preferred new varieties.

6-Row Varieties

Our primary export market for 6-row barley is the U.S. The growth in exports to the U.S. in the nineties has been primarily the result of good 6-row varietal expansion in Canada and the fusarium head blight infestation in U.S. 6-row. This latter problem has resulted in lower and lower barley acreage in the tri-state 6-row area. Poor producer returns for barley and a probable increase in durum acres are expected to cause a further 15-20% drop in North Dakota barley acreage in 1999.

The move to new 6 Row varieties

Existing Varieties	*New Varieties*
B1602	CDC Sisler
Robust	BT 435
Excel	BT 941
Stander	
Foster	

CWB

As with Harrington, some of the older 6-row varieties such as B1602 and Robust are agronomically falling behind newer varieties. Producers are going to be less willing to seed them without assurance of selection for malt and a significant premium.

Another development which is accelerating is the *proprietary ownership* of varieties. Non-government investment is necessary to help finance breeding programs. Companies of course want a return on their investment. Marketing problems could occur if several seed and grain companies attempt to promote several varieties at the same time, some of which do not have the necessary quality requirements. There should be a coordinated industry effort in market development and commercial plant-scale testing of newly-registered varieties. This should be followed by an agreed-upon marketing industry list for recommended/approved varieties, which will send the right signal to growers and customers.

Section III: Prospects for Canadian Malting Barley Exports

As already indicated, world malting barley and malt trade are lower in 1998-99 compared to the last two years. This is a step back after a period of long-term growth. However, world malting barley and malt trade are likely to resume their growth trend in the long term as Asian and Latin American economies shrug off the current economic problems and their populations increase per capita beer consumption. This section looks at the major global malting barley import markets and future import prospects, ending with a short and long term outlook for trade and prices.

Major Malting Barley Importers

The table on the right shows the major malting barley import markets in recent years. The U.S. and Mexico are largely 6-row markets while the others are primarily 2-row markets.

Bearing this in mind, the table clearly illustrates the importance of the Chinese market and its significance in terms of 2-row malting barley values.

World malting barley importers*

*Excludes malt

	1996/97	1997/98 - 000 T -	1998/99
China	1,800	1,500	1,200
U.S.	850	750	630
Colombia	200	150	200
Brazil	175	100	150
Mexico	125	200	230
South Africa	75	150	120
Taiwan	100	90	120
Poland	120	95	85
Total	4,125	3,925	3,500

Major Canadian Malting Barley Markets

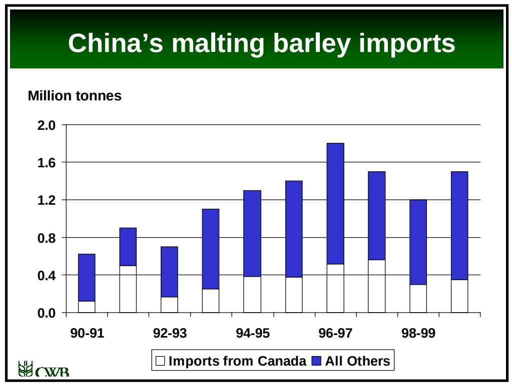
Canada's largest market for malting barley is the domestic malting industry. The domestic maltsters typically use 1.2 MT of malting barley of which one-third is consumed domestically and two-thirds are processed for export.

Our largest malting barley export markets are the U.S. and China with the U.S. importing predominantly 6-row and China buying exclusively 2-row. Of the malting barley which is sold as malt for export, Japan, Brazil, S. Korea, Mexico and the U.S. are some of our key markets.

Major Canadian Malting Barley Markets

	1997-98	1998-99 f
	thousands of tonnes	
Canada	1,165	1,000
U.S.	750	620
China	550	275
Mexico	60	75
Japan	50	60

Chinese Malting Barley Imports



Currently, we are forecasting China's 1998-99 malting barley imports at 1.2 MT, a drop of 300,000 T from last year, and down from 1.8 MT in 1996-97. While this drop in demand has contributed to lower world malting barley prices, it has also corresponded to a year when both Australia and Canada have reduced supplies. Generally, poor commodity prices, and especially large EU barley export subsidies, have been the main culprits pressuring malting barley values this year.

Canada has consistently been a major supplier of malting barley to China over the years. In the eighties, malting barley exports to China, the largest 2-row market in the world, ranged from zero to 275,000 T per year. Since 1994-95, when China's imports surged to well over 1 MT, Canada has supplied around 400,000 T or more annually to China, typically accounting for 80-95% of our 2-row malting barley exports.

In the current year, the pattern has shifted significantly. China's malting barley purchases have been slow and unpredictable. There has been a shift toward greater private sector participation in importing which has meant an increased number of smaller purchases. Previously, China's state-owned importing agency, COFCO, was wholly responsible for China's malting barley imports. This change, combined with tighter credit and the fear of devaluation, has led to reduced forward buying and more "hand to mouth" purchases.

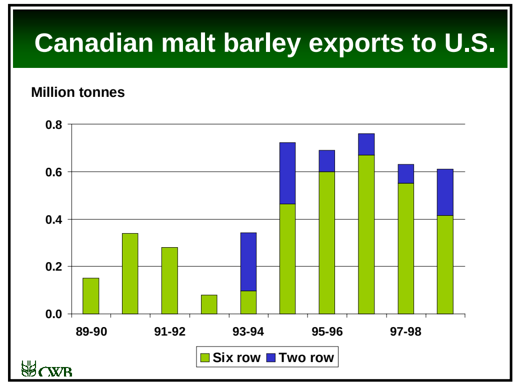
Latin American Markets

Colombia has been an important market for Canadian 2-row barley over the years. It has often been our number three market after China and the U.S.. However, in the last two years, Colombia has bought very little Canadian malting barley mainly because their specifications are too stringent. Instead, Colombia has purchased barley from the EU and from Australia. In the future, this market still holds promise. However, it is a very price-sensitive market which could favour subsidized EU imports in the long term.

Brazil is another country with serious import potential, although they import primarily malt (550,000 T annually, second only to Japan). Typically, Brazil requires 150,000 T of malting barley imports each year although a good portion of this is imported from Mercosur countries (Argentina and Uruguay in particular). Last year, imports were only 100,000 T. This year, Brazil's harvested a poor barley crop which could lead to increased demand and opportunities for exporters outside the Mercosur (est. 25,000 to 50,000 T).

Mexico has been an important growth market for malting barley in recent years, increasing from an average of 50,000 T of imports in the early nineties to 230,000 T in the current year. Typically sourcing their malting barley imports from the U.S., Mexico has begun increasingly to look to Canada for imports of fusarium free 6-row. In 1998-99, Canada will ship around 50,000 T of 6-row malting barley to Mexico.

Canadian Malting Barley Exports to the U.S.



In 1993-94, the U.S. became Canada's largest malting barley export market as North Dakota grappled with fusarium problems. The bulk of exports to the U.S. are 6-row varieties which are used in the majority of U.S. beer production. However, in 1998-99, Canada will export more 2-row malting barley to the U.S. than ever before. This is due to a smaller and poorer quality 2-row crop in the U.S. last year and better returns compared to the world market.

The main 6-row varieties being marketed into the U.S. are B1602, Excel and Robust. The newer varieties of Stander and Foster are also grown in Canada but markets for these are limited.

U.S. imports of 6-row Canadian malting barley this year will be lower than last year given the lower levels of DON (deoxynivalenol) in the U.S. crop. In contrast, imports of 2-row from Canada are up considerably this year.

Other Malting Barley Markets

Other important malting barley markets include Japan, South Korea, Taiwan, Ecuador, Poland and South Africa. All of these markets have potential for Canada, although Taiwan relies entirely on Australian barley and Poland buys almost exclusively EU barley.

Outlook

Short term: In the summer and fall of 1998, world 2-row malting barley prices were at their lowest levels in four years. Reduced demand and generally poor coarse grain prices combined with heavy EU export subsidies kept malting barley prices under pressure. However, as we look out to 1999-2000, the prospects for prices and exports are definitely brighter.

Reduced U.S. 6-row area: Most analysts are projecting at least 10-15% lower U.S. 6-row planted area this year as a result of poor prices and on-going fusarium problems. This could mean increased demand for Canadian 6-row and generally firmer prices.

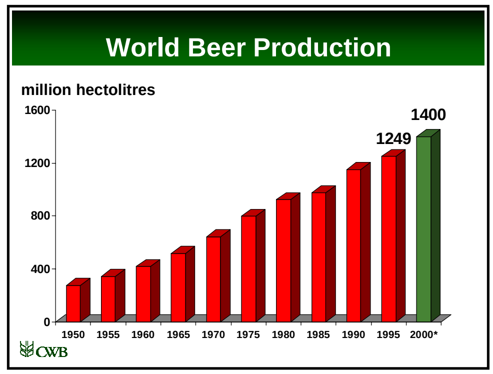
Limited exporter surplus: All three of the major exporters have limited surpluses this year. Canada has already sold a large portion of its 1998-99 malting barley crop with only limited supplies of 6-row and 2-row left to export. The EU also had a smaller spring barley surplus this year, but has still managed to export 500,000 T. Thus, there is currently limited remaining malting barley for export in the EU. Australia's export surplus is 400,000 T lower this year compared with the last two years. Therefore, although they still have supplies for export, exports will only target traditional markets.

Lower EU subsidies; Higher spring barley area: EU barley export subsidies have fallen by US $20 over the last three months with improved feed barley demand. This trend is expected to continue and will support malting barley prices as subsidies fall. On the bearish side, poor planting weather in the fall reduced winter barley seedings leaving the door open for higher spring barley plantings and potentially larger malting barley supplies next year. EU domestic malting barley prices remain depressed and prices will have to improve before producers plant malting barley.

Long term: 1998-99 has not been a stellar year for world malt and malting barley prices and trade. In fact, trade in both were down this year, and a number of countries around the world have experienced a drop in beer consumption and production.

However, malting barley is a specialized commodity and while beer consumption has stagnated in Western countries, there is still huge potential for growth in Asia and Latin America. Moreover, these countries will have difficulty expanding their domestic production of malting barley as their climates are often not suited for it. The Chinese government is currently promoting the improvement of domestically grown malting barley, but it is unlikely that the initiative will allow China to keep up with demand growth.

In the long term, the prospects for Canadian malting barley exports are positive. According to Pollock and Pool, beer production is expected to continue to expand in coming years. Given that this forecast was completed prior to the current recession being experienced in Asia and Latin America, it is safe to assume that the forecast increases in beer production may have to be pushed back a few years. However, with their young populations, beer consumption is expected to continue to increase in the long term in these regions.



While Canada is definitely well placed to benefit form the increases in global demand for malting barley, we should not underestimate our competition. The EU is no longer a residual supplier of malting barley on the world market but a major competitor. Moreover, in Australia, the resources dedicated to malting barley varietal research dwarfs expenditures in Canada.

Therefore, while the future looks bright, the competition also looks steep. Canada will have to invest in varietal research and focus on market development to keep its place as a leading malting barley and malt exporter in the new millennium.

Sources:

Canadian Grain Commission: *Exports of Canadian Grain and Wheat Flour*

Pollock and Pool: *The Malting Industry (1997)*

USDA

IGC: *Grain Market Report (monthly)*

H.M. Gauger

Export Markets for Canadian Malt: Past, Present, Future

Philip de Kemp, Malting Industry Association of Canada
Ottawa, Ontario, Canada

Overview

Canada has developed one of the most successful value-added malt processing and export industries in the world.

It's a good news story that everyone associated with the malting industry can take credit in.

From the barley breeders, to the farmer, to the CWB, and to the companies themselves, all have played an important role in the successful expansion of the industry.

Today, Canadian malt plants are now among the most technologically modern and efficient in the world, producing top quality malt in a clean and healthy environment with highly trained technical experts.

Over the past two decades the industry has shown vision and cautious "expansionary restraint" in its forward planning of export growth potential.

To understand where the industry would like to be in the years ahead, it is important to get a sense as to the "genesis" of the industry: its markets; its expansionary years; its reasons for success; and finally what conditions or sets of criteria are required to ensure the health and prosperity of not only the malt industry but those of our suppliers -- you, the Canadian malting barley producer.

The Past (Snapshot)

In the early 1970's – only two companies: Canada Malting Company Limited and Dominion Malt.

Domestic sales to Canadian brewers were predominantly 6-row.

Domestic sales were roughly the same as they are today (275,000 mt malt) – 350,000 mt malting barley.

Canada was ranked 7th in the world in terms of exports – approximately 112,000 mt in 1976.

In 1977, construction of Canada's 3rd malt plant, Prairie Malt, was completed.

By 1983, Canada was ranked 5th in the world (following France, United Kingdom, Belgium and Australia), exporting approximately 250,000 mt of malt annually.

In 1984, the bottom fell out of the market due to inflation of the subsidy war between the U.S. and E.E.C.

Canadian exports began to plummet: 179,000 mt in 1984; 162,000 mt in 1985; and 140,000 mt in 1986.

In the mid-1980's, Canadian exports of malt were exclusively concentrated in two areas: Japan and the Caribbean (total of seven most notable countries).

In 1988, Japan accounted for approximately 75% of all Canadian malt exports.

Harrington was introduced and became an overnight success story with domestic and export brewers.

Canadian sales increased, markets were expanded, a new plant built (WestCan), and other plants were expanded and/or retrofitted.

The Present

In the past eight years, the industry has spent nearly $250 million through expansion, upgrades, new facilities, etc.

The industry has increased its production capacity by roughly 50% – to approximately 900,000 mt of malt and 1.2 mmt barley.

Exports have more than doubled over the past 10 years and are now approaching almost 500,000 mt of malt.

Capacity utilization within the industry is approximately 90%.

Markets have expanded considerably in South East Asia, Central and South America due to increased economic activity and associated increase in personal wealth and disposable income.

Today, Canadian industry exports malt to over 20 countries world-wide.

Japan, our most valued export customer, purchases approximately 200,000 mt annually – 45% of all Canadian exports (versus 75% 10 years ago).

Brazil has had some explosive per capita growth in beer consumption over the past five to six years.

Canada’s 2nd largest market at approximately 100,000 mt.

New opportunities now available in South Korea, Mexico, Venezuela, Vietnam, Malaysia, Singapore and Chile.

Canada is now the 2nd largest exporter of malt in the world (behind the E.U.) and holds a 16% marketshare of 3.2 mmt.

Markets for Canadian malt in 1997/98 were the following:

Canadian Brewers	35%
Japan	30%
Brazil	15%
U.S.	5%
South Korea	5%
Others	10%

Current Industry Difficulties/Concerns

1998/99 E.U. aggressiveness – subsidy was doubled to about $135 Cdn./mt.

MIAC initiatives – Brussels (feed versus malting).

Harrington beginning to show its age re: disease, hull adherence.

Additional E.U. plant capacity coming on line.

The Future

No question that Canada has an advantage over competitors in terms of quality plant efficiencies, geographic location, lower input costs re: energy and water.

However, for increased "profitable trade" in export of malt, four things must happen over the next five years:

1. New WTO agreement on elimination of export subsidies and tariff and non-tariff barriers.
2. Need increased social and economic prosperity in the evolving markets of S.E. Asia, Central and South America.
3. Need to promote newer/better 2-row varieties i.e. Metcalfe, Lager, etc.
4. Need China in the WTO with reduction of inbound tariffs on malt – currently over 40% duty.

Consider the Following

Beer consumption in:

Czech Republic:	176 litres per capita
Germany:	144 litres
Canada/U.S.:	73 litres
China:	7 litres

If China increased their consumption of beer by 1 bottle – elimination of existing idle Canadian capacity.

If China increased their consumption of beer by 2 bottles – elimination of existing idle Australian capacity.

If China increased their per capita consumption of beer by an additional 7 litres, there presently isn't enough malting capacity world-wide to handle it.

Subsidies would become a moot point in an expanding market with finite processing resources **and** limited additional malting barley (function of weather).

Developing Food Markets for Canadian Barley

R.J. (Dick) Klaffke, Agricore
Calgary, Alberta, Canada

Introduction

Many of the basic steps associated with developing food markets for Canadian barley are not unlike those used to develop markets for other products. There are, however, some specific differences because of the products themselves, the business culture you are working in and the uniqueness of each customer. There were many ways I could have approached this subject. In the end, I decided to make the presentation based on my own experience at Alberta Pool, and now at Agricore, in developing markets for Canadian barley for food uses.

Where are the Markets?

Whenever you are looking to develop markets for a product, some of the first questions you must answer include:

- are there currently markets for the product?
- where are they?
- how big are they?
- who supplies them now?
- can we compete?

On the other hand, if you have a product without a known market that requires starting from scratch, things become much more complicated and costly. Waxy barley is a good example of such a situation in the case of barley for food use.

While barley has a long history of being used for food, this use has diminished dramatically over the past two centuries.

A company in western North America looking for countries which use barley for food, and can afford to buy it, would conclude that Japan is the place to concentrate. As many of you know, Japan has a long history of using barley for the production of rice extender, barley tea, miso soup and Shochu liquor. While all of these products are consumed by humans, they are obviously very different from each other, and therefore the specifications for the raw barley to make them are also very different. Suddenly, barley isn't just a commodity but a very specific raw material, and as a result, we must be able to deliver on that basis. From a Canadian perspective, this means we can not be successful meeting the needs of these markets by simply taking some select malting barley out of our West Coast terminals or from local country elevators and expect it to work.

Who are the Buyers?

After one establishes where the markets are, the next step is to find the buyers. However, meeting the buyers and learning what they need is not enough – especially in Japan. In our case, doing market development work for Canadian food barley was probably somewhat less complicated than it might have been for others because we had been selling various agricultural products in Japan for nearly 20 years. As a result, we had already established ourselves with most of the large and mid-size trading companies. Some of their staff in turn, have long and close personal relationships with many of the owners of the food processing companies and their processor associations. These relationships, and our reputation with the people at the trading companies, considerably reduced the time required to make progress with the buyers. Not only that, but Japanese companies like to deal with people who visit them on a regular basis and have a history of doing business with companies they know.

What are the Final Products?

One of the first things we had to do when establishing ourselves as a supplier of barley, was to understand what the final products were and what the specifications were for the barley used to make them. Our experience with this has been somewhat frustrating in that it is fairly easy to get the most important requirements for the raw barley, but it is often very difficult to learn about the subtle and less measurable traits they want in the barley they buy. One rarely gets this understanding on the second visit – let alone the first! It often takes years to learn the more subtle preferences of customers. Part of this problem is probably because of the language barrier, and part of it is just customers not being familiar with Canadian barley, thereby expecting it to be the same as what is locally grown. In some cases, we may experience the customer trying to raise the quality without raising the cost. We have also experienced quality issues which have not occurred previously. A good example occurred last year when some of our barley had a relatively high percentage of hollow kernels which, of course, wasn't obvious to us when we selected the barley.

Matching Barley Specifications with Varieties and Growing Environment

After we became familiar with the customer's specifications, the challenge was to deliver the type of product they were looking for. We have worked long and hard with customers to evaluate varieties in an attempt to identify those which best meet their needs, yet remain profitable for us and our growers. To assist us with this, we have carried out replicated field trials at several locations to not only compare varieties for various quality traits, but also to try and determine what environmental conditions most consistently give the best overall quality package. One thing we learned very quickly was how different varieties are for things like endosperm colour, kernel hardness, time required to pearl, etc. In order to screen genotypes for endosperm colour, kernel breakage, time to remove the hull and aleurone layer, we purchased the same type of pearling machine that our customers use. This helps us to identify superior cultivars and the best commercial lots, so we can do a better job of selecting barley for our customers.

Another important point in developing Japanese markets is to involve the customers in your work. While they are limited in the number of samples they can evaluate in any year, they do appreciate our efforts in trying to meet their needs. By doing our own evaluation using the equipment we have purchased and then having the customers evaluate the same samples, we can then correlate results. In the process, we learn how to provide better products. To date, we have had very good correlation for endosperm colour but must admit we have a ways to go in the area of kernel breakage and time to dehull.

Mechanics and Regulations of the Market

Once we identified varieties which were at least somewhat acceptable for the rice extender and barley tea markets, the customers started purchasing barley. Ironically, although Japanese companies like to do business with people they trust and feel comfortable with, the

Japanese Food Agency acts as a purchasing agent for all food barley coming in, thereby placing the buyer and supplier somewhat at arms length in the process. This can create problems, as specifications may be different from what was asked for by the end user, requiring a need to have two price quotes in Canada on the business. What is most likely lost, is the lack of communicating the subtle quality preferences mentioned earlier. This can be somewhat disappointing to both the buyer – who may receive barley he isn't happy with, and the Canadian supplier – who has worked closely with the end users to identify specific varieties only to lose the business to a competitor who hasn't made any effort to develop the market and doesn't understand the quality requirements other that what is provided in the JFA tender. Fortunately, this doesn't happen very often to my knowledge, however, it does require various strategies by companies like ours to reduce the incidence of this happening.

On the Canadian side, we have a central selling agency. This agency is in a position to do anything from complicating our business to being helpful. The biggest concern we had in the early stages of trying to position ourselves in this market was that we could see it was possible for us to develop or purchase a proprietary barley variety, do considerable market development work to get it accepted by the customer only to find, at the time of sale, that the barley was priced in such a way that it wasn't possible for us to either make the sale or a reasonable return. To make our concerns known, we brought this concern to the CWB. I don't know if the discussion was helpful or whether we didn't have anything to worry about in the first place, but I can say we haven't run into any unreasonable road blocks. For the most part, our experience with market development work in Japan is that customers prefer working directly with their actual supplier. Obviously, this is a problem when there are two state agencies between them and their supplier, however, we continue to work within the system and while it is a bit cumbersome at times, it isn't working too badly.

Quality Assurance, Selection and Follow-up

All customers want a quality product and, if one wants to increase market share, it is critical to deliver that quality. To do this, we must ensure varietal purity and provide the best physical quality possible. In the rice extender market, we are starting to utilize the Satake pearler to identify the best lots we have for colour and kernel breakage. Obviously, most food barley markets would have to be considered niche markets and, therefore, more care must be taken to identify quality barley as per the specifications of the various end uses. This means we are dealing with an "identity preserve product." In addition to providing the required variety with the best possible quality, one must follow up sales with face-to-face meetings with the customer. As well, the search for new and improved varieties is an ongoing process. The bottom line is – market development doesn't stop with the identification of an acceptable variety and a satisfied customer. As a result, we continue to work with customers to identify better varieties as well as identifying where the best product is produced most often. By doing as much as possible to satisfy the customer, you develop a personal and business relationship which in turn makes it hard for other suppliers to match.

Market Development of New Barley Types

Developing a market for Canadian barley in an established marketplace, though not easy, is a walk in the park compared to establishing a market for a barley type which does not have a defined use. Our experience in this situation currently exists with waxy barley. To us, the first potential market for this barley was in the established food markets of Japan. The main problem is that the historic preference by most end users in Japan is for 6-rowed varieties, which immediately puts all of the waxy barley varieties we have at a disadvantage. Nevertheless, we have had these barleys tested for rice extender where white endosperm is preferred. From first evaluations done by customers, results haven't been that positive. Certainly, the white endosperm and reduced numbers of steely kernels has been a positive for this material, however, kernel breakage has been a problem. Work done by Dr. Michael Edney at the Grain Research Laboratory, however, has since shown that kernel breakage in waxy varieties was less than in both covered and hulless types. As such, these evaluations will probably be revisited.

Once waxy varieties were registered and we produced volumes large enough for people to work with, we tried to get the word out that material was available for evaluation. We cooperated with food scientists at various universities by providing small samples to commercial quantities so as to run various research projects. We also provided test material to food processing companies in Canada, the United States, Australia and Europe for evaluation. To date, results have been mixed (as expected), with everything from essentially no continuing interest to some companies doing commercial product development. Each year, as commercial processors move along with their evaluations, we work with them to prepare for the next step in the process. We do this by growing the supplies they feel are required for the next step, as well as carry out any comparative small plot production required to do comparative laboratory evaluations. Things like beta-glucan and viscosity levels are examples of things being measured in addition to the material being put through various processes.

As academic and commercial food scientists work with this new material, we are hopeful that new uses will be found for barley as a food. Because these barleys have shown potential health benefits and with the rapid increase in functional food interest, we think there is a good chance that this type of barley will become an important component of many food products in the future. Obviously we are still in the preliminary stages of this work. Right now, the most important thing for us to do is stick with it until most reasonable approaches have been exhausted.

Summary

In conclusion, I would like to say that developing food markets for Canadian barley does require effort, resources and a commitment to providing the best products and service we can to the food barley customers who have choices in where they buy their supplies.

In grain market terms the food barley market is not large. The market in Japan for imported food barley is estimated at between 225,000 and 250,000 tonnes.[*] About one half of this is for Shochu production and is supplied mainly from Australia. The rice extender and barley tea markets which we have been most focused on is a 50,000 to 70,000 tonne market

[*] Shigeto Nakashima, presentation to International Food Barley Program, October 1998, Canadian International Grains Institute, Winnipeg, Manitoba, Canada.

depending on acceptable local production in a given year. If we add the miso requirement to this, the market then rises to about 100,000 tonnes. The market for waxy barley is pretty much impossible to estimate because so much of the potential market for this barley doesn’t exist today.

We have learned that delivering top quality products is only part of the requirement for success. My experience of working in a grain company for many years is that traditional grain traders have a commodity mentality which revolves around selling large quantities of grain with somewhat standardized specifications – that is what they do everyday. Meeting the needs of smaller users who require an IP product which may also require a small amount of processing is not a regular business practice for these people. This is not to criticize them but to simply point out that these people work in a different business and don’t always have the patience to do market development work and deal with very specific and unfamiliar specifications. I strongly believe that to work successfully in this type of marketplace requires people from departments or companies which are not involved in commodity sales but who deal with smaller quality specific markets. This type of business is a specialty in its own right.

In addition to the product side of the business, we know that good personal and business relationships between supplier and buyer go a long way in helping business and future market development work – cooperation is key.

Prospects for Barley Improvement Through Barley Genome Projects

Diane Mather, McGill University
Ste-Anne-de-Bellevue, Quebec, Canada

Barley Breeding

Barley breeders have made remarkable progress in exploiting the natural genetic diversity of *Hordeum vulgare* L. They have developed cultivars with improved grain yield, resistance to diseases and pests, a wide range of quality profiles, and adaptation to diverse environments. Breeders have sought and found phenotypic variants for traits of interest, made crosses to generate new genetic combinations, and selected superior progeny. They have tested and re-tested the products of their work, and have discarded far more than they have kept. Some of their work has been guided by knowledge about the genetic control of the traits of interest, but most has not. For most of the history of formal barley breeding, breeders have navigated very successfully without the aid of genome maps.

Genome Mapping

For some species, whole-genome sequencing projects are underway (e.g. human, rice, *Arabidopsis thaliana*) or have been completed (e.g. *Escherichia coli*, *Saccaromyces cerevisiae*), but for large-genome crop species such as barley, genome projects involve genome mapping, rather than whole-genome sequencing.

The basic theory of genome mapping has been known and used for several decades, but it is only in recent years that plant geneticists have had the tools to develop detailed genome maps. The primary tools have been molecular markers (RFLP, RAPD, AFLP, SSR, etc.). These permit the detection and mapping of DNA polymorphisms along the chromosomes, creating framework map onto which genes of interest can be mapped. These genes may be DNA sequences with known gene products, individual genes with distinct effects on the plant phenotype (e.g. genes conferring complete resistance/susceptibility to barley diseases), or ‘quantitative trait loci’ (QTL), genes that contribute towards the expression of quantitatively varying traits such as grain yield or malting quality characteristics.

Barley Genome Maps

In barley, thousands of markers have been mapped, and major genes and QTL have been mapped for dozens of traits. For some traits, the complete gene sequences are known, gene positions have been estimated precisely, and the mechanism of gene action is well understood. For others (especially quantitative traits) we know only the approximate number, position and effect of the genes. Either way, the knowledge we have today is enormous compared to what was known just a decade ago. Perhaps the most important consequences of genome mapping in barley will be its contribution to our understanding of the biology of important traits. Here, however, I will focus on the more direct applications of genome mapping in the genetic improvement of barley. As pointed out above, breeders of barley (and other crops) have managed very well to date without genome maps. What role(s) might genome maps play in the future of barley improvement?

Map-Based Cloning

The cloning of important genes in crop plants can open up the possibility of engineering those genes in crop improvement. Once the sequence of a gene is known, it may be possible to modify that sequence to produce an altered gene product. In some species, genome mapping has led directly to gene cloning; this 'map-based cloning' involves 'chromosome walking' between markers that flank the gene of interest. This has exciting potential because it allows for gene cloning based on knowledge of gene position only, without requiring knowledge of the gene sequence or the gene product. Unfortunately, in large-genome species such as barley, chromosome walks can be long and difficult. Nevertheless, genome map information may still contribute to gene discovery in barley, probably with the aid of comparative mapping, and sequence information from the rice genome.

Marker-Assisted Selection for Qualitative Traits

When an individual gene has a major effect on the plant phenotype, selection can be based upon observation of the plant phenotype. Mapping of the gene relative to molecular markers opens up an alternative: marker-assisted selection. Marker-assisted selection may be applied at markers closely linked to the gene of interest (as a substitute for direct phenotypic selection) and/or at loci elsewhere in the genome (usually to accelerate the recovery of one of the parental genotypes at other loci). Marker-assisted selection is particularly advantageous if the trait phenotype is not reliably expressed, if the trait phenotype is difficult or expensive to evaluate and/or when rapid recovery of one of the parental genotypes is desired. The cost-effectiveness of marker-assisted selection relative to phenotypic selection is largely a function of the cost of marker genotyping relative to trait phenotyping.

Marker-Assisted Selection for Quantitative Traits

Marker-assisted selection can also be used to manipulate QTL. It may be particularly advantageous for quantitative traits that are subject to environmental influences and QTL-by-environment interactions and/or that are difficult or expensive to evaluate. Ironically, these are the traits for which QTL mapping is the most difficult, and for which QTL position estimates may be the least precise. In barley, marker-assisted selection has been used to manipulate QTL for grain yield, malting quality and disease resistance.

Genome Maps as Navigational Aids for 'Conventional' Barley Breeding

Genome mapping permits estimation of the number, effects, and relative positions of the genes influencing one or more traits. This information may provide useful guidance for barley breeders, even in the context of a 'conventional' program that employs neither genetic engineering nor molecular markers. A genome map can tell us whether a trait is affected by many or few genes, whether the gene effects are large or small, whether any of the genes are linked to each other, and how the alleles are distributed among the parents. When more than one trait is mapped, we can gain insight about relationships among traits. For correlated traits, is the cause pleiotropy or linkage? Are there any genes or genomic regions that affect only one of the traits? This kind of information can guide a breeder in choosing breeding methods and population sizes appropriate for the trait(s) to be improved.

Barley Transformation in Canada

Ken J. Kasha / Xu Gu, University of Guelph
Guelph, Ontario, Canada

Introduction

Barley (*Hordeum vulgare* L.) has been second to wheat as the most important cash crop in Canada for many years but recently has been challenged for that position. In 1998, Canola surpassed barley in hectares planted but not in total yield (BMBRI Barley Briefs, #400, 1998). Annually, about five million hectares are planted to barley, mainly for livestock feed. However, since barley with malting quality commands a premium price, seeking to improve this quality has been a major influence, up to now, in breeding and growing of barley cultivars. Presently, feed quality is also receiving much attention. Thus, the major traits of interest for barley transformation research in Canada are related to quality and stress tolerance. Stresses include disease and insect resistance as well as drought and cold tolerance.

While gene transformation is still in its infancy relative to technology development and knowledge of the process of DNA incorporation and gene expression, work on crop improvement has progressed with many species. This push of applications has been spurred by the speed with which genes can potentially be incorporated into elite lines. Transformation of barley requires the development of a complete system. It requires a totipotent cell or tissue culture system, the identification, isolation and reconstruction of genes into vectors, and the efficient delivery of the vector into target cells where the desired genes are incorporated into the host cell DNA. The successful methods of delivery, and target tissues and genes utilized will be briefly reviewed prior to summarizing barley transformation research in Canada.

Successful Methods of Barley Transformation

In the past ten years, plant transformation has been successfully developed in cereals and some methods have been widely used for gene transfer. The successful methods used in barley transformation for obtaining transgenic plants are listed in Table 1. The merits of those methods are evaluated.

Table 1. Successful methods in barley transformation.

Method	Explant	Year	Gene	Research Group
Biolistics	endosperm	1991	(*uidA*)	Knudsen et al.
	cell suspension	1993	(*nptII uidA*)	Ritala et al.
	immature embryo	1994	(*bar*, *uidA*)	Ritala et al.
	immature embryo	1994	(*bar*, *uidA*, $BYDV_{cp}$)	Wan et al.
	immature embryo	1995	(*hpt*, *uidA*)	Hagio et al,Ritala et al..
	immature embryo	1996	*(bar)*	Rikiishi et al.
	immature embryo	1996 1998	(*stilbene synthase*)	Brauer et al., Leckband et al.
	scutella from immature embryo	1996	*(bar, nptII)*	Weir et al.
	microspore	1994 1997 1998	(*bar*, *uidA*) (*bar*,*uidA*) (*gfp*, *uidA*)	Jahne et al. Yao et al . Carlson et al.
Agro-mediated	immature embryo	1997	(*bar*, *uidA*)	Tingay et al.
	immature embryo	1998	(*xynA*, *bar*)	Patel et al.
	callus-derived from mature embryo	1998	*(BYDV, hph)*	Wang et al.
Direct transfer (PEG or Electroporation)	protoplast-derived from microspores	1995	(*nptII*)	Salmenkallio et al.
	protoplast	1995	*(nptII)*	Funatsuki et al.
	protoplast	1996	*(BaYMV BaMMV)*	Kuroda et al.
	protoplast	1996	*(β-glucanase)*	Jensen et al.
	protoplast	1997	*(β-amylase)*	Kihara et al.
	callus-derived from protoplast	1998	*(nptII)*	Kihara et al.

Direct Gene Transfer

Protoplasts are most often used as the target tissue for direct gene transfer and two procedures, polyethylene glycol (PEG) and electroporation, have been utilized successfully for transformation. The first regeneration from protoplasts was in tobacco (Nagata and Takebe, 1971) and this technique has been extended to all major cereal crops such as wheat, maize, rice, barley and sorghum.

The first transgenic plants of rice and maize were obtained from protoplasts using PEG. Treatment with PEG enlarges holes in the plasma membranes, permitting the uptake of foreign DNA or assists in cellular fusion for transformation via chimeric cell formation. Junkker et al. (1987) first reported transient expression of chimeric genes in barley protoplasts using a PEG based direct DNA uptake system. Transient GUS expression was also detected using PEG treatment of barley microspores (Kuhlmann et al., 1991). Lazzeri et al. (1991) and Mendel et al. (1991, 1992) reported stable transformation of barley via PEG-induced direct DNA uptake into protoplasts. Using the PEG procedure, at least four research groups have now regenerated barley transgenic plants (Funatsuki et al., 1995; Jensen et al., 1996; Kuroda et al., 1996; Kihara et al., 1997, 1998).

Electroporation produces electrical impulses which also make holes in the plasma membrane, allowing DNA to enter the cell. Compared with PEG, electroporation has not been widely used for plant transformation, probably because of difficulties in regeneration of plants and limited successful reports. In barley, only one paper has reported that transgenic barley plants were obtained from microspore-derived protoplast electroporation (Salmenkallio et al., 1995).

Microprojectile Bombardment

Although it is a relatively new method of transformation, microprojectile bombardment, or biolistics, has made great progress for plant transformation, essentially providing a breakthrough for cereal transformation. The foreign DNA, coated on microscopic particles of tungsten or gold, is fired to the target tissues using the special devices with pneumatic, helium, nitrogen, or an electronically triggered discharge. Particle acceleration can efficiently deliver foreign DNA into the surface layers of the cells. The first successful example of fertile transgenic plants induced by bombardment in grain crops was obtained from maize in 1990 (Fromm et al., 1990). Subsequently, fertile transgenic rice plants (Christou et al., 1991) and transgenic wheat plants (Weeks et al., 1993; Vasil et al., 1992) were reported.

For barley transformation, transient expression of marker genes in barley cells using particle bombardment was demonstrated in 1989 (Kartha et al., 1989; Mendel et al., 1989). Subsequently, reporter genes and selectable marker genes were stably expressed in barley cells (Ritala et al., 1993; Mannonen et al., 1991; Mendel et al., 1993). The successful regeneration of transgenic barley plants was first reported using the selectable marker genes *nptII* and *Bar* in the elite malting barley cultivar *Kymppi* (Ritala et al., 1994). Also, the *Bar* gene, *uidA* gene and $BYDV_{cp}$ gene were introduced into the cultivar Golden-Promise (Wan et al., 1994) through particle bombardment. Many successful barley transformations (Hagio et al., 1995; Ritala et al., 1995) have shown that immature embryos are suitable target tissues. However, the haploid tissue such as microspores was also found to be a suitable source for plant transformation. Transient expression of foreign DNA delivered by particle gun has been detected in mature tobacco microspores (Stöger et al., 1992), maize microspores (Jardinaud et al., 1995) and barley microspores (Harwood et al., 1995). Jähne et al. (1994) reported the recovery of homozygous transgenic barley plants following microspore bombardment. In our lab, using microspore bombardment, Yao et al. (1997) obtained transgenic barley plants with a heterozygous expression of *bar* and *uidA* genes in the winter habit barley cultivar Igri. Carlson et al. (1998) fired the *gfp* and *uidA* genes into barley microspores and were able to visually select transformed structures and plants. In Carlson's report, 38 GFP expressing multicellular structures were isolated from bombarded microspore cultures and six regenerated into green plants. These showed positive PCR results for the introduced marker genes. Southern blot analysis on the five that were doubled haploids confirmed the presence of *gfp* and *uidA* gene sequences.

Agrobacterium-Mediated Transformation

Agrobacterium-mediated transformation has been a routine method for transforming dicotyledonous species, but attempts to produce transgenic cereals before the 1990s were unsuccessful. However, this situation greatly changed after the first successful reports of *Agrobacterium*-mediated transformation in maize (Gould et al., 1991) and rice (Chan et al., 1992; Hiei et al., 1994). Improved vectors created much interest *Agrobacterium* transformation, culminating in very successful reports in maize (Ishida et al., 1996) and wheat (Cheng et al., 1997).

The possibility of *Agrobacterium*-mediated transformation for barley was studied in 1989 (Boulton et al., 1989). One year later, agroinfection and T-DNA transfer were found using *Agrobacterium* (Deng et al., 1990; Creissen et al., 1990). Although stable integration of the wheat dwarf virus (WDF) was detected (Creissen et al., 1990), no transgenic plants were obtained. After many more attempts, the first stable barley transformation via *Agrobacterium* was finally achieved in 1997. Genetically transformed barley plants were produced by co-cultivating immature embryo explants with *Agrobacterium tumefaciens* carrying binary vector with *Bar* gene and *GUS* gene (Tingay et al., 1997). Following this successful example, Wang et al. (1998) transformed callus derived from mature barley embryos using *Agrobacterium* with *BYDV* (barley yellow dwarf virus) and *hph* genes. They demonstrated the stable integration of foreign DNA in transgenic plants. In the same year, Patel et al. (1998) reported regeneration of barley plants with expression of *xynA* (a fungal xylanase cDNA) and *Bar* genes using *Agrobacterium.*

Barley Transformation in Canada

Relative to the importance of barley as a crop in Canada, there has been very little effort on barley transformation. Only two labs (Chibbar and Kasha) have been researching this topic for some time utilizing the biolistic approach. Three other labs (Eudes, Hill and Jordan, Table 2) have recently initiated projects when the potential of *Agrobacterium* mediated transformation was clearly demonstrated (Tingay et al., 1997).

The major tissue culture system for transformation is the scutella of immature embryos as developed for biolistic methods and now also used with *Agrobacterium*. Much effort has gone into inducing good regeneration via secondary embryogenesis on many agronomically important genotypes (Weir et al.,1996b; Eudes and Jordan, personal communication). It is also necessary to have good visual or culture selectable markers in the vector constructs to achieve success due to low frequency of cells transformed. The *uidA* (GUS) and *Bar* genes have been used to a great extent for visualization and selection respectively. Since the GUS reaction is a non-viable procedure, the sacrifice of some early cultures is required to determine the extent of transgenic expression. Thus, other visual marker genes have been sought. The green fluorescent gene (*gfp*) from the jelly fish has been tested quite extensively with some success (Carlson, 1998) when examined under UV or blue light. However, some other researchers have expressed some concern that GFP may have deleterious effects on cell division, resulting in lower frequencies of transgenic plants when compared to herbicide or antibiotic selection. However, we have found that both herbicide (Yao et al., 1997) and antibiotic (*nptII*) selection (unpublished) have resulted in a high proportion of escapes and are much more tissue culture labor intensive procedures.

The other target tissue being studied is the haploid isolated microspore of barley. This target has many potentially desirable traits such as very large populations of haploid (single set of chromosomes), synchronized staged, single cells which are capable of regenerating large numbers of plants in a plate from most genotypes. Thus, plants obtained could be homozygous for the transgene as culture procedures result in 75 to 80% of plants regenerated being doubled haploids. Unfortunately, the first fertile transgenic plants that we obtained (Yao et al., 1997) were heterozygous for the transgene, while those obtained by Jähne et al (1994) were homozygous. One difference in the procedures was the inducing pretreatment. Jähne et al. (1994) used a cold pretreatment while Yao et al. (1997) used mannitol. Subsequently, the combination of cold plus mannitol has yielded homozygous transgenics (Kasha unpublished). Although the frequency of transformed plants from microspore bombardment has been improved since the reports of Jähne et al. (1994) and Yao et al. (1997), it is still low. However, this approach is feasible and can result in plants that are fertile, non-chimeric and homozygous for the transgene. Most microspores hit with particles during bombardment are killed (Yao & Kasha, 1997) and this is the likely reason for the low frequencies. Therefore, the efficiency of *Agrobacterium* transformation of barley microspores is also under investigation (Kasha, unpublished). This has been attempted previously with little success (Huang, 1992; see Harwood et al., 1996).

Shot Gun Approach to Gene Expression

There are many traits that are of interest to Canadian barley growers as described elsewhere in these proceedings. Because of the speed with which a desired gene of major effect could be integrated into an otherwise superior cultivar by transformation, there is a major emphasis on using such systems for barley and other crops. Despite the fact that the first transgenic plants were produced less than 15 years ago, and that this science is in its infancy, many transgenic crops and their products are now in the markets (Gelvin, 1998). This has occurred without a clear understanding of the process of DNA integration and expression. Thus, these attempts are a 'shot-gun' approach that requires producing large numbers of transgenic plants in anticipation of finding one that will have stabile expression across environments. Some factors thought to be important are low copy number of transgenes, non-rearranged copies, the location in the host chromatin, and the host tissue type and genotype used as targets.

Of the three doubled haploid transformed barley plants obtained by Yao and Kasha (1997), all were heterozygous. In the next generation, two segregated in an expected 3:1 ratio while one was partially sterile and its progeny fit a 1:1 ratio. Plants selected as embryos and later seedlings expressing GFP (Carlson, 1998) have shown two quite different levels of GFP expression in the mature pollen and in germinating embryos from their seed progeny (unpublished). Based upon GFP expression in progeny, some of these plants appear to be homozygous for the *gfp* transgene that was introduced via haploid microspore bombardment.

Weir et al. (1996a) produced transgenic plants using biolistic bombardment of isolated immature embryo scutella from three different cultivars. Three different plasmids and both Basta herbicide and antibiotic selection were employed. There was some sterility in the transgenic plants but their progeny were quite fertile. The Southern analyses were not always consistent with the PCR analysis and the GUS expression was not consistently observed. The field analysis in 1998 confirmed that there were problems with gene silencing or loss in the transgenic lines.

As seen in Table 2, two main approaches are being used to deliver genes into barley cells, namely biolistic bombardment and *Agrobacterium tumefaciens* mediated T-DNA incorporation. Until recently the biolistic approach was used, however, now that success has been achieved with *Agrobacterium* on cereals, including barley (Tingay et al., 1997), all five Canadian labs have initiated this approach. Hill (personal communication) has produced a number of plants using the procedures of Tingay et al. (1997). It is thought that *Agrobacterium* provides a higher efficiency, lower copy number of inserts and more intact transgenes. However, other researchers are developing procedures combining both systems by bombarding cells with Ti plasmids containing T-DNA and some critical *vir* genes (Hanson and Chilton, 1996). This might also be considered by Canadian researchers. Research to remove the selectable markers genes after integration, to obtain site specific gene integration, and to add chromatin domains along with the gene construct may help to reduce the variability of transgene expression (Gelvin, 1998). With time and knowledge of the systems, transformation is expected to become more efficient and reliable. Tissue specific promoters attached to the genes should enhance their effectiveness.

In the few experiments planned or in progress in Canada, there is a wide range of objectives being considered (Table 2). They include resistance to the major Fusarium disease threat in barley (Jordan), improved winter survival of winter barley (Kasha), studies on forage barley digestibility (Eudes), reduced fatty acid for improved beer shelf life (Kasha), modified starch for industrial purposes (Chibbar), and systems for evaluating gene expression (Hill, Chibbar et al., 1993). Much effort has been expended on developing scutellar tissue culture regeneration systems (Weir et al., 1996a, 1996b; Jordan, Eudes, King and Kasha, 1994) and isolated microspores (Yao et al., 1997) for transgenic systems. While this effort represents a range of studies, the effort is insignificant relative to the importance of barley in Canada and the efforts in many other countries.

Much basic work on transformation systems, gene isolation and transgene construction is desperately needed.

Table 2. Summary of targets, methods, traits and results at Canadian labs involved in barley transformation in 1998.

	Lab	Target material	Procedure	Traits of interest	Results stage
1	R. Chibbar PBI, NRC Saskatoon	Immature embryos, isolated scutella (AC Metcalf & HB 325)	Biolistic gun, antibiotic and herbicide selection	Starch modification and herbicide resistance	Field tests in 1998
2	F. Eudes AAFC Lethbridge	Immature embryos scutellum	Biolistic gun *Agrobacterium*	Forage quality – digestibility enzymes	Tissue culture and bombardment initiated in 1998
3	R. Hill Univ.-Manitoba	Immature embryos, (Golden Promise)	*Agrobacterium*	Nonsymbiotic hemoglobin expression	Transgenic plant verification
4	M. Jordan AAFC Winnipeg	Immature embryos (Canadian elite lines)	*Agrobacterium*	Fusarium head blight resistance	Testing marker selection: *Bar*, *nptII*, *Gfp*
5	K. Kasha (retired) Univ. of Guelph	Isolated haploid microspores (Igri)	Biolistic gun *Agrobacterium*	Winter barley survival, beer shelf life	Confirmed plants, selected by *Bar*, *nptII* & *Gfp*

Acknowledgments

The authors are grateful to Drs. R Chibbar, F. Eudes, R. Hill and M. Jordan for the information that they provided about their research on barley transformation. Our own research on transformation has been supported by NSERC and OMAFRA.

References Cited

Brauer, G., A. Jähne-Gartner, D. Becker, R. Brettschneider and H. Lörz. 1996. Transformation of barley with a stilbene synthase gene in order to produce plants with an increased fungal resistance. In: A. Slinkard, G. Scoles, & B.G. Rossnagel (Eds.). Proc. Vth Intl. Oat Conf., VIIth Intl. Barley Genet. Symp. Vol 2. Univ. Saskatchewan, Saskatoon. 402-404.

Boulton M.L., Bucholz W.G., Marks M.S., Markham P.G., and Davis J.W. 1989. Specificity of *Agrobacterium*-mediated delivery of maize streak virus to members of the Graminae. Plant Mol.Biol. 12:31-40.

Carlson A. R. 1998. Visual selection of transgenic barley (*Hordeum vulgare* L.) structures and their regeneration into green plants. M.S. thesis. Crop Science, University of Guelph. 85pp.

Chan M.T., Lee T.M., and Chang H.H. 1992. Transformation of indica rice *(Oryza sativa L.)* mediated by *Agrobacterium tumefaciens* . Plant Cell Physiol. 33: 577-583.

Cheng M., Fry J.E., Pang S., Zhou H., Hironaka C.M., Duncan D.R., Conner T.W., and Wan Y. 1997. Genetic transformation of wheat mediated by *Agrobacterium tumefaciens*. Plant Physiol. 115: 971-980.

Chibbar, R.N., Kartha, K.K., Datla, R.S.S., Leung, N., Caswell, K., Mallard, C.S. and Steinhauer, L. 1993. The effect of different promoter-sequences on transient expression of *gus* reporter gene in cultured barley (*Hordeum vulgare* L.) cells. Plant Cell Reports 12:506-509.

Christou P., Ford T. L., and Kofron M. 1991. Production of transgenic rice (*Oryza sativa L.)* plants from agronomically important indica and japonica varieties via electric discharge particle acceleration of exogenous DNA into immature zygotic embryos. Bio/Technology 9:957-962.

Creissen G., Smith C., Franic R., Remolds H., and Mullineaux P. 1990. *Agrobacterium*-and microspore-mediated viral DNA delivery into barley microspore-derived culture. Plant Mol.Biol.8: 680-683.

Fromm M.E., Morrish F., Armstrong C., Williams R., Thomas J., and Klein T.M. 1990.

Inheritance and expression of chimeric genes in the progeny of transgenic maize plants. Bio/Technology. 8:833-839

Funatsuki H., Kuroda H., Kihara M., Lazzeri P.A., Müller E., Lörz H., and Kishinami I. 1995. Fertile transgenic barley generated by direct DNA transfer to protoplasts. Theor. Appl. Genet. 91: 707-712.

Gelvin, S.B. 1998. The induction and expression of transgenes in plants. Curr. Opinion in Biotech. 9:227-232.

Gould J., Devery W., Hasegawa O., Ulian E.C., Peterson G. and Smith R.H. 1991. Transformation of *Zea mays L* using *Agrobacterium tumefaciens* and the shoot apex. Plant Physiol. 95:426-434.

Hagio T., Hirabayashi T., Machii H., and Tomotsune H. 1995. Production of fertile transgenic barley (*Hordeum vulgare L.*) plants using the hygromycin-resistance marker. Plant Cell Rep. 14: 329-334.

Hanson, G. and M-D. Chilton. 1996. 'Agrolistic' transformation of plant cells: integration of

T-strands generated *in planta.* Proc. Natl. Acad. Sci. USA 93:14978-14983.

Harwood W.A., Bean S.J., Chen D.F., Mullineaux P.M., and Snape J.W. 1995. Transformation studies in *Hordeum vulgare* using a highly regenerable microspore system. Euphytica. 85:113-118.

Hiei Y., Ohta S., Komari T., and Kumashiro T. 1994. Efficient transformation of rice *(Oryza sativa L.)* mediated by *Agrobacterium* and sequence analysis of the boundaries of the T-DNA. Plant J. 6:271-282.

Huang,B. 1992. Genetic manipulation of microspores and microspore-derived embryos. In Vitro Cell Dev. Biol. 28P:53-58.

Ishida Y., Saito H., Ohta S., Hiei Y., Komari T., and Kumashiro T. 1996. High efficiency transformation of maize (*Zea mays L*.) mediated by *Agrobacterium tumefaciens.* Nature Biotechnology 14: 745-750.

Jähne A., Becker D., Brettschneider R., Lörz H. 1994. Generation of transgenic, microspore-derived, fertile barley. Theor. Appl. Genet. 89: 525-533.

Jardinaud M. F., Souvré A., Alibert G., and Beckert M. 1995. *UidA* gene transfer and expression in maize microspores using the biolistic method. Protoplasma. 11:1-5.

Jensen E.G., Olsen O., Kops O., Wolf N., Thomsen K.K., and Von Wettstein D. 1996. Trangenic barley expressing a protein-engineered, thermostable (1,3-1,4) βglucanase during germination. Proc.Nat.Acad.Sci.USA. 93:3387-3491.

Junkker B., Zimmy J., Luhrs R., and Lörz H. 1987. Transient expression of chimeric gene in dividing and non dividing cereal protoplasts after PEG-induced DNA uptake. Plant Cell Rep. 6: 320-332.

Kartha K.K., Chibbar R.N., Georges F., Leung N., Caswell K., Kendall E and Qureshi J. 1989. Transient expression of chloramphenicol acetyltransferase (CAT) gene in barley cell cultures and immature embryos through microprojectile bombardment. Plant Cell Rep. 8: 429-432.

Kihara M., Okada Y., Kuroda H., Saeki K., Yoshigi N., Ito K. 1997. Generation of fertile transgenic barley synthesizing thermostable βamylase. In: Proc 26th Congr. Eur. Brewery Convention. Oxford University Press, Oxford. 83-90.

Kihara M., Saeki K., and Ito K. 1998. Rapid production of fertile transgenic barley (*Hordeum vulgare L.)* by direct gene transfer to primary callus-derived protoplasts. Plant Cell Rep. 17: 937-940.

King, S.P. and K.J. Kasha. 1994. Optimizing somatic embryogenesis and particle bombardment of barley(*Hordeum vulgare* L.) immature embryos. In Vitro Cell Dev. Biol. 30P:117-123.

Knudsen S., and Müller M. 1991. Transformation of the developing barley endosperm by particle bombardment. Planta. 185:330-336.

Kuhlmann U., Foroughi-Wehr B., Graner A., and Wenzel G. 1991. Improved culture system for microspores of barley to become a target for DNA uptake. Plant Breed. 107:165-168.

Kuroda H., Kashiwazaki S., Kihara M., Hibino H., Ito K. 1996. Production of fertile transgenic barley plants expressing barley yellow mosaic virus or barley mild mosaic virus capsid protein gene. In: Slinkard A, Scoles G, Rossnagel B.G.(Eds.). Proc Vth Int Oat Conf

VIIth Int Barley Genet Symp, Vol.2. Univ. Saskatchewan, Saskatoon. 417-419.

Lazzeri P.A., Brettschneider R., Lührs R., and Lörz H. 1991. Stable transformation of barley via PEG-induced direct DNA uptake into protoplasts. Theor. Appl. Genet. 81:473-474.

Leckband G. and Lörz H. 1998. Transforamtion and expression of a stilbene synthase gene of *Vitis vinifera L.* in barley and wheat for increased fungal resistance. Theor. Appl.Genet. 96:1004-1012.

Mannonen L., Ritala A., Salmenkallio M., Aspegren K., Teeri T.H., and Kauppinen V. 1991. Optimization of gene transfer in barley by microporjectile bombardment. In: L. Munck, K. Kirkegaard and B. Jensen(Eds.). Barley Genetics VI, Vol 1, Copenhagen, Munksgaard Int. Publ., 237-239.

Mendel R. R., Muller B., Schulze J., Kolesnikov V., and Zelenin A. 1989. Delivery of foreign DNA in intact barley cells by high velocity microprojectiles. Theor. Appl. Genet. 78:31-34.

Mendel R.R., Clauss E., Schulze J., Steinbiss H.H., and Nerlich A. 1992. Gene transfer to barley. In: P.M. Greshoff.(Ed.), Plant Biotechnology and Development, Current Topics in Plant Molecular Biology. CRC Press, Boca Raton. 117-121.

Nagata T., and Takebe I. 1971. Plating of isolated mesophyll protoplasts on agar medium. Planta (Berlin) 99:12-20.

Patel M., Johnson J.S., Thornto S., Brettell R., Jacobsen J., and Xue G-P. 1998. Production of a fungal xylanasenin the developing endosperm of transgenic barley.In: P.J. Larkin (Ed.), Proceedings of the 4th Asia-Pacific Conference on Agricultural Biotechnology. 150-152.

Rikiishi, K., S. Takumi, T. shimada, M. Maekawa, K. Takeda and K. Noda. 1996. Efficient transformation in barley variety 'Lenins' by particle bombardment. In: Slinkard, A., Scoles, G., Rossnagel, B.G. (Eds.). Proc. Vth Intl. Oat Conf., VIIth Intl. Barley Genet. Symp. Vol. 2. Univ. Saskatchewan, Saskatoon. 435-437.

Ritala A., Mannonen L., Aspegren K., Salmenkallio-Marttila M., Kurtén U., Hannus R., Lozano J.M., Terri T.H., and Kauppinen V. 1993. Stable transformation of barley tissue culture by particle bombardment. Plant Cell Rep. 12: 435-440.

Ritala A., Aikasalo R., Aspegren K., Salmenkallio-Marttila M., Åkerman S., Mannonen L., Kurtén U., Ruupponen-Pimiä R., Terri T.H., and Kauppinen V. 1995. Transgenic barley by particle bombardment. Inheritance of the transformed gene and characteristics of transgenic barley plants. Euphytica. 85: 81-88.

Ritala A., Aspegren K., Kurtén U., Salmenkallio-Marttila M., Mannonen L., Hannus R., Kauppinen V., Terri T. H., and Enari T. 1994. Fertile transgenic barley by particle bombardment of immature embryos. Plant Mol. Biol. 24:317-325.

Salmenkallio-Marttila M., Aspergren K, Åkerman S., Kurtén U., Mannonen L., Ritala A., Teeri T.H., and Kauppinen V. 1995. Transgenic barley (*Hordeum vulgare L.*) by electroporation of protoplasts. Plant Cell Rep. 15:301-304.

Stöger E., Benito Moreno R.M., Ylstra B., Vicentr O., and Heberle-Bors E. 1992. Comparison of different techniques for gene transfer into mature and immature tobacco pollen. Transgenic Res. 1: 71-78.

Tingay S., McElroy D., Kalla R., Fieg S., Wan M., Thornton S., Brettell R. 1997. *Agrobacterium tumerfaciens*-mediated barley transformation. The Plant J. 11:1369-1376.

Vasil V., Castillo A. M., Fromm M. E., and Vasil I.K. 1992. Herbicide resistant fertile transgenic wheat plants obtained microprojectile bombardment of regenerable embryogenic callus. Bio/Technology 10:667-674.

Wang M-B., Graham M., Brettell R., Jacobsen J., Ramm K., Upadhyaya N., and Waterhouse P. 1998. Transformation of an elite barley cultivar with barley yellow dwarf virus (BYDV) resistance genes. In: P.J. Larkin (Ed.), Proc. 4th Asia-Pacific Conf. on Agric. Biotechnology. 18-20.

Wan Y., and Lemaux P.G. 1994. Generation of large numbers of independently transformed fertile barley plants. Plant Physiol. 104:37-48.

Weeks J.T., Anderson O.D., and Blechil A.E.1993. Rapid production of multiple independent lines of fertile transgenic wheat (*Triticum asetivum.*). Plant Physiol. 102:1077-1084.

Weir, B.J., K.J. Lai, K. Caswell, N. Leung, B.G. Rossnagel, M. Baga, K.K. Kartha, and R.N. Chibbar. 1996a. Transformation of spring barley using the enhanced regeneration system and microprojectile bombardment. In: A. Slinkard, G Scoles and B.G. Rossnagel(Eds.), Proc. V Intl. Oat Cong. & VII Intl. Barley Genetics Symp. Vol 2. Univ. Saskatchewan, Saskatoon, 440-442.

Weir, B.J., K.J. Lai, K. Caswell, B.G. Rossnagel, K.K. Kartha and R.N. Chibbar. 1996b. Optimization of the enhanced regeneration system for selected feed and malting barley lines. In: A. Slinkard, G. Scoles and B.G. Rossnagel (Eds.), Proc. V Intl. Oat Conf. & VII Intl. Barley Genetics Symp., Vol 2. Univ. Saskatchewan, Saskatoon, 443-445.

Yao Q. A., Simion E., William M., Krochno J., and Kasha K.J. 1997. Biolistic transformation of haploid isolated microspores of barley (*Hordeum vulgare L*.) Genome. 40:570-581.

Yao, Q.A. and K.J. Kasha. 1997. Potential of biolistic transformation of barley microspores based on viability and transient β-glucuronidase activity. Genome 40:639-643.

Marker Assisted Selection in Barley

Greg A. Penner, Monsanto
Winnipeg, Manitoba, Canada

Summary

This presentation is a summary of our experiences and thoughts in regard to the application of molecular markers to barley breeding. Some of the first applications of marker assisted selection to crop improvement have occurred in barley. Thousands of lines in Canadian barley breeding programs have been screened for the presence of alleles exhibiting resistance to stem rust and scald resistance. The application of molecular markers to breeding programs has forced both breeders and biotechnologists to work together to facilitate the necessary high throughput analysis at an affordable cost. The level of marker assisted application in barley has led to an evolution in the thought processes underlying this type of analysis. Due to both the crowding of desirable alleles linked in repulsion, and the limited number of chromosomes, marker assisted selection in barley is most efficiently directed towards selecting specific recombination events. The limited number of chromosomes also means it is possible to rapidly select recurrent parent genomes in backcrossing by selecting for non-recombinant chromosomes.

Marker Applications

Some of the world's first applications of molecular markers to plant breeding programs occurred in Canada. Stem rust resistance in barley had not been an issue for forty years following the introgression of the rust resistance gene, Rpg1 (or the T gene). In the late 1980's, this resistance was overcome by a new rust race, designated QCC. Dr. Brian Steffenson at North Dakota State University identified a resistance gene which he designated as rpg4 and identified a linked RAPD marker. We reproduced Brian's marker and converted it to a simple plus/minus marker (allele specific amplicon) that could be applied readily in barley breeding programs.

It is very difficult to select visually for the presence of either the rpg4 or the Rpg1 genes by themselves, and next to impossible to select for the combination of both. An RFLP marker linked to the Rpg1 gene had been identified by Andy Kleinhofs. We converted this marker into another allele specific amplicon and developed a technique whereby both the rpg4 and the Rpg1 markers could be combined into one assay. This marker analysis was applied to several thousand lines in western Canadian barley breeding programs.

This was the first high throughput application of a molecular marker to a barley breeding program that we were aware of, and thus the scaling up of application broke new ground. We found that it was possible for one person to routinely perform up to 300 analysis per week, including DNA extraction, PCR amplification, gel analysis and data reporting. This results in an estimated cost per analysis of $2.72 per line analyzed. Given that two markers were combined together, the cost per gene assayed was only $1.36.

Subsequent to this study, several markers linked to various scald and net blotch resistance genes were identified. It has not always been possible to convert these markers into allele specific amplicons that were applicable to western Canadian barley breeding programs. This is, however, an ongoing activity.

Markers for Recombination Points

A significant number of the molecular markers identified for scald resistance were co-located on chromosome 3H. In addition, in collaboration with Dr. Pat Hayes (Oregon State), we were able to define the location of a BYDV resistance locus relative to these scald resistance loci. In terms of applying marker assisted selection for these alleles, it became readily apparent that it would be necessary to define exactly where recombination events were occurring. No breeding lines contained all the useful alleles on a single chromosome. That meant it would be necessary to use markers to select for specific recombination events between loci with desirable alleles linked in repulsion.

The linkage distance between these loci could be used to determine the probability of given recombination events, and thus the appropriate population size necessary for selection. This is an example of how marker assisted selection and plant breeding are co-evolving to create selection results that were nearly impossible otherwise.

In most breeding applications, the need to break negative linkages in repulsion will likely arise. The probability associated with identifying the necessary recombination event in association with the probability of other recombination events, will constrain selection pressure. It is probable, in most cases, that only the one trait could be effectively introgressed in any given breeding cycle. The selection of appropriate recombination events will severely limit the remaining variability in a given population. I am suggesting that the most effective way to proceed with marker assisted selection in barley breeding programs may be to select for the necessary recombination event in the F2 population derived from a straight cross. The selected individual(s) should then be backcrossed to the parental lines, to regenerate segregating variability in the rest of the genome. This variability will then be subjected to selection with or without molecular markers.

Backcrossing Transgenes

It is increasingly probable that genetic constructs will exist that can be used to improve barley through genetic transformation. As in most crops, the genotype that responds best in tissue culture is not the best adapted agronomically. In barley, most transformation laboratories use the cultivar Golden Promise. Following successful transformation it is necessary to backcross the transgene from Golden Promise into adapted elite barley lines. The BC1 progeny contain, on average, 75% of the recurrent parent genome. This is on average, however, and individual lines may vary considerably in the amount of recurrent parent they contain.

From mapping studies, there is evidence that a recombination event occurs, on average, once per chromosome arm in barley. This means that there is a 50% probability that any given chromatid arm will not be involved in a recombination event, and a probability of 25% that any given entire chromatid will not be involved in a recombination event. These probabilities would be binomially distributed across the seven chromosomes (Table 1). In a BC1 population of 200 individuals it should be possible to identify individual lines that carry four non-recombinant chromosomes, and one chromosome containing the transgene with a single cross-over. In a subsequent doubled haploid population, it should be possible to identify individuals that carry six non-recombinant chromosomes, and the transgene containing chromosome with a cross-over on the other side of the transgene. Thus, it should be possible to accelerate the delivery of transgenes into an elite background in one backcross and one doubled haploid generation in barley.

Table 1.

Probability (%)	Number of chromosomes not involved in a recombination event
13.34	0
31.14	1
31.14	2
17.30	3
5.76	4
1.15	5
0.12	6
0.006	7

Improving Malting Quality Through Biotechnology

A.W. (Sandy) MacGregor, Canadian Grain Commission
Winnipeg, Manitoba, Canada

Introduction

During the past 25 years there has been a dramatic switch in the type of malting barley grown on the Prairies from the 6-rowed types that dominated the Canadian scene until the 1980’s to the 2-rowed cultivars that are the major types of malting barley in Canada today. This switch from 6-rowed to 2-rowed types was driven by the recognition that the malt and malting barley export market is largely a 2-rowed market. An extensive team effort was required for this remarkable change but the contribution of the barley breeders was, obviously, of prime importance. The barley development programs have been so successful today that the high quality of Canadian malting barley is recognized worldwide. However, to remain competitive in a world of changing technologies and structure, and of ever-increasing demands on quality and uniformity of processing performance, we must continue to enhance the end-use quality of our barley. To this end, we must be vigilant in identifying new ideas, knowledge, approaches and technologies that may be utilized to enhance barley quality.

New advances in plant molecular biology and in genetic engineering of cereals provide new tools for quality improvement in crops (McKinnon and Henry, 1995). These technologies cannot be applied in isolation nor should they be thought of as magic solutions to all problems. They are additional tools that, when used in conjunction with our current arsenal of technologies, have the potential to enable us to manipulate, in fine detail and in a controlled manner, individual quality characteristics of barley. This is in addition to the use of these technologies for improvements in agronomic traits and disease resistance, as aids in breeding programs, and to extend and deepen our knowledge of biochemistry and physiology of grain development, maturation and germination. Some of these topics will be covered in other presentations at this Symposium.

In this presentation, a few examples will be given of the potential of molecular biology to enhance the malting quality of barley. Particular emphasis will be given to improving mash characteristics (Table 1).

Table 1. Desired Mash Characteristics.

Maximum extract level	Desired level of soluble protein
Required level of fermentable carbohydrates	Appropriate colour
No filtration problems	Produces stable beer
Produces beer with desired flavour profile	

Starch Conversion

Extract is a measure of the amount of material that can be extracted from malt under specified conditions of temperature and time and is produced during the mashing stage of brewing. In theory, the extract level predicts how much fermentable product the brewer should expect from a given amount of malt. Obviously, this is a very important malt characteristic and extract levels should be as high as possible. Malt extracts are expected to be 80% or higher these days and are approaching the theoretical maximum of ca. 84%. A high percentage of the extract should be in the form of carbohydrate that has the potential for a high level of fermentability. Starch is the major carbohydrate in barley and malt and is the major component of malt extract. Therefore, malting barley should have as high a starch content as possible.

Starch is not fermented by brewing yeasts and so must be converted to fermentable carbohydrates during the mashing process by enzymes in the malt. This conversion has two stages. The malt starch must first be solubilized in order to render it accessible to the degrading enzymes and then conversion of the starch to fermentable products must take place rapidly. The most important functional property of starch for brewing purposes is its gelatinization temperature – the temperature required to solubilize it. This usually occurs in the 60 to 65°C temperature range but some of the starch degrading enzymes are unstable at temperatures approaching 65°C (Sjöholm et al., 1995). Therefore, it is important that barley/malt starch has as low a gelatinization temperature as possible. There is evidence that the gelatinization temperature can vary with cultivar and growing environment and this variation can affect the fermentability of the resulting extract (Stenholm et al., 1999). The effect of starch structure on gelatinization is not well understood so it is not possible, at this time, to formulate ideas on how to lower the gelatinization temperature of barley starch through changes in its molecular structure. Large granules from normal barley starch appear to have the lowest gelatinization temperature and so are the granules of choice for brewing purposes.

The conversion of starch to fermentable carbohydrates is carried out by a family of enzymes (α-amylase, β-amylase, limit dextrinase, and α-glucosidase), working in concert. α-Amylase is the most heat stable of these enzymes and is of prime importance for rapidly hydrolyzing the starch, once it has been solubilized, and producing substrate for the other enzymes. This hydrolysis prevents the formation of high viscosities that could be produced by the potentially very high starch concentrations developed in a high-gravity mash. It is unlikely that α-amylase levels are (50 to 60 DU) limiting in current Canadian malts. α-Amylase gene families in barley have been identified and characterized (Muthukrishnan and Chandra, 1988) and could be manipulated, if necessary, to increase α-amylase levels in malt.

β-Amylase is a more heat labile enzyme and is rapidly inactivated at mashing temperatures above 63°C (Sjöholm et al., 1995). The enzyme is most active on the products formed by α-amylase action on starch and so has a narrow window of opportunity for effective action during mashing. β-Amylase is a major contributor to malt DP and, since malts derived from Canadian barley appear to have adequate levels of DP, it is unlikely that β-amylase in Canadian malts (DP ca. 120°L) is limiting under most mashing situations. However, the effectiveness of the enzyme could be increased by improving the heat stability of the enzyme. Currently, two approaches are being taken to achieve this goal. One is to increase the proportion of β-amylase components in barley that have been shown to have improved heat stability (Kihara et al., 1997; Eglinton et al., 1998). This could be achieved through conventional breeding programs. In another approach, mutants of barley β-amylase with significantly improved heat stability have been developed (Yoshigi et al., 1996). It may be possible to insert genes for these mutants into barley and so improve the heat stability of malt β-amylase. This would enhance the effectiveness of malt β-amylase during mashing without the need to develop barley cultivars containing significantly higher levels of β-amylase.

Complete conversion of starch to fermentable products requires the hydrolysis of the α-(1→6) branch linkages in starch by the debranching enzyme, limit dextrinase. This enzyme is present in malt but appears to be relatively ineffective during mashing because high levels of branched starch dextrins are found in finished beer (Enevoldsen and Schmidt, 1973). It is now known that barley contains proteins that complex with, and strongly inhibit, the limit dextrinase (MacGregor et al., 1994). Sufficient levels of these proteins remain in the finished malt to inhibit a high proportion of the limit dextrinase during mashing. Significant increases (if desired) in the levels of fermentable carbohydrates during mashing could be achieved by lowering the levels of these inhibitors in malt. This could be accomplished by increasing the rate of degradation of the inhibitor by proteases during malting. However, this could result in the development of unacceptably high levels of soluble protein during mashing. Another approach would be to identify and characterize the inhibitor gene and suppress its expression in barley using genetic engineering technology.

There is evidence that the potential of limit dextrinase to increase the levels of fermentable sugars in a malt extract can be realized only in the presence of high levels of β-amylase (MacGregor et al., 1999).

β-Glucan Degradation

β-Glucan is the major component of the endosperm cell walls and a minor component of the aleurone cell walls of barley. It is a glucose containing polysaccharide in which 70% of the glucose residues are linked by β-(1→4) bonds and 30% are linked by β-(1→3) bonds. The polysaccharide forms very viscous solutions and causes filtration problems during brewing and stability problems in beer during storage if it is not adequately degraded to small products during malting and mashing (Bamforth, 1985). One approach to minimizing this problem is to lower the β-glucan levels in barley and this is a major objective of malting barley breeding programs. Another approach is to maximize the extent of β-glucan degradation during malting and mashing. This could be accomplished in a number of ways but the chances of success may be greatly increased by using genetic engineering technology.

The major enzymes responsible for β-glucan degradation are the β-glucanases, which are synthesized, essentially, in aleurone and scutellum cells during malting. These enzymes are relatively heat labile, lose a significant amount of activity during kilning, and are rapidly inactivated during mashing. Therefore, it is essential that they carry out extensive hydrolysis of β-glucan during the germination phase of malting. For this to be accomplished, high levels of β-glucanases must be synthesized rapidly in the aleurone and scutellum during malting and secreted immediately into and through the entire endosperm to break down the β-glucan.

Progress has been made in increasing the levels of β-glucanase in malt; but it would be advantageous to increase the rate of enzyme synthesis and secretion. This could be accomplished, for example, by replacing the promoter part of the β-glucanase gene with a more powerful one such as that of malt α-amylase.

Another approach is to increase the heat stability of barley β-glucanase by genetic manipulation of the barley gene or by inserting, into barley, genes for heat stable β-glucanases from other sources, such as fungi (Aspegren et al., 1995) or bacteria (Jensen et al., 1996). It is highly likely that the first transformed barley with improved end-use quality will be one containing β-glucanase with significantly increased heat stability.

β-Glucanase, by itself, is not able to degrade β-glucan completely to products that pose no threat to ease of technological processing. There are relatively long chains of β-(1→4)-linked glucose residues in β-glucan that are completely resistant to attack by β-glucanase but do have the potential to cause processing problems during brewing (Izydorczyk et al., 1998). These chains can be hydrolyzed to glucose by enzymes such as β-glycosidases and β-glucan exohydrolases, which are present in only low concentrations in malt (Hrmova et al., 1997). Again, it may be possible to manipulate the genes of these enzymes to make them more effective during malting. This would have the double advantage of ensuring complete degradation of β-glucan, and so prevent it from causing processing problems, and of converting β-glucan completely to glucose, and so increasing malt extract levels.

Arabinoxylans

These are polymers of xylose and arabinose that are also present in the endosperm and aleurone cell walls of barley. They produce highly viscous solutions and relatively high levels are found in beer (Han and Schwarz, 1996). They have the potential to cause processing problems either on their own or in combination with β-glucans (Izydorczyk et al., 1998). More information is required on the role of these macro-molecules during malting and brewing, on their structure/functional relationships, and on the enzymes in malt that have the potential to degrade them, before practical strategies can be formulated to reduce their potential to cause problems during brewing.

Proteins

Proteins play a multi-faceted role in malting and brewing, so their influence on malt and beer quality is complex (Enari and Sopanen, 1986). For example, they form the matrix in the barley endosperm within which starch granules are embedded. This matrix must be broken down during malting to release the starch. Excessive breakdown, however, results in excessive colour development in malt extracts and poor head stability in beer (Narziss, 1998). Insufficient breakdown, on the other hand, prevents complete release of starch during malting with concomitant reduction in starch conversion during mashing, beer storage problems and insufficient production of amino acids for yeast metabolism during brewing. Some proteins are associated with poor filtration performance during brewing (Moonen et al., 1987) and these should be hydrolyzed to harmless products during malting. Protein hydrolysis during malting is carried out by a large number of protein-degrading enzymes (Jones, 1995) but most of the hydrolysis appears to be carried out by a few major enzymes, which are synthesized in the aleurone during germination.

It is important to distinguish between aleurone and endosperm proteins. Aleurone cells are rich in protein and account for ca. 20% of the protein present in barley. Unlike the endosperm, aleurone does not contain hordein proteins but readily soluble globulins (Yupsanis, 1990). During germination, these globulins are probably broken down very quickly to provide building blocks for the synthesis of the many hydrolytic enzymes formed in the aleurone. This hydrolysis may be under the control of aleurain, an aleurone specific protease, that is synthesized during barley germination (Jones and Jacobsen, 1991). This series of reactions must occur quickly in the aleurone if rapid germination is required. Degradation of protein in the endosperm is carried out, largely, by proteases synthesized in and secreted from the aleurone and it is this degradation that must be controlled by malting and mashing conditions so as to achieve the desired level of protein modification in mashes. There might be an advantage to de-linking the synthesis of these proteases from that of β-glucanase so that rapid synthesis of high levels of β-glucanase need not be accompanied by high levels of protease with corresponding excessively high levels of soluble protein in extracts. Manipulation of protease development during malting could be achieved through genetic engineering technologies.

Over recent years, evidence has been accumulating that barley contains inhibitors to some of the major hydrolytic enzymes produced during malting (Jones and Marinac, 1995; MacGregor et al., 1994; Weselake et al., 1983). Manipulation of the levels of these inhibitors would also be possible through new gene technologies.

Many other examples of potential improvements in malting barley quality through genetic engineering could be cited such as lowered lipoxygenase levels to maintain beer freshness, alteration in the amino acid composition of wort to shorten beer maturation time, and increasing the levels of lipid transfer protein in barley to improve head stability in beer (Inoue, 1996).

It is important to remember that barley is a complex, living organism and that its many components and biochemical and physiological systems are there for good reasons. Alteration of these to benefit malting and brewing technologies may have an adverse effect on the agronomic characteristics of the barley. This would be counter productive and unacceptable.

Conclusions

There will be on-going demands for malting barley with enhanced end-use quality and trouble-free processing characteristics. The use of malting and brewing aids will diminish further and this will put even more emphasis on barley and malt quality. New gene manipulation technologies allied to the current scientific disciplines involved in the development of improved barley varieties have great potential for improvements in end-use quality of barley. Advances using these new technologies, however, will have to be handled carefully and will be dependent on their acceptance by customers and the general public.

References

Aspegren, K., Mannonen, L., Ritala, A., Puupponen-Pimiä, R., Kurén, V., Salmenkallio-Marilla, M., Kauppinen, V., and Teeri, T. H. (1995). *Molecular Breeding* **1**: 91–99.

Bamforth, C. W. (1985). *J. Inst. Brew*. **91**: 154–160.

Eglinton, J. K., Langridge, P., and Evans, D. E. (1998). *J. Cereal Sci.* **28**: 301–309.

Enari, T.-M., and Sopanen, T. (1986). *J. Inst. Brew*. **92**: 25–31.

Enevoldsen, B. S., and Schmidt, F. (1973). Proc. of 14th Congress of European Brewery Convention, p. 135–148.

Han, J. Y., and Schwarz, P. B. (1996). *J. Am. Soc. Brew. Chem*. **54**:, 216–220.

Hrmova, M., Banik, M., Harvey, A. J., Garrett, T. P. J., Varghese, P. B., Høj, P. B., and Fincher, G. B. (1997). *Int. J. Biol. Macromol*. **21**: 67–72.

Inoue, T. (1996). Proc. of V International Oat Conference and VII International Barley Genetics Symposium, Saskatoon, p. 30–35.

Izydorczyk, M. S., Macri, L. J., and MacGregor, A. W. (1998). *J. Carbohydr. Polymers* **35**: 249–258.

Jensen, L. G., Olsen, O., Kops, O., Wolf, N., Thomsen, K. K., and von Wettstein, D. (1996*). Proc. Natl. Acad. Sci.* **93**: 3487–3491.

Jones, B. L. (1995). Proc. of 7th Australian Barley Tech. Symposium, p. 141–149.

Jones, B. L., and Marinac, L. A. (1995*). J. Am. Soc. Brew. Chem*. **53**: 194–195.

Jones, R. L., and Jacobsen, J. V. (1991). *Int. Res. Cytol*. **126**: 49-88.

Kihara, M., Kaneko, T., Fukudo, K., and Ito, K. (1997). Proc. of 8th Australian Barley Tech. Symp., p. 3:5.

MacGregor, A. W., Bazin, S. L., Macri, L. J., and Babb, J. C. (1999). *J. Cereal Sci*. (in press).

MacGregor, A. W., Macri, L. J., Schroeder, S. W., and Bazin, S. L. (1994). *J. Cereal Sci.* **20**: 33–41.

McKinnon, G. E., and Henry, R. J. (1995). *J. Cereal Sci*. **22**: 203-210.

Moonen, J. H. E., Graveland, A., and Muts, G. C. (1987). *J. Inst. Brew*. **93**: 125–130.

Muthukrishnan, S., and Chandra, G. R. (1988). Adv. in Cereal Sci. and Technology (Y. Pomeranz, ed.), AACC, St. Paul, MN. **IX**: 129–159.

Narziss, L. (1988). *Brauwelt International* **16**: 14–25, 46.

Sjöholm, K., Macri, L. J., and MacGregor, A. W. (1995). Proc. of 25th Congress of the European Brewery Convention, p. 277-284.

Stenholm, K., Wilhelmson, A., and Hame, S. (1999). Proc. of 5th Aviemore Conference, Aviemore, Scotland (in press).

Weselake, R. J., MacGregor, A. W., and Hill, R. D. (1983*). Pl. Physiol*. **72**: 809–812.

Yoshigi, N., Okada, Y., Maeba, H., Sahara, H., and Tanaki, T. (1996). *J. Applied Glycoscience* **43**: 227–235.

Yupsanis, T., Burgess, S. R., Jackson, P.J., and Shewry, P. R., (1990). *J. Exp. Bot.* **41**: 385–392.

Malting Barley Quality for Domestic and Export Markets

Xiang S. Yin / Walter J. Fernets, Prairie Malt Limited
Biggar, Saskatchewan, Canada

Introduction

The barley specifications selected for malting have a direct influence on the quality of malt produced. These malt specifications are determined by brewers and are tailored for their specific brewing processes. This brief paper will discuss barley quality requirements and provide some insight regarding the general requirements as they relate to domestic and export markets.

Basic Barley Requirements

The following barley requirements are common to either domestic or export needs. Different malting conditions determine the malt specification ranges attainable within barley varieties.

Quality malt production starts with the maltster selecting a pure lot of an accepted malting variety. This indicates the variety has undergone testing by the malting and brewing industry. This testing provides assurance that the variety could be accepted by the industry if the malting performance consistently delivers the desired specifications. **Varietal purity** is a precondition for setting process parameters to produce malt of high homogeneity and uniform characteristics, even if the end-users often require specific blends of malt from different varieties for their brewhouse operations.

Many major malt characteristics, such as enzymes and extractable materials, are rendered through barley germination. At least 95% of the barley should germinate, which is expressed in terms of **germination energy**. Immature, weathered or deeply stained kernels do not germinate with vigor, and can be visually distinguished at barley selection. Husk damage affects the uniformity of water uptake by the kernels during the malting process, hence **peeled and broken grains** should be less than 3%.

Plumpness of the kernel relates to the potential extract level the malt will give, therefore, uniform and plump kernels are required. It is usually specified that the plumpness for 2-rowed barley is 85% over the 6/64" slotted screen, and 6-rowed barley 80% over 6/64".

The **protein content** of barley affects the chemical composition of the extract from malt. It should be high enough to give sufficient nutrients for fermentation and to produce peptides for beer head retention, but not so high as to cause problems to beer stability. Preferred range is 9.5 to 12.5% on dry basis.

Moisture of barley should be within 12.5 to 13.5%. As well as economic reasons, high moisture kernels are susceptible to infestation, mold growth, and loss of vitality during storage and transportation.

Visually, malting barley should be **bright healthy kernels**, free from heated kernels, and free from contaminants such as insect damage, large oilseeds, Ergot, treated seeds, smut and odour. **Pre-harvest sprouted barley** is rejected.

Quality and availability of barley vary according to crop year. Upon harvest maltsters, who determine changes in barley characteristics, normally carry out micro-malting tests. Results then provide indications for necessary changes to be made to adjust for tendencies such as induced dormancy and water sensitivity.

Malting Process

What brewers need from malt is a package of extractable materials and a series of enzymes that can further solublize and hydrolyze these materials into more simple forms ready for fermentation. Malting is the process required to convert barley to malt with these functions. The malting process involves barley cleaning, steeping, germination, kilning and malt cleaning.

Steeping washes the grain, and hydrates kernels to about 45% moisture to activate acrospire growth. **Germination**, the main stage of malting, is carried out for four to five days under controlled levels of aeration, temperature and humidity. Cell wall degradation occurs in the barley kernel, and proteins in the endosperm are partially degraded to a specified degree. These activities allow the starch granules to be exposed to enzymes developed in the kernel. Objectives of malt modification process are to direct the operational conditions to produce malt that the brewers require in terms of quality emphasis. **Kilning** at the end stops the germination progress. During this phase colour and flavour are formed, and malt is finally stabilized at very low moisture content (about 4%).

To a limited extent, maltsters can manage the production operational control to adjust the quality of the resultant malt. Barley selected, however, must have the innate properties to yield malt that meets the brewers specifications.

Trend in Quality Requirement for Canadian Barley and Malt

The distinct breeding and registration system for malting barley in Canada has provided barley growers and maltsters a great competitive edge in today's global market, particularly since Harrington was released in 1981. Brewers have appreciated high values of enzymatic activities, balanced protein and extract, and homogeneous modification all over the world. A convincing example is the historic trend of Canada's malt export to Japan, a highly competitive quality market. Canada over-took Australia in the 1980's becoming the number one supplier of imported malt to Japan. The total annual volume of Canadian malt imported to Japan is averaged at over 200,000 mt since 1991, a third of its total import. However, other malting barley producers in Europe and Australia are striving hard to improve their varieties for the global market. Canada must continuously improve its barley quality to stay ahead.

Protein Content and Protein Degradation

The relatively high protein characteristic of Canadian barley is normally viewed as a negative aspect since it affects the malt modification and level of carbohydrate extract. However, brewing with substantial amount of starch/sugar based adjuncts, Canadian malt is found to complement malt of low protein (9.5 to 10.5%) from Europe and Australia, as specified amounts of soluble protein is required in the brewer's wort to feed the yeast for fermentation and to provide beer foam. Protein content specification at around 11% is now becoming common.

It is also observed that control on the degree of protein solublization is important. Too much degradation of protein causes a decrease of the foam-enhancing peptides, that are partially hydrolyzed products from barley protein. Research work has indicated that the foam stability of beer is correlated to the ratio of soluble to total proteins (Kolbach Index) in the malt. As beer head retention becomes more critical to brewers and consumers worldwide, the requirement for Kolbach Index narrows to the range of 38 to 44 %, which is quite a challenge for Canadian maltsters since the barley tends to have rapid proteolysis during germination. While it was noted that barley from some other parts of the world could give both controlled protein degradation and high overall kernel modification, the growing climate as well as varieties of barley may play an important role in Canada.

A notable trend in Japan is the launch of Happoshu (sparkling liquor) using only 25% or less malt in its grain bill, which is rapidly reaching a market share of 15 to 20% in the country. One of the reasons for its success is very low government taxation – hence low retail price. Technically it is similar to beers with a very high adjunct ratio. The high diastatic power (DP) (eg. 500 wk) and high soluble nitrogen characters, rendered naturally by Canadian barley with relatively high proteins, are recognized as advantages for this purpose. Brewing Happoshu is not yet an international phenomenon.

Soluble Beta-Glucans in Malt

A portion of the beta-glucans in barley is degraded during malting, and the residual beta-glucans can be further degraded during brewing by beta-glucanases produced in malt. Beta-glucans in the final wort, however, can be viscous in nature and affect the efficiency of wort separation and beer filtration. As the rate of filtration directly affects productivity in the brewery, end-users are gradually introducing wort beta-glucan measurement into the specifications. The brewers put significant emphasis on this parameter. In practical malting, it is very difficult to lower levels of beta-glucans without increasing levels of soluble nitrogen. This means that barley for malting must have low beta-glucans or high potential beta-glucanase as prerequisites for quality malt production.

Hull Adherence

Most malting barley and malt shipments to export customers go through intensive handling procedures. Particularly, large amounts of malt are moved through bulk handling for economic reasons. Poor hull adherence leads to kernel breakage, excess dust, handling loss and process difficulties, which could be a bitter commercial experience for suppliers. Manley has tighter hull adherence than Harrington and has shown benefits in improving the perception for Canadian malt.

Diastatic Power

High levels of starch-degrading enzymes are a well-known feature of Canadian malt. Requirements for this parameter are broad. While many customers are satisfied with the current levels (DP > 200 wk), certain large international brewers are very critical about the range of DP in malt. There are circumstances when some present 2-row barley varieties in Canada can not readily guarantee malt that will meet the minimum requirement for DP. The “dry” note of beers is derived from more complete fermentation of sugars, released from starch by these diastatic enzymes. The types of brewing materials, process and product at breweries determine specifications for DP. These developments indicate that Canada needs diverse barley varieties that can produce malt with a broader range of starch-degrading abilities.

Long Term Germination and Slight Dormancy

This is an area of concern for malting barley export. Barley stored on the dry Canadian Prairies does not seem to show significant change in germination capacity over the summer. There are incidents, however, where a drastic drop (up to 30%) in germination energy occurred when barley from Canada went through transportation and storage under more warm and humid conditions overseas. In addition to moisture content and fungal load, varietal traits such as dormancy, water sensitivity, and enzyme potential of barley might be factors affecting this loss in germination vigor. Research projects are underway to find the cause of this problem and measures to prevent it. Progress in this quality trait is of high significance for the continuous development of overseas markets for Canadian malting barley.

Agrochemical Residues

Consumers worldwide are increasing attention on agrochemical residues in food and beverages. Many countries publish a list of tolerance on grains annually. Relatively low tolerance levels are set for common agrochemicals that are approved for use on barley in Canada. For example, the tolerance level for malathion residue on barley for Japan is 2.0 ppm, while Canada’s maximum permitted level is 8.0 ppm. Many countries also strictly regulate the amount of glyphosate residue.

The customer product liability Acts require the supplier to be responsible for residues in malt even though intensive washing and kilning processes during malting would reduce the presence of most agrochemicals on barley. New potential varieties with built-in disease resistance would be advantageous in this respect.

Conclusions

Due to the ever-increasing demand for “perfect” malt, some aspects of barley quality need to be addressed in Canada. Emphases vary depending on individual brewers, but certain parameters such as hull adherence, beta-glucan, protein, and germination vigor, that associate with the nature of barley, tend to influence the malt performance more prominently.

In today’s market economy, desired characteristics of malt come from the brewer’s requirements in terms of malt specifications that is a dynamic living document. The specifications and varieties are determined and endorsed by brewers depending on the process and market requirements, with or without the input from the maltsters. The role of the maltster is working as agent between the producers and brewers to facilitate communication, direct breeding programs, and to promote new varieties by malting to meet or exceed specifications.

In conclusion, final decisions and support for varieties are brewer driven. A variety may have excellent agronomic features and efficient malting and brewing performance, but it must pass the brewer’s beer taste evaluation and performance requirements. A variety that is granted registration does not automatically mean that maltsters or grain exporters can switch their market to take this variety instantly. With the collective effort of breeders, researchers, producers and processors, and the input of the end-users through marketing representatives, the Canadian system for malting barely can make continuous improvement in quality to keep up with the market challenges ahead.

Acknowledgement

The authors wish to thank Prairie Malt Limited for permission to publish this report.

A Customer’s Perspective on Canadian Malting Barley

Alan Slater, Busch Agricultural Resources, Inc.
Winnipeg, Manitoba, Canada

Introduction

Anheuser-Busch enjoys the honour of being the world’s largest brewer, and its flagship brand, Budweiser—The King of Beers—reigns as the world’s most popular beer. Our beers are brewed using only the finest quality ingredients…the choicest hops, rice and best barley malt. It is the promise that comes with every beer brewed by Anheuser-Busch, Inc., and the secret to the company’s success. As every brewer knows, quality beers can only be made with quality ingredients.

Importance of Barley Quality

Malt is the soul of beer. Without high quality malt, the consistent quality of today’s beer would not be possible. High quality malt, of course, comes from high quality malting barley. Breweries and malthouses are becoming increasingly automated. This has led to the need for uniformity and consistency in barley supplied for the malting process. High levels of variability reduce product quality and increase production cost.

Quality Assurance

Barley quality varies widely by crop year, growing region, variety, grower and handling/storage techniques. The challenge and reward is to meet the maltster’s quantity requirements while minimizing the amount of quality variation. This is no small task. The only proven method for shipping malting barley 100 percent within specification, 100 percent of the time, is to produce it that way in the first place. Quality assurance begins with growers. Barley, as most other grains, is grown as a commodity. For growers to meet our quality standards they need to grow and handle the crop in a value added manner. It is critical that the grower and the handling system understand the end-users specifications and its importance to the quality of our products. Canada’s bulk handling system is going through a rapid rationalization and modernization process. Some question the ability of the grain handling and transportation network to manage the quality assurance system required to meet our specifications. We are working closely to assist our suppliers in this transition throughout Western Canada. Our demand for specific quality characteristics will continue and it will be up to all of us to find ways to identity preserve (IP) grain efficiently and at lower cost.

Monitoring

Continued monitoring of the barley production, handling and blending process is important. Our experience dictates that, while this principle is obvious, it’s not always observed. As your system shifts the barley selection process from a centralized system to the local country elevator, it becomes even more important that elevator operators have the technical equipment and training to run a quality assurance system. The decision the elevator operator makes at the pit is the last opportunity to catch a mistake before it becomes extremely expensive. Know your end user, identify the product quality specifications and develop quality targets. Duplicating how your end-user monitors quality at destination will greatly reduce rejections and increase overall satisfaction.

Barley Quality

We recognize Canada as an important producer of quality 2-rowed and 6-rowed malting barley. In Canada, your environmental factors play a major role in determining malting quality. Fortunately, you produce from a vast geographic area which can minimize the impact of weather problems on the overall quality and supply of malting barley. However, one of the more elusive issues related to Canadian barley is the percent of crop which is accepted as malting barley.

The official grade specification changes that reflect more closely the quality factors being demanded by end users is certainly a step in the right direction. Stricter varietal purity requirements, lower peeled and broken and 13.5 percent moisture maximum specs were needed to allow Canada to maintain high malting barley quality standards.

Increasing direct origin to end-user shipments has also improved quality and direct communications with the country handling system. This will only improve grower satisfaction as your street pricing program speeds up the decision making process. Our challenge is to implement a quality assurance system at the country elevator level.

Summary

As a customer of your malting barley, I hope we have provided some insight into our perspective of Canadian barley. Malting and brewing are very complex biological processes that require consistent high quality ingredients. Whether we like it or not, we're all subject to what the customer requires and that is immovable.

Anheuser-Busch has been a customer of high quality malting barley for more than 100 years and as it heads into the 21st century, global expansion continues to be a priority. An unwavering commitment to quality ingredients will continue. It will take a coordinated approach involving all sections of the Canadian malting barley industry to maintain a reliable and quality supply.

Does the Feed Industry Have Barley Quality Needs?

Dave R. Hickling, Canadian International Grains Institute
Winnipeg, Manitoba, Canada

The short answer to the question posed in the title of this presentation is “Yes,” although the fact that the question is even asked indicates that not everyone is aware that the feed industry does have barley quality needs. The feed industry, both in Canada and worldwide, generally does differentiate feed barley by quality and in most cases applies premiums, discounts or refusals basis those quality specifications. The real issue is that different feed users have different quality requirements based on the different types of animals that they are feeding the barley to and the different methods that they use to process the barley before feeding. The resulting situation is that there is no “uniform” set of quality needs for feed barley, which makes it difficult to develop a set of quality standards.

Most commonly used feed ingredients such as barley, corn, wheat, soybean meal and canola meal are used because they contribute nutrients to the feed cost effectively. Computer least cost feed formulation is routinely used to select ingredients which contain nutrients at the lowest cost. Different types of animals value ingredients differently based on the animal’s nutrient requirements. Due to these animal differences, barley is generally of highest value in ruminant feeds, of intermediate value in hog feeds and of lower value in poultry feeds. Compared to other ingredients, the interesting thing about barley is that it is often still used in feeds despite lower cost nutrient alternatives. For barley, there may sometimes be considerations other than the price of its nutrients. For example, it may be used in beef and hog feeds because of its positive effects on meat quality. Or, it may be used to feed sheep because it does not require processing and minimizes feeding management.

Quality Considerations for Feed Barley Use in Canada

Barley is fed to all types of animals in Western Canada although the major market (5 million tonnes of the 8 million tonne total) is for beef cattle. The hog (1.5 million tonnes) dairy (1 million tonnes) and poultry (0.5 million tonnes) industries are secondary feed barley markets. Generally then, the quality specifications for feed barley in Western Canada reflect the requirements of the beef industry.

For cattle, the Canadian Grain Commission’s primary grade standards for feed barley provide some information about quality. For 1 CW barley there is a maximum tolerance on foreign material of 2.5%, a minimum volume weight of 60 kg/hL and a maximum moisture content of 14.8%. The Winnipeg Commodity Exchange has a minimum bushel weight of 48 lbs/bu on their Western Feed Barley contract, with a penalty of $5/tonne for 46 lbs/bu barley. Feed companies and cattle feedlots usually have additional specifications on kernel plumpness and uniformity. There are also specifications on degrading factors such as broken or weathered kernels and disease damage. Generally, the CGC’s grade standards cover the pertinent degrading factors quite well. Combining the CGC, WCE and industry specifications would result in the following specification which would be fairly typical of good quality barley - primarily intended for feeding cattle.

Table 1. Typical Quality Specifications for Feed Barley in Western Canada.

Specification	Amount
Volume weight	48 lbs/bu (approx. 60 kg/hL) minimum
Moisture	14.8% maximum
Plumpness and Uniformity	65% over # 6 slotted screen (2.38 mm) and 95% over a # 5 slotted screen (1.98 mm)
Dockage	1.5% maximum

The volume weight and plumpness minimums are required because a plumper kernel is easier to process and provides a better quality product after processing. Most barley fed to cattle is either dry or wet rolled. Kernel uniformity is important when grain is passed through a roller since small kernels will be under-processed and large kernels will be over-processed. Users who wet-roll barley also prefer barley with fast water uptake ability since this reduces processing costs and provides a better quality end product. Barley volume weight is considered by some feed users to be related to energy value, however, above a minimum volume weight (approximately 45 lbs/bu) there is only a very weak positive relationship between volume weight and energy. The fact that 46 lbs/bu barley is discounted, $5/tonne is probably more related to volume weight being an indirect measure of thin kernels rather than nutritional value.

Again, beef cattle are the major consumers of feed barley (over 60%) in Western Canada. Cattle feeders value barley as an energy source. They prefer barley with thin hulls (low fibre) and high starch levels (high digestible energy levels). Since much of the feed barley used in Western Canada is rejected malting barley, it is fortuitous, but coincidental, that many of the above quality specifications for feed barley are also shared by maltsters: thin hulls, rapid water uptake, high starch levels, plump and uniform kernels. Maltsters like barley with a high malt yield (low fibre, high starch) and rapid processing characteristics (rapid water uptake). Kernel uniformity is also important for uniform germination during the malting process. Also related to overall feed barley quality – since the standards for malting barley selection are quite high, it is often only very small problems that result in a barley being rejected for malt and used for feed. Generally then, feed barley in Western Canada is good quality. Malting barley varieties such as Harrington are often preferred by the feed industry, in fact, a standard comment by the feed industry is, "Give me a 2-row malting barley!". This overall high quality of our barley supply may be one of the reasons that the feed industry does not complain too much and why the question in the title of this presentation is asked.

Despite the dominance of the beef industry in the barley market, approximately 3 million tonnes of barley is fed to dairy cattle, pigs and poultry in Western Canada (a bit less than 1 million tonnes of this is hulless barley). While energy is still the most important nutrient in barley for these animals, protein is also economically significant. Dairy, pigs and poultry have a higher protein requirement than beef cattle. Also, the protein quality of barley is good since it contains high levels of lysine – which is important for growing pigs and poultry. The following table lists the economic value of high protein barley in diets for feedlot beef cattle, lactating dairy cattle, growing pigs and broiler chickens.

Table 2. Increase in the value of barley (Can $/tonne) for different animals with increased barley protein levels. Prices used for other ingredients were based on market value in Winnipeg in January 1999.

Parameter	Beef	Dairy	Pigs	Broilers
Feed Protein	13.0%	16.0%	16.0%	21.0%
Barley 10.0% CP	$0.00	$0.00	$0.00	$0.00
Barley 11.0% CP	$0.53	$3.76	$4.39	$6.30
Barley 12.0% CP	$0.53	$3.76	$4.39	$6.30
Barley 13.0% CP	$0.53	$3.76	$4.39	$6.30

Note from Table 2 that as the protein level in the animal's diet increases, then the value of extra protein in the barley also increases. The reason that extra protein has a higher value in pig feeds compared to dairy feeds even though the protein level is the same, is that pigs obtain value from the extra amino acids, especially lysine, to a greater extent than dairy cattle. Given the overall dominance of the beef market in the barley trade, however, it is unlikely that significant premiums will develop for high protein barley. Also, malting barley varieties are generally selected for lower protein levels, and as long as rejected malting barley comprises a major portion of the feed barley supply, there will be no increase in barley protein levels.

Much is made about the presence of ß-glucans in barley. Certainly the levels of ß-glucans in barley have anti-nutritive effects when fed to young poultry and sometimes to young pigs. The use of supplemental ß-glucanase enzyme has negated these effects however, and ß-glucan levels in barley are generally not a practical quality concern.

Quality Considerations for Feed Barley Use in Export Markets

The feed barley quality requirements of the international market are generally more subjective than the requirements for the Canadian market. This reflects the unique ways that feed barley is used in the two largest feed barley importing countries: Saudi Arabia (5 million tonnes) and Japan (1.5 million tonnes).

In Saudi Arabia, feed barley is purchased unprocessed and in bags by the Bedouins and is fed whole to their herds of sheep and camels. Barley from many origins (Canada, Europe, Australia, U.S.) is mixed together prior to sale to the Bedouins. This blending tends to obscure quality differences. The only real quality concerns of note to the Saudi Arabian buyer are moisture content and foreign material levels.

In Japan, most of the barley is fed to Wagyu cattle after it is steam flaked. Japan has similar quality issues as Canada when it comes to processing barley: kernel plumpness and uniformity are very important. The Japanese processors are also concerned about foreign material levels – there is a cost in removing dockage. They also prefer lower moisture levels than Canada usually provides – a high moisture content makes is difficult and costly to dry the barley after steam flaking. Also, the Wagyu beef farmer prefers a light-coloured kernel. Kernel colour is a cosmetic issue but probably reflects long-held beliefs that a dark kernel is a damaged kernel. Nutrient levels in the barley, such as protein content and energy digestibility, are often stated by the Japanese buyer to be of less importance, but I think that energy and protein levels are more important than they generally admit.

Other countries buy Canadian feed barley for various uses: the U.S. for dairy cattle feeds, Iran for dairy cattle feeds, Taiwan for specialty feeds and Mexico for hog and beef cattle feeds. Generally they have similar quality specifications to western Canadian users and the 1 CW grade specification is usually sufficient for quality purposes.

Quality Considerations for Hulless Barley

Hulless barley production has increased rapidly over the last seven years. The advantage of hulless barley is that without the hull, the levels of crude fibre decrease and the levels of starch and protein increase through concentration. The energy value of hulless barley is approximately 10% higher than covered barley, and is similar to wheat and corn. This makes hulless barley suited for use in high energy feeds such as pig and poultry feeds. As well, the protein content of hulless barley is similar to wheat, and because of the high lysine concentration in barley, there is significant value from this extra protein.

The ß-glucan levels are more of a quality issue with hulless barley than they are with covered barley. Hulless barley has higher levels of ß-glucans than covered barley since ß-glucans are concentrated in the endosperm. Also, since higher inclusion levels of hulless barley than covered barley are used in hog and poultry feeds, this makes the use of ß-glucanase enzyme essential in broiler chicken and baby pig diets, recommended in layer chicken diets and possibly required in hog grower and finisher diets.

The key quality issue with hulless barley is the amount of adhering hulls. The grade for Standard CW hulless barley is 15% maximum kernels with adhering hulls, as measured by weight. In fact most feed users would prefer a maximum of 5% adhering hulls and the industry is moving in that direction. Hull adherence is the biggest quality challenge to the success of hulless barley.

Summary

Historically, the quality requirements for feed barley have been somewhat subjective and inconsistent. Greater importance has been placed on physical characteristics than on nutritional characteristics. This reflects the multiple uses of feed barley – different processing methods and feeding to different types of animals. It also reflects the fact that Canadian feed barley has generally been of very good quality.

The recent increase in hulless barley production has the potential to more clearly define barley quality needs by the feed industry. Hulless barley is becoming very popular with hog and poultry feeders. The high energy and protein levels in hulless barley are economically important, and quality factors such as hull adherence, starch content and amino acid levels will become more important quality factors. Covered feed barley quality will increasingly be driven by its use in the beef cattle industry, where processing characteristics are more important. This divergence of use between covered and hulless barley should encourage development of more specific quality specifications for each type of barley.

Barley Research in Eastern Canada

T.M. (Alek) Choo, Agriculture and Agri-Food Canada
Ottawa, Ontario, Canada

Introduction

Barley (*Hordeum vulgare* L.) has been grown in Eastern Canada for almost 400 years. First grown in Port Royal in 1606 (Hamilton, 1955), barley is now grown in all six provinces of Eastern Canada. Eastern Canada produced 1,000,700 tonnes of barley grains and 438,700 tonnes of mixed grains (mainly mixtures of barley and oats) in 1998 (Statistics Canada, 1998). Despite this, Eastern Canada, on average, purchased 364,400 tonnes of barley annually from Western Canada under the Feed Freight Assistance Program (Canada Grains Council, 1997). Barley is used mainly for livestock feed. Almost all of it is consumed by dairy cattle (44%), hogs (38%) and beef cattle (16%) (Statistics Canada, 1995). Canada Malting purchases malting barley from Western Canada for its Montreal and Thunder Bay plants, which have the capacity to process annually 81,700 and 144,700 tonnes of barley, respectively (Canada Malting, 1995).

Barley in Eastern Canada is of spring type; some winter barley is also grown, exclusively in southern Ontario. Six-row barley predominates because of its high yield (Jui et al., 1997). Some 6-row varieties, however, are high in fibre (Kong et al., 1995) and thus hog producers prefer to buy 2-row varieties (anonymous, 1997). Until now, only covered barley is grown commercially in Eastern Canada. This will change in the future with the impending release of the first hulless barley variety (AB168-11) for Eastern Canada. Barley research is conducted by federal and provincial governments, universities, as well as the private sector. This article provides an overview of the current research activities on barley across Eastern Canada.

Breeding

Breeding Programs

Agriculture and Agri-Food Canada has consolidated its previous barley breeding efforts in one single program at the Eastern Cereal and Oilseed Research Centre (ECORC). The goals of the ECORC’s program are to develop barley varieties (including both 2-row and 6-row, and both covered and hulless) for Eastern Canada and to develop early maturing varieties for northern Ontario, northern Quebec and Newfoundland. The University of Guelph has been funded by the Ontario Ministry of Agriculture, Food, and Rural Affairs to develop 6-row barley varieties for Ontario. Besides these two public breeding programs, six private companies in the region are actively involved with barley breeding. W. G. Thompson and Sons Limited aims at feed barley varieties (both 2-row and 6-row) for Eastern Canada, and 2-row (for malt) and 6-row (for malt and feed) varieties for Western Canada. Thompson also runs the only winter barley breeding program in Canada to develop 6-row varieties for Ontario and north-eastern United States. Similarly, Semico Inc. runs a strong private breeding program to develop 6-row varieties for Eastern Canada. Coopérative Fédérée de Québec is breeding 6-row barley. Prograin Inc. conducts its 6-row barley breeding in partnership with Laval University. C & M Seeds works on 6-row and 2-row barley breeding in collaboration with the University of Guelph and a German company, respectively. It is also searching for malting barley and hulless barley. Minas Seed Co-op Limited is introducing European varieties/lines to Canada.

The barley breeding programs in Eastern Canada have been very successful. The yields of barley varieties released from 1935 to 1988 increase at a rate of about 0.03 t/ha/yr (Bulman et al., 1993). Twenty-nine of the 76 barley varieties on the 1990 List of Registered Varieties originated in Eastern Canada (Kong et al., 1994). Some of the eastern varieties yield well in both Eastern and Western Canada (Kong et al., 1994). Since 1990, Eastern Canada has registered 32 spring barley and 2 winter barley varieties (Appendix 1).

Breeding Objectives

The above breeding programs aim at improving specific traits of barley. The important traits for spring barley for Eastern Canada are: high grain yield, disease resistance, lodging resistance, resistance to neck break, good threshability, high protein, high test weight, low fibre, early maturity, high straw yield, tolerance to water/heat stress, and tolerance to low pH. For winter barley, winter survival, barley yellow dwarf virus (BYDV), and scald resistance are the major challenges.

Breeding Methods

A variety of breeding methods are used by barley breeders in Eastern Canada. The most common one is the modified bulk method. Guelph, however, is using male sterile facilitated recurrent selection to conduct its breeding program (Kannenberg and Falk, 1995). Kasha and Kao (1970) developed the bulbosum method for producing doubled-haploid (DH) lines. Since then, Eastern Canada has used it to develop 20 barley varieties (Table 1). Ouédraogo et al. (1998) developed an amino acid enriched FHG medium for barley anther culture. The medium is now used routinely by Laval to produce DH lines. In vitro selection for resistance to biotic and abiotic stresses is also used by Laval to develop new barley lines (St-Pierre et al., 1998). Recently, Kasha et al. (1997) perfected the isolated microspore culture system for barley, and ECORC is attempting to use it to produce DH lines for breeding barley. A callus derived line (RE80) recently received support for registration from the Ontario Cereal Crops Committee.

Pathology

Diseases

Barley suffers many diseases in Eastern Canada, with the most important ones being net blotch, spot blotch/common root rot, scald, powdery mildew, fusarium headblight, BYDV, leaf rust, stem rust, loose smut, covered and semi-loose smuts, and ergot. Net blotch could reduce yield by 15% (Martin, 1985) and increase kernel discoloration (Edney et al., 1998). The epidemiology of *Pyrenophora teres* is being studied by the Crops and Livestock Research Centre (CLRC). Pathotypes of *P. teres* in Eastern Canada remain unknown. It is believed that they are similar to the isolate WRS102. The most prevalent isolates of *Erysiphe graminis* are those virulent to genotypes with resistance genes *Ml-h*, *Ml-p, Ml-a1,* and/or *Ml-k* (Louter, 1991). OAC Kippen possesses three resistance genes (*Ml-a1, Ml-h,* and *Ml-g),*

Table 1. Barley varieties developed by the bulbosum method in Eastern Canada.

No.	Variety	Year	Institution	Reference
1.	Mingo	1979	Ciba-Geigy Seeds	Ho and Jones (1980)
2.	Rodeo	1983	Ciba-Geigy Seeds	Campbell et al. (1984)
3.	Craig	1988	W. G. Thompson	Shugar (Pers. Comm.)
4.	Winthrop	1989	W. G. Thompson	Shugar (Pers. Comm.)
5.	Lester	1990	W. G. Thompson	Shugar (Pers. Comm.)
6.	Ontario	1990	W. G. Thompson	Shugar (Pers. Comm.)
7.	TB891-6	1992	W. G. Thompson	Shugar (Pers. Comm.)
8.	Prospect	1993	W. G. Thompson	Shugar (Pers. Comm.)
9.	Bronco	1993	W. G. Thompson	Shugar (Pers. Comm.)
10.	Beluga	1995	W. G. Thompson	Shugar (Pers. Comm.)
11.	McGregor	1995	W. G. Thompson	Shugar (Pers. Comm.)
12.	Sandrine	1995	W. G. Thompson	Shugar (Pers. Comm.)
13.	Belmore	1996	W. G. Thompson	Shugar (Pers. Comm.)
14.	Grant	1996	W. G. Thompson	Shugar (Pers. Comm.)
15.	McDiarmid	1996	W. G. Thompson	Shugar (Pers. Comm.)
16.	Gamine	1996	Semico	Bastien (Pers.Comm.)
17.	Serena	1996	Semico	Bastien (Pers.Comm.)
18.	Breslau	1997	W. G. Thompson	Shugar (Pers. Comm.)
19.	Sunderland	1997	W. G. Thompson	Shugar (Pers. Comm.)
20.	AC Westech	1998	Ag. & Agri-Food Canada	Choo et al. (1999)

but it became susceptible within a few years after it was released. Falak (1994) attributed this to an increase of isolates that are virulent to genotypes with the *Ml-g* gene. Many 2-row varieties, however, show durable resistance to powdery mildew. Some callus derived lines were found to be resistant to powdery mildew (Choo et al., 1998). Fusarium infection is higher in barley than wheat in Quebec (15% vs. 11%) (Couture, 1982) and in Prince Edward Island (65% vs. 52%) (Sturz and Johnston, 1985). The most frequently isolated fusaria from barley ear tissues are *F. graminearum* (30%), *F. poae* (25%), *F. avenaceum* (16%), and *F. culmorum* (8%) (Sturz and Johnston, 1985). Despite high infection levels, fusaria seem to have very little effect on barley yield (Sturz and Johnston, 1985). Effects of fusarium infection on the DON content, however, remain to be investigated. Some barley seeds or products from Quebec in 1992-94 contained up to 6 mg/kg of DON and 24 mg/kg of ochratoxin A (Canadian Food Inspection Agency, Mycotoxin Databank). Mycotoxins at these levels would have deleterious effects on animal health and productivity (Friend and Trenholm, 1988). The impact of weather conditions on the airborne spore load of *Fusarium sp*. is being studied by CLRC.

Control

Currently, resistant varieties to major diseases are very limited. AC Kings is resistant to WRS102 of *P. teres,* whereas ACCA was found to be resistant to BYDV (*Yd2*) and to isolate 1493 of *Rhynchosporium secalis*. Both AC Sterling and Morrison are resistant to powdery mildew. Winthrop is resistant to ergot. ECORC and CLRC are screening barley accessions for fusarium headblight and DON content. CLRC and New Liskeard are evaluating seed treatments and/or foliar fungicides for controlling diseases for both covered and hulless barley. The Nova Scotia Agricultural College (NSAC) is also studying seed treatments. The Soils and Crops Research and Development Centre (SCRDC) is searching for tolerance to root rot, BYDV, and waterlogging.

Cytogenetics

Xu and Kasha (1992) transferred a dominant gene for powdery mildew resistance from *H. Bulbosum* to cultivated barley. At ECORC, resistance to QCC of stem rust was transferred from *H. bulbosum* to cultivated barley. Populations are being developed for inheritance studies and gene tagging. The *Hordeum-Secale* amphyploid and *Hordeum-Elymus* hybrids will be backcrossed to barley in order to transfer tolerance to biotic and abiotic stresses to barley (Fedak and Petroski, 1996). The meiotic behaviour of these interspecific hybrids are under investigation. *H. spontaneum* accessions are being screened for salinity tolerance. Laval will continue its work on interspecific hybridization and novel germplasm development.

Biotechnology

Variety Identification

Barley varieties were successfully distinguished on the basis of random amplified polymorphic DNA (RAPD) (Tinker et al., 1993; Baum et al., 1998), restriction fragment length polymorphism (RFLP) (Molnar and McKay, 1995), and simple sequence repeats (SSRs) (William et al., 1997). Baum et al. (1998) published an identification key for all the 65 registered 6-row barley varieties in Canada. The transferability of SSRs across species and their stability over time are being investigated by Guelph. It is now possible to use DNA extracted from single seeds for variety identification (William et al., 1997; Baum et al., 1998).

Molecular Systematics

Baum et al. (1997) used RAPDs to study molecular diversity in *H. spontaneum*. Molnar et al. (1992) used RFLPs to analyze the phylogenetic relationships in the genus *Hordeum*. Baum and Johnson (1994; 1996; 1998) studied the 5S rRNA gene thoroughly in many *Hordeum* species. Use of molecular markers to study the phylogenetic relationship among the *Hordeum* species will be continued at ECORC. The extent of synergy between barley and oat will be investigated.

QTL Analysis

QTL analysis for the Harrington/TR306 cross led by Kasha was completed (Tinker et al. 1996; Mather et al. 1997; Spaner et al., 1998). The genome mapping project is currently led by Mather with an objective of testing strategies for using molecular markers in the development of barley lines with good adaptation and malting quality. Studies on QTL mapping, QTL verification, and marker-assisted selection for QTL are being conducted at

McGill. Two DH populations have been created by ECORC to identify QTLs affecting agronomic traits, physiological traits, disease resistance, and feed quality of barley. Single seed descent lines are being developed for the purpose of tagging fusarium resistance gene(s). Attempts to tag net blotch resistance genes are in progress at ECORC using RAPD and sequence characterized amplified regions. Three independent loci that are resistant to loose smuts have been tagged; further work is in progress at Laval to perform interval mapping in order to more precisely locate these loci and to assess their respective contributions to resistance.

Transformation

Transgenic barley plants have been produced by bombardment of isolated microspores (Yao et al., 1997; Yao and Kasha, 1997). Selection of transgenic plants was achieved using the herbicide Basta and the antibiotic geneticin in the medium and by visual selection using the green fluorescent protein. Efforts are continuing at Guelph to improve the frequencies of transgenic plants using both bombardment and Agrobacterium methods.

Physiology

Research on intensive cereal management has been conducted at McGill. Post-anthesis application of ethephon increases yield (Ma and Smith, 1992). Higher rates of nitrogen fertilizer applied at seeding or at awn emergence increase grain protein concentration (Bulman and Smith, 1993). Grain protein accumulation seems to be more limited by the ability of roots to take up N from the soil than by the seed to take up N from the rest of the plant (Foroutan-pour et al., 1997). The final conclusion of their research is that the short growing season in Eastern Canada does not allow much time for barley to respond to really high levels of N fertilizer and the application of ethephon. The feasibility of using physiological traits as selection criteria for high yield and using canopy reflectance for early prediction of grain yield are being evaluated. Barley is being used by Laval and NSAC as a indicator plant to estimate the uptake of nutrients.

Agronomy

A multi-discipline, multi-institute project on mixed grains is in progress to identify the best varietal combinations of barley and oat for commercial production in Eastern Canada and to assess the benefits of mixed grains over pure stands. In a rotation study, Johnston (1997) investigated the effects of management practices on the forage yield and quality of barley and on subsequent alfalfa establishment. CLRC is studying the effects of seeding rate, variety, and management practices on the total production of both barley and red clover and to assess the usefulness of barley as a cover crop after potatoes in the control of soil erosion. Three rotation systems for corn were compared by the St-Hyacinthe Research Station. Results showed that corn in the second year yielded more in the barley-corn or soybean-corn system than in the corn-corn system and that soybean did not supply as much as barley did for corn that followed because of nitrate leaching on soybean. Recently, the Atlantic Cool Climate Crop Research Centre (ACCCRC) initiated an active research program to develop sustainable feed grain production and utilization systems for cool climates. CLRC is screening barley varieties for tolerance to low pH for use in potato rotation. A study is conducted by Emo (Ontario) to assess the effects of paper mill biosolids on barley if they are used as soil conditioner.

Animal Nutrition

Grains

The chemical composition of 76 Canadian barleys has been studied (Kong et al. 1995; Narasimhalu et al., 1995). Six-row breeding materials from ECORC are now screened for high protein and low fibre. ECORC is developing Grainspec calibration for estimating the protein content of hulless barley. The Atlantic Veterinary College wants to find ways of improving the feeding value of barley for pigs. For pigs, application of xylanase improves digestibility and availability of nutrients in barley and hulless barley based diets. Shur-Gain's research also focuses on anti-nutritional or negative nutritional factors in barley for monogastric species. Its goal is to develop better formulation methods which counter these negative factors and identify feeding situations where these factors are of concern.

Straw and Silage

Two-row barley yields more straw than 6-row barley (Narasimhalu et al., 1998). Two-row barley straw is higher in rumen degradability than 6-row barley straw (Salgado et al., 1995). Preliminary results from Guelph showed that production performance of dry pregnant beef cows is not affected with diets containing up to 75% of barley straw from 2-row varieties and that there was no difference in production performance between control (alfalfa haylage) and mix diet (25% alfalfa haylage and 75% barley straw). Eventually, Guelph wants to develop an environmentally friendly approach for improving the utilization of straw for ruminants. Silage barley was evaluated by New Liskeard for yield and quality. The first forage barley variety (Summerville) was registered in Canada by W. G. Thompson and Sons Limited.

Malting and Food Barley

Several scientists have collaborated with Canada Malting in identifying malting barley varieties for Eastern Canada. Two malting barley varieties (B1602 and Robust) show promise in Eastern Canada. In food barley research, the Southern Crop Protection and Food Research Centre (SCPFRC) aims at developing novel techniques for processing barley into bran and flour fractions; exploring the use of bran and flour fractions in food and non-food applications; and evaluating the content, molecular weight distributions and rheological properties of β-glucans.

Summary

In summary, the goals of the barley research in Eastern Canada are to:
1. develop new technologies in order to speed up the breeding process, to increase selection precision for economically important traits, to facilitate gene transfer, and to protect intellectual property rights;
2. better understand the behaviour of pathogens and to devise environmentally and economically sustainable approaches for controlling diseases;
3. explore the genetic diversity in barley and its related species, and to transfer the resistance/tolerance genes from wild species to barley;
4. develop sustainable cultural practices for barley production and to find ways of optimizing barley production under unfavourable environments;
5. identify value-added products for feed and for food, and to reduce/neutralize anti-nutritional factors in livestock feed; and ultimately
6. develop superior barley varieties for feed, food, and malting purposes.

Acknowledgements

The author is grateful to the following scientists for written input regarding their respective barley research which was provided during the preparation of this manuscript: C. Azar (Coop Fédérée), B. R. Baum (ECORC), F. Belzile (Laval), C. D. Caldwell (NSAC), F.-P. Chalifour (Laval), J. Collin (Laval), H. Chrétien (Prograin), P. E. Colucci (Guelph), A. Comeau (SCRDC), S. Cui (SCPFRC), L. M. Dwyer (ECORC), G. Fedak (ECORC), J. Frégeau-Reid (ECORC), S. Guertin (St-Hyacinthe), K. M. Ho (ECORC), J. Johnston (New Liskeard), K. J. Kasha (Guelph), B. L. Ma (ECORC), R. A. Martin (CLRC), D. E. Mather (McGill), E. McMillan (Shur-Gain), S. J. Molnar (ECORC), J. Rowsell (New Liskeard), L. Shugar (W. G. Thompson), D. Smith (McGill), D. Spaner (ACCCRC), E. Sparry (C & M Seeds), C. A. St-Pierre (Laval), and T. Van Lunen (AVC).

References

Anonymous. (1997). PEI Grain Elevator Newsletter 2(4): 1-2.

Baum, B. R. and Johnson, D. A. (1994). Genome 37: 992-998.

Baum, B. R. and Johnson, D. A. (1996). Genome 39: 140-149.

Baum, B. R. and Johnson, D. A. (1998). Genome 41: 652-661.

Baum, B. R. et al. (1997). Genetic Resources and Crop Evolution 44: 147-157.

Baum, B. R. et al. (1998). Seed Sci. & Technol. 26 (in press).

Bulman, P. and Smith, D. L. (1993). Agron. J. 85: 1109-1113.

Bulman, P. et al. (1993). Euphytica 71: 35-48.

Canada Grains Council. (1997). Canada Grains Council, Winnipeg.

Canada Malting. (1995). Canada Malting, Toronto.

Campbell, K. W. et al. (1984). Can. J. Plant Sci. 64: 203-205.

Choo, T. M. et al. (1998). Can. J. Plant Sci. 78: 316-317 (Abstr.).

Choo, T. M. et al. (1999). Can. J. Plant Sci. (in press).

Couture, L. (1982). Can. J. Plant Sci. 62: 29-34.

Edney, M. et al. (1998). Can. J. Plant Sci. 78: 217-222.

Falak, I. (1994). M.Sc. Thesis, University of Guelph, Guelph.
Fedak, G. and Petroski, R. (1996). Proc. 5th IOC & 7th IBGS, Vol. 1: 323.
Foroutan-pour, K. et al. (1997). Physiologia Plantaram 100: 190-201.
Friend, D. W. and Trenholm, H. L. (1988). Pigs News and Information 9: 395-401.
Hamilton, D. G. et al. (1955). Barley Improvement Institute, Winnipeg.
Ho, K. M. and Jones, G. E. (1980). Can. J. Plant Sci. 60: 279-280.
Jui, P. Y. et al. (1997). Theor. Appl. Genet. 94: 549-556.
Johnston, J. E. (1997). Proc. 18th International Grassland Congress, Vol. 2: 25-26.
Kannenberg, L. W. and Falk, D. E. (1995). Can. J. Plant Sci. 75: 45-53.
Kasha, K. J. and Kao, K. N. (1970). Nature 225: 874-876.
Kasha, K. J. et al. (1997). Barley Genetics Newsletter 27: 13-15.
Kong, D., et al. (1994). Can. J. Plant 74: 737-744.
Kong, D., et al. (1995). Can. J. Plant Sci. 75: 865-870.
Ma, B. L. and Smith, D. L. (1992). Agron. J. 84: 370-374.
Martin, R. A. (1985). Can. J. Plant Pathol. 7: 83-90.
Mather, D. E. et al. (1997). Crop Sci. 37: 544-554.
Molnar, S. J. and McKay, A. (1995). Can. J. Plant Sci. 75: 191-193.
Molnar, S. J. et al. (1992). Hereditas 116: 87-91.
Narasimhalu, P. et al. (1995). Can. J. Plant Sci. 75: 371-376.
Narasimhalu, P. et al. (1998). Can. J. Anim. Sci. 78: 127-134.
Louter, J. H. (1991). Ph.D. Thesis, University of Guelph, Guelph.
Ou_draogo, J. T. et al. (1998). Plant Cell, Tissue and Organ Culture 53: 59-66.
Salgado, A. et al. (1995). Ontario Beef Research Update, 1995: 45-48.
Spaner, D. et al. (1998). Crop Sci. 38: 843-850.
Statistics Canada. (1995). Statistics Canada, Cat. No. 23-212E.
Statistics Canada. (1998). Statistics Canada, Cat. No. 22-002-XPB 77(7).
St-Pierre, C. A. et al. (1998). Proc. 9th International Wheat Genetics Symposium, Vol. 1: 49-52.
Sturz, A. V. and Johnston, H. W. (1985). Can. J. Plant Pathol. 7: 270-276.
Tinker, N. A. et al. (1993). Theor. Appl. Genet. 85: 976-984.
Tinker, N. A. et al. (1996). Crop Sci. 36: 1053-1062.
William M. et al. (1997). J. Amer. Soc. Brew. Chem. 55: 107-111.
Xu, J. and Kasha, K. J. (1992). Theor. Appl. Genet. 84: 771-777.
Yao, Q. A. and Kasha, K. J. (1997). Genome 40: 639-643.
Yao, Q. A. et al. (1997). Genome 40: 570-581.

Appendix 1. Eastern Canada barley varieties registered from 1991 to 1998.

Agriculture and Agri-Food Canada: AC Alma, AC Burman, AC Hamilton, AC Legend, AC Nadia, AC Stephen, AC Westech, AC Kings, AC Parkhill, AC Queens, AC Sirius, AC Sterling, and Almonte.

University of Guelph: Codac.

W. G. Thompson and Sons Limited: Beluga, Brucefield, Grant, Sandrine, TB891-6, Sommerville (forage), Belmore, Breslau, Sunderland, McDiarmid (winter), and McGregor (winter).

Semico Inc.: Bella, Gamine, Myriam, and Serena.

C & M Seeds: Formosa, Frin, and Viking.

Laval University: ACCA

McGill University: Labelle.

Food Quality Aspects of Barley

Thava Vasanthan, University of Alberta
Alberta, Edmonton, Canada

Introduction

The average Canadian production of barley is between 12 to 13 million metric tones per year (Canadian Wheat Board, 1998). This includes the production of 0.75 million metric tones of hulless barley. Overall, the food market for Canadian barley is very small (<5%). However, in recent years, the demand for this grain, especially hulless barley, has been increasing in non-malting food uses. Consequently, the concept of non-malting food-barley quality evaluation is of increasing importance to the Canadian barley industry, and has started receiving more research attention.

In theory, the basic concepts of grain quality are easy to understand. However, the practicality of this phenomenon is very complex. This is due to many reasons:

- Desired quality attributes (sensory and nutritional) of a grain differ with end use because, for each end use, there is diversity in quality perception by various ethnic groups and their industries who demand the grain;
- In Canada, grain is produced in vast quantities in different geographical regions under diverse climatic/soil conditions and agronomic practices, which have been shown to influence grain quality; and
- It is a difficult task to build a set of desirable grain physicochemical characteristics into a variety.

Therefore, realization of food barley supply chains, each with defined set of quality criteria for individual food uses, in order to provide high/consistent quality grains is a challenge.

In Canada, as with wheat, there exists a lucrative and successful model for grading of feed and malting barley. There also exists, for food barley, a grading system that needs improvement. A coordinated research effort among various barley stakeholders (processors, marketing agencies, breeders, bio-technologists and food processing scientists) is underway to further refine this grading system in order to deliver consistent quality food barley grain/products to demanding groups.

Why Barley and its Components Into Food?

Barley is a nutritious grain. It is a good source of a neutraceutical called beta-glucan. The whole/pearled/milled grain is suitable for production of cereal-based functional foods. Results from several clinical and animal trials have suggested that regular intake of barley foods may benefit human health. As with oats, barley contains a soluble dietary fiber component, beta-glucan, which has shown significant cholesterol lowering effects (Martinez et al., 1992; McIntosh et al., 1991). Also, the beta-glucan in barley increases the viscosity of intestinal fluid and thereby slows down the rate of absorption of sugar/starch. This is beneficial to diabetics. Barley contains tocotrienols, a sub-component of vitamin E (tocols), which also have been postulated to reduce blood serum cholesterol (Quershi et al., 1986).

When compared to other common cereal grains (wheat, oat and corn), barley contains the highest amount of tocotrienol (0.67 to 0.85 mg/100g seed) (Budin, 1996). In addition, this grain is free of any known anti-nutritive factors. As with corn, barley cultivars containing starches with low (<2%, waxy), regular (approx. 25%) or high (approx. 40%) amylose content are available. Waxy starch is well suited to food applications due to its unique textural implications, water holding capacity and excellent freeze-thaw stability. In addition, waxy hulless barley contains higher amount of beta-glucan (up to 8%) than other regular barley (up to 5%) and oat (up to 5%). Due to these reasons, the majority of studies in the area of barley grain fractionation or whole-grain utilization focus on waxy hulless barley.

Barley and Japanese Food Market

Traditionally, rice has been the choice of Japanese for most of their cereal grain based foods [boiled rice, miso paste (*Aspergillus* mold fermented product), saki/shochu (*Aspergillus* mold and yeast fermented, distilled alcoholic beverage), etc]. However, barley with its unique sensory and superior nutritional properties has been used as an extender, replacing a portion of rice in these foods. The use of barley in Japanese foods increased during and after World War II because of rice shortages. Pearled barley produced by removing grain tissue layers from outside to inside gradually (up to 55% dry grain weight basis) by abrasive forces is most often used in these foods. Physicochemical properties of barley grains such as plump kernel, narrow/shallow crease, whiter kernel, mealy texture of the cooked kernel, uniform grain size, absence of steely/vitreous kernels and high starch content of the grain are demanded by Japanese processors and consumers.

Grain breakage during pearling is considered as a loss of yield. Plump kernel has been shown to increase pearling yield, through minimal grain breakage, which is desirable in Japanese foods. Narrow/shallow crease is preferred because if the crease is wider and deeper, it makes seed coat removal difficult at this region and, consequently, undesirable "wormy" specks appear on the final product. Whiter (less yellow) barley kernels blend well with polished rice. Mealy texture is required for miso paste where barley exists as whole kernels. Although waxy barley shows mealy texture just after cooking, it absorbs too much moisture during aging and becomes soggy; thus, it is not fit for meso production. Uniform grain size ensures efficient and uniform pearling with minimal damage to kernel. The absence of steely/vitreous kernels is important because such kernels do not cook easily, thus imparting an undesirable non-uniform texture to the final product. High starch content is desired mainly for the production of shochu, which is an alcoholic beverage produced by yeast fermentation of sugar/starch.

Barley Quality for Pearling

Pearling is an important primary process in barley grain utilization. This process removes outer grain tissue by abrasive forces and is carried out to various degrees, usually ranging from 12 to 55% (dry grain weight basis). Most Japanese food market uses require barley to be pearled to at least 60%. Pearling removes bran (pericarp, seed coat, aleurone, sub-aleurone and part of endosperm) and germ. Removal of bran in barley yields a bright white kernel that is well suited for various food applications. Bran and germ contain most of the barley lipid; it is relatively high in unsaturated fatty acids (oleic, 18:1; linoleic, 18:2 acid) (Morrison 1993) which are highly prone to auto-oxidation and rancid odour development. Therefore, the storage stability/quality of pearled barley is superior to that of unpearled. Removal of barley phenolic compounds and enzymes, such as polyphenoloxidase and peroxidase, which primarily exist in the outer grain layers is important in the end use of barley especially in foods. If not removed, oxidation of these phenolic compounds would lead to darkening of barley products. However, the loss of tocols (vitamin E, a fat soluble component) with the bran and germ during pearling will be a negative aspect in terms of the nutritional quality of pearled barley.

My earlier research on wet-fractionation of barley investigated the isolation of grain components (i.e. starch, protein, beta-glucan and fiber) and their potential use in food and non-food applications (Vasanthan and Bhatty, 1995; 1996; 1998; Vasanthan et al., 1997). During wet fractionation of unpearled barley grains, darkening of the barley flour + water mix had been a major problem. All the final products were off-white or light brown in color and had to be thoroughly washed with excess water. Pearling of barley to a degree of 15% substantially minimized the darkening problem during wet fractionation. My current research (unpublished) on the extrusion processing of barley grains also revealed the importance of pearling. Barley pasta was processed using minimally pearled (10 to 12%) barley grains and surface darkening of boiled pasta during storage was observed. In order to rectify the problem, a study was carried out to determine the minimum degree of pearling required to avoid the colour problem. Barley was pearled to various degrees and ground into flour. Colour measurements (Hunter lab) on the cooked flour paste, just after cooking and after storage at 4°C for four days were performed. The results indicated that a minimum pearling of approximately 32% is required to avoid the surface darkening problem.

Studies have suggested that barley should be plump, uniform in size and resist breakage for production of good quality pearled barley, therefore these grain characteristics should be used in grading barley for pearling. Colour of the pearled barley is another important factor. Kernel colour depends on barley variety and usually ranges from light yellow to bright white. Colour requirements differ with the end product for which the pearled barley is used. For instance, in Japanese foods, whiter kernels are well suited as boiled rice extender and the light yellow kernels are preferred for the production of miso. Light yellow colored kernels would also benefit extruded foods. The science of breeding/ biotechnology may be used to select the kernel colour of barley destined to different food applications.

Barley Quality for Milling

Barley does not contain the functional gluten protein that is necessary for production of high quality bread and other bakery products. Therefore, the focus on the use of milled barley flour is primarily due to its nutritional quality and human health benefits. A number of product development research efforts have been focussed to use barley flour as wheat flour extender. However, unlike wheat, the quality criteria of barley flour for use in bakery and other products have not yet been established. Thus, the consistency of this commercial flour quality is questionable.

In Canada, milled barley flour is available in certain commercial and health food stores. Although there is no standard milling process established for barley, milling of this grain will not be as complex as milling wheat. Pearling of dehulled or hulless barley up to 32% followed by pin or hammer milling may yield good quality flour. Care must be given to heat generation during such milling processes, especially hammer milling, which would induce Maillard browning and alter the natural flour colour.

Laboratory scale studies (Bhatty, 1986; 1987; 1992) have reported that dry milling of barley after tempering may yield about 70% flour and 30% bran. Another study (Bhatty, 1993) concluded that barley for use in commercial foods would preferably be white, of soft type and have waxy starch. The flour produced from such barley would be white, have low starch damage and high beta-glucan content. Barley bran, well known for its brittleness, shatters during roller milling. Extensive bran shattering will enhance bran contamination of flour and increase flour ash content, which will be detrimental to flour quality. The quality of barley flour in baked products would depend on, as well as ash/bran content, its particle size, starch damage, water absorption and flour rheology. Multi regional field trials are needed to establish the following relationships:

- The influence of variety and grain moisture content on bran shattering; and
- The relationship between grain hardness, particle size index, starch damage, farinograph water absorption and flour rheology/viscoelasticity. Also, pilot scale milling trials are needed to define the effect of milling conditions on the viscoelasticity of flour.

Barley Quality for Wet Fractionation

There have been a number of research efforts (Bhatty, 1995; Vasanthan and Bhatty, 1995; Vasanthan et al., 1997; Temelli, 1997; Burkus and Temelli, 1998) to wet-fractionate barley into its valuable components (starch, beta-glucan, etc.). The objective of barley wet-fractionation is to isolate starch and beta-glucan without damage to their structure and physicochemical properties. Research to date in dry and wet milling of barley seems to suggest that pearling of barley up to 30% to remove most of the bran and germ prior to wet-fractionation is required to avoid the darkening problem. Flour from the pearling operation can be further used for extraction of lipids and antioxidants using solvents or other techniques such as supercritical carbon dioxide. The residue after extraction may be used into food/feed formulations.

Quality standards of barley for this process have yet to be established. However, for the aforementioned process the best choice of barley would be high in beta-glucan, lipid and antioxidants and contain waxy starch. Also, the grain should posses sprout resistance since the onset of germination of grain, placed under improper storage conditions would deteriorate the quality of grain components of interest. Enzymes secreted within the grain during germination would hydrolyze grain components and alter their functionality. The falling number test used in the wheat industry may be of interest to the barley industry as a means to predict grain harvest and storage history, and therefore quality. Research is warranted to precisely understand the agronomic, harvesting and storage conditions on the quality of barley grain components, in order to preserve a high quality supply chain.

Barley Quality for Extruded Food Products

Extrusion technology is used in the industry to produce a variety of foods such as pasta, breakfast cereals and puffed snacks. Knowledge in the use of extrusion to process barley grains is limited. The focus of one of the major research programs in my laboratory is determination of barley flour suitability in the production of extruded foods. These investigations are geared towards defining quality requirements of barley for extrusion processing.

In Canada, durum wheat is dry milled to produce semolina which is a yellow gritty endosperm particles (size ranges from 150 to 550 microns) which is commonly used in the production of high quality extruded foods. The semolina extraction from durum wheat grain is usually between 65 to 75% (extraction rate). The good semolina for pasta will have a particle size range from 150 to 550 microns (as narrow as possible in order ensure uniform water absorption), show minimal starch damage (to minimize water usage during pasta processing), yellow in colour (high consumer acceptability), contain very minimal bran specks, bright (low ash/bran), appropriate protein content and gluten strength (Feillet and Dexter, 1996). It will be impossible to produce semolina-like product from barley grains without substantial loss of flour. This is primarily due to the softer nature of barley endosperm. Research is needed to optimize the milling conditions for the production of barley semolina with minimum flour (as by-product) and bran specks content.

Furthermore, unlike durum wheat, barley lacks gluten protein which acts as a binder and is especially important in the production of good quality pastas and noodles. Also, barley grain does not contain enough yellow pigment. Development of new barley cultivars with improved binding gluten protein content and yellow pigment would benefit barley for extrusion processing. Another alternative would be to blend wheat protein isolate into barley flour to enhance binding. Recent research in my laboratory has involved investigation on the effect of blending wheat protein isolate in various proportions into waxy and regular barley flour, and the extrusion conditions (moisture content, temperature, screw speed/shear) on the cooking and sensory qualities and storage stability of the extruded foods. Some of the conclusions to date are:

- Vital wheat gluten incorporation of >15% is essential for the production of good quality pasta; and
- Pearling of barley >32% is required to prevent the surface darkening of cooked barley pasta. Pearling quality of barley, as discussed above, will apply.

Earlier research has indicated that extrusion cooking causes fragmentation of food molecules such as starch and beta-glucan. Since extrusion induced fragmentation would influence the functionality and nutritional quality of these food molecules, the study has been extended to investigate the effect of extrusion-induced fragmentation on the molecular characteristics (size and chain length) and functionality of barley beta-glucan and starch. Gel permeation chromatography (GPC), high performance liquid chromatography (HPLC) and methylation analysis are being used to probe the changes, caused by extrusion cooking, in the molecular size and chain length profiles of barley starch and beta-glucan molecules.

Conclusion

A means for the evaluation of barley quality for non-malting food uses is becoming of increased importance as the demand for this grain increases. A great deal of research is required in order to develop simple innovative methodologies that would evaluate barley grain quality for its grading and use in various food/non-food industries.

Reference

Bhatty, R. S. (1986). Cereal Chem., 63, 31-35.

Bhatty, R. S. (1987). Cereal Foods World, 32, 268-272.

Bhatty, R. S. (1992). Cereal Chem., 69, 469-471.

Bhatty, R. S. (1993). Cereal Chem., 70, 397-402.

Bhatty, R. S. (1995). J. Cereal Sci., 22, 163-170.

Budin, J. T., et al. (1996). JAOCS, 73, 475-481.

Burkus, Z and Temelli, F. (1998). Cereal Chem. 75, 805-809.

Canadian Wheat Board. (1998) - http://www.cwb.ca/

Feillet, P. and Dexter, J. E. (1996). Pages 95-131 in: Pasta and noodle technology. J. E. Kruger, R. B. Matsuo and J. W. Dick, eds. American Association of Cereal Chemists, Inc., St. Paul, Minnesota, USA.

Martinez, V. M., et al. (1992). J. Nutr., 122, 1070-1076.

McIntosh, C. H., et al. (1991). Am. J. Clin. Nutr., 33, 1205-1209.

Morrison, W. R. (1993). Pages 199-246 in: Barley chemistry and technology, AACC monograph series. A. W. MacGregor and R. S. Bhatty, eds. American Association of Cereal Chemists, Inc., St. Paul, Minnesota, USA.

Qureshi, A. A., et al. (1986). J. Biol. Chem., 261, 10544-10550.

Temelli, F. (1997). J. Food Sci., 62, 1194-1201.

Vasanthan, T. and Bhatty, R. S. (1995). Cereal Chem., 72, 379-384.

Vasanthan, T. and Bhatty, R. S. (1996). Cereal Chem., 73, 199-207.

Vasanthan, T. and Bhatty, R. S. (1998). Starch/Starke, 50, 286-291.

Vasanthan, T., Bhatty, R. S., Tyler, R. T. and Chang, P. (1997). Cereal Chem., 74, 25-28.

Fusarium Graminearum – A Spreading Problem

Randy Clear, Canadian Grain Commission
Winnipeg, Manitoba, Canada

In Canada, there are over 13 species of Fusarium which can be recovered from cereal seed. Most are saprophytes or weak parasites which do little to affect the health or value of grain. However, three species, *F. graminearum* Schwabe, *F. culmorum* (W.G. Smith) Sacc. and *F. avenaceum* (Corda ex Fr.) Sacc. are important as causal agents of the cereal disease fusarium head blight (FHB). FHB can reduce the yield, grade, and quality as well as contaminating the grain with mycotoxins. Mycotoxins, such as deoxynivalenol (DON), reduce the grain's suitability as feed, and even very low levels can result in barley being rejected for use in malting. In North America, South America, Asia, and much of Europe, *F. graminearum* is the primary FHB pathogen. Although both *F. culmorum* and *F. avenaceum* can and do cause FHB in Canada, their importance here is limited. *F. culmorum* and *F. graminearum* are similar in their pathogenicity and toxin producing ability, but in Canada *F. culmorum* is important only in the irrigated areas of southern Alberta. *F. avenaceum* is more widely distributed than *F. graminearum* and *F. culmorum*, but is a weaker pathogen and a less important toxin producer.

Fusarium graminearum is not new to the grasslands of North America. It has been present in the upper midwest US since at least 1900. By the middle of this century it was an important pathogen of corn and small grain cereals in southern Minnesota and North Dakota (MacInnes and Fogelman, 1923; Tervet, 1945), and by the mid 1900's had almost eliminated barley production in the eastern and central US Corn Belt (Mathre, 1997). In Western Canada, *F. graminearum* was detected as early as 1923 on corn stubble in Winnipeg (Bisby and Bailey, 1923). By the mid 1940's, after numerous seed and soil surveys, it was still considered to be very rare in Western Canada, and although more common in Eastern Canada, it was not among the four most common Fusarium species recovered from eastern cereal seed (Gordon, 1944, 1952, 1954, 1956; Gordon et al, 1948; Greaney and Machacek, 1942; Machacek et al 1951).

It wasn't until 1980 that *F. graminearum* was considered an important cereal pathogen in Canada (Sutton, 1982). That year, the Ontario winter wheat crop was badly damaged by FHB caused by *F. graminearum*. The disease became even more important when DON was detected in the damaged grain. In Western Canada, *F. graminearum* was not a concern until 1984 when two wheat samples from a farm south of Winnipeg were found to be badly damaged by *F. graminearum* and contaminated with DON (Clear and Abramson, 1986). At that time the conventional wisdom was that the environmental conditions of the Prairies, notably the amount of precipitation, and the small amount of acreage in Western Canada planted to corn (corn stubble was considered an important factor in the previous epidemics in the USA and Ontario because it is an excellent source of inoculum for the disease) was not suitable for this organism to become an important cereal pathogen.

Surveys for* Fusarium *species causing FHB

Wheat

Since 1984, the CGC has done yearly seed surveys for the presence and cause of FHB. Wheat samples sent to the CGC for the harvest survey are screened for the presence of fusarium damaged kernels (FDK). FDK are removed from the samples and cultured on agar to determine the causal organism. Wheat was chosen for the survey because FHB on wheat is readily evident in the form of FDK. In barley and oats, symptoms of FHB are much less frequent and often difficult to find on the seed. Beginning in 1986, these seed surveys of several thousand wheat samples per year were complimented in Manitoba by annual surveys of wheat and barley fields by personnel from Agriculture and Agri-Foods Canada (AAFC) and Manitoba Agriculture. In 1997, personnel from AAFC in Saskatchewan and Saskatchewan Agriculture began field surveys for FHB as well. In Alberta, because of the continued very low levels of *F. graminearum* in that province, surveys for the pathogen still rely almost entirely on seed surveys conducted by the CGC.

Barley

Between 1995 and 1997, the CGC conducted a study to determine the type and average level of fungal infection in barley seed grown in Western Canada. Samples were collected from the CGC harvest survey and composited according to crop district (CD). Two hundred seeds per CD were plated each year and the fungi developing from them identified.

Results of Wheat Seed Survey

Since 1984, *F. graminearum* has been spreading westward from southeastern Manitoba. By 1993 it was well established in Manitoba, and detected in a few fields in southeastern Saskatchewan. By 1998 it was well established in eastern Saskatchewan and present in all CD’s in Alberta (Figures 1, 2 and 3). To date, most of the locations where *F. graminearum* has been detected are within the black soil zone, which is also the area of highest moisture. In areas where *F. graminearum* has become established, the frequency with which *F. culmorum* and *F. avenaceum* are recovered from FDK has declined sharply. In addition, increasing dominance of *F. graminearum* has coincided with increased FHB, as seen in Saskatchewan in recent years (Table 1, Figures 4 and 5). Not since 1987 has another Fusarium species been the dominant FHB pathogen in Manitoba (Clear and Patrick, 1990). In recent years, between 77% and 92% of FDK in Manitoba were infected by *F. graminearum*. In 1997 and 1998, *F. graminearum* was the dominant FHB pathogen in Saskatchewan as well.

Spread of *F. graminearum* westward has also been accompanied by an increase in pathogen levels in those areas where *F. graminearum* was already established. Spread of the pathogen and inoculum build-up was not halted by several dry years in the 1980’s. Record amounts of precipitation in 1993 resulted in the worst epidemic of FHB in Manitoba. Although moisture patterns in 1993 also favoured FHB development in many parts of Saskatchewan and Alberta, including eastern Saskatchewan, the disease remained a very minor problem in those provinces till 1998. In 1998, increasing levels of *F. graminearum* in eastern Saskatchewan combined with favourable weather conditions to result in the first serious FHB problem in any western province outside of Manitoba. (Table 1). In southern Alberta, *F. graminearum* has been present in the irrigated area since at least 1984, but usually at low levels (Figures 1, 2, and 3). Since 1994 we have been detecting it in an ever increasing number of fields outside of the irrigated areas. However, only once (1994) have we seen a high disease level in any non-irrigated Alberta sample.

Spread of *F. graminearum* in Western Canada has followed a series of steps.

Step 1. Detection at low levels in a few fields, especially in the more susceptible classes and varieties.

Step 2. Detection at low levels in many fields in an area.

Step 3. Detection at higher levels in many fields in an area.

The interval between steps depends upon climatic conditions. The more often that years favourable to FHB occur, the faster the transition. In eastern Saskatchewan, step 1 comprised the years 1993 to 1996; step 2, 1997; and step 3, 1998.

Today, *F. graminearum* is at step 3 in most of Manitoba and CD’s 1 and 5 in eastern Saskatchewan, steps 1 and 2 in central Saskatchewan, and step 1 in western Saskatchewan and Alberta. In both Manitoba and Saskatchewan, the highest levels of *F. graminearum* and FHB are found in the more southerly parts of the province (Table 1 and Figure 4). This may be due to the influence of temperature, which has been considered as a primary factor in deciding which Fusarium species will predominate in an area (Cook 1981).

Results of Barley Seed Survey

No barley seeds infected by *F. graminearum* were found in the Alberta samples, and only a trace level was seen in Saskatchewan barley seed each year (Figure 6). In Manitoba, the annual average increased each year of study (Figure 6) due to considerable increases in the southwest CD’s (CD 1, 2 and 3) and from increases in the traditional *F. graminearum* area of the south central CD’s 7, 8 and 9 (Table 2). Seeds from the northwest CD’s 4, 5 and 6, were the least infected by *F. graminearum*, as was found in 1993 and 1994 (Clear et al. 1996).

Factors Affecting the Spread of* F. graminearum *and Disease Severity

Many factors have influenced the recent spread of *F. graminearum* and its emergence as a serious pathogen of cereal crops on the eastern Canadian Prairies. In spite of a few dry years, there has been a series of several years in the affected areas where average or above average precipitation has fallen during anthesis. It is at anthesis when cereals are most susceptible to infection by FHB pathogens. Changing tillage practices designed to reduce erosion by retaining crop residue on the soil surface may well have contributed to the build up of *F. graminearum*. Survival of *F. graminearum* and production of inoculum is enhanced when cereal residue colonized by the pathogen is allowed to remain above the soil surface. The planting of susceptible varieties may also have increased the level of disease and inoculum. In 1993, close to half the bread wheat acreage in Manitoba was planted to Roblin, one of the most susceptible varieties in Canada to FHB. In contrast, in 1998 nearly half the bread wheat acreage in Manitoba was planted to AC Barrie, one of the most resistant wheat. In general, wheat classes in Canada increase in susceptibility from Canada Western Red Spring to Canada Prairie Spring to Canada Western Amber Durum. In barley, the 2-row are less susceptible than the 6-row varieties. Infected seed may also be serving as a long distance dispersal mechanism. Infected seed is considered an important dispersal mechanism for many fungi which cause plant diseases, and may well be serving this same function for the spread of *F. graminearum*. The use of clean seed and the application of a seed treatment effective against Fusarium species is recommended to both control seedling blight and, in areas where it is rare or absent, to perhaps delay the introduction of *F. graminearum* into fields free of this pathogen.

Dealing with the Spread of F. graminearum

Although *F. graminearum* was found to be capable of causing FHB in essentially all CD's in Western Canada (Figures 2 and 3), it is still uncertain if it will ever be an important pathogen of cereals in Alberta or western Saskatchewan. Climatic differences between the eastern and western Prairies, notably in temperature and moisture, may serve to contain the spread or limit the damage caused by this species. However, in areas where levels of *F. graminearum* are presently very low, it would be prudent to adopt control measures now that might reduce future losses. These measures would include:

1. Use of seed free or essentially free of the pathogen combined with seed treatments effective against Fusarium species.
2. Monitoring of fields and harvested grain for *F. graminearum* infection in order to detect *F. graminearum* while it is still at a low population level. Early detection of the pathogen followed by immediate implementation of cultural control measures (ie. crop rotation to non-cereals) will increase the effectiveness of the control measure.
3. Use of varieties with the best resistance to FHB when *F. graminearum* is present in the field or nearby fields.

Until such time as resistant varieties become available, only modest success in dealing with this pathogen can be expected. However, given the economic impact of *F. graminearum*, even a modest success will more than repay the cost of achieving it.

References

Abramson, D., R.M. Clear and T.W. Nowicki. 1987. Can. J. Plant Sci. 67: 611-619.

Bisby and Bailey. 1923. Page 33 In Fourth Annual Report of the Survey of the prevalence of plant diseases in the Dominion of Canada, Ottawa, Ont.

Clear, R.M. and D. Abramson. 1986. Can. Plant Dis. Surv. 66(1): 9-11.

Clear, R.M. and S.K. Patrick. 1990. Can. J. Plant Sci. 70: 1057-1069.

Clear, R.M. and S.K. Patrick. 1993. Can. Plant Dis. Surv. 73(2): 143-149.

Clear, R.M., S.K. Patrick, R.G. Platford, and M. Desjardins. 1996. Can J. Plant Path. 18: 409-414.

Cook, R.J. 1981. Pages 39-52 in: *Fusarium* Diseases, Biology, and Taxonomy. P.E. Nelson, T.A. Toussoun, and R.J. Cook, eds. Pennsylvania State University Press, University Park.

Duthie, J.A., R. Hall and A.V. Asselin. 1986. Can. J. Plant Pathol. 8: 282-288.

Gordon, W.L. 1944. Canadian J. of Research 22: 282-286.

Gordon, W.L. 1952. Can. J. Bot. 30: 209-251.

Gordon, W.L. 1954. Can. J. Bot. 32: 622-629.

Gordon, W.L. 1956. Can. J. Bot. 34: 833-846.

Gordon, W.L., J.E. Machacek and W.A.F. Hagborg. 1948. Can. Plant Dis. Surv. 28: 1.

Greaney, F.J. and J.E. Machacek. 1942. Sci. Agric. 22: 419-437.

Machacek, J.E., W.J. Cherewick, H.W. Mead, and W.C. Broadfoot. 1951. Sci. Agric. 31: 193-206.

MacInnes, J. and R. Fogelman. 1923. U. of Minn. Agric. Exp. Sta. Tech. Bull. 18, 32 pp.

Mathre, D.E., 1997. The American Phytopathological Society, 90 pp.

Sutton, J.C. 1982. Can. J. Plant Pathol. 4: 195-209.

Tervet, I.W. 1945. The Plant Disease Reporter 29(19): 474-487.

Figure 1. Area where *Fusarium graminearum* was recovered from fusarium damaged kernels of wheat, 1984 to 1994.

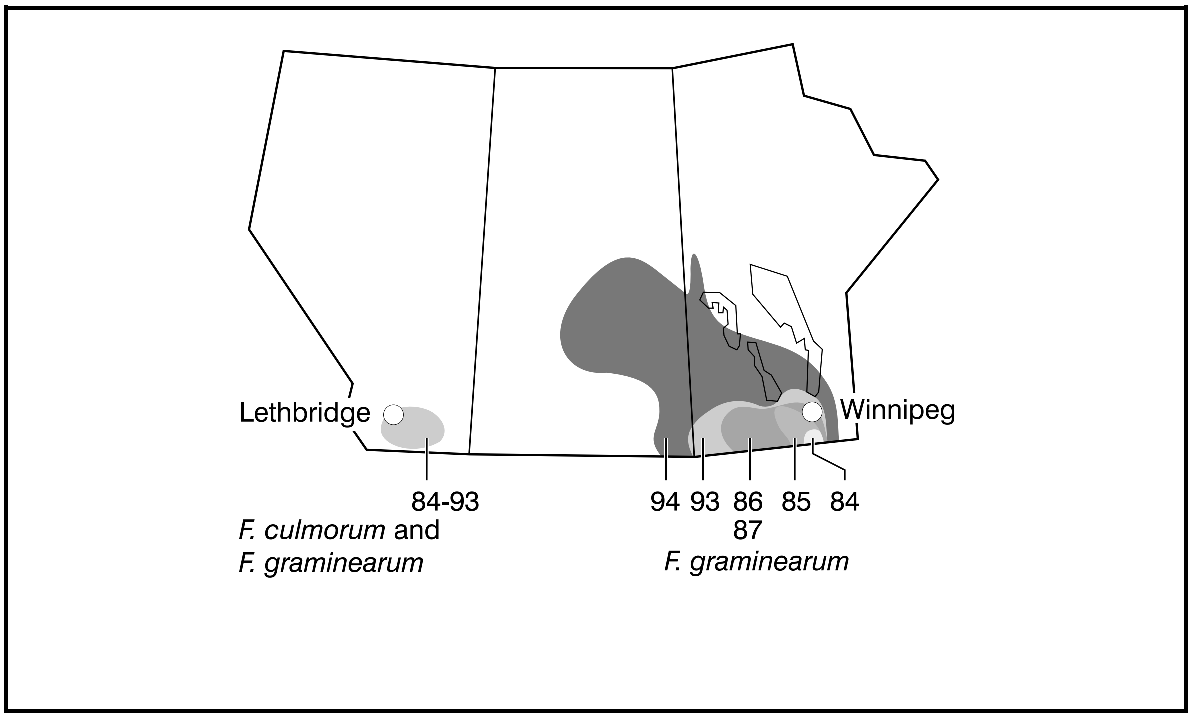


Figure 2. Individual locations where *Fusarium graminearum* was recovered from fusarium damaged kernels of wheat, 1994 to 1996, and their relationship to soil zones.

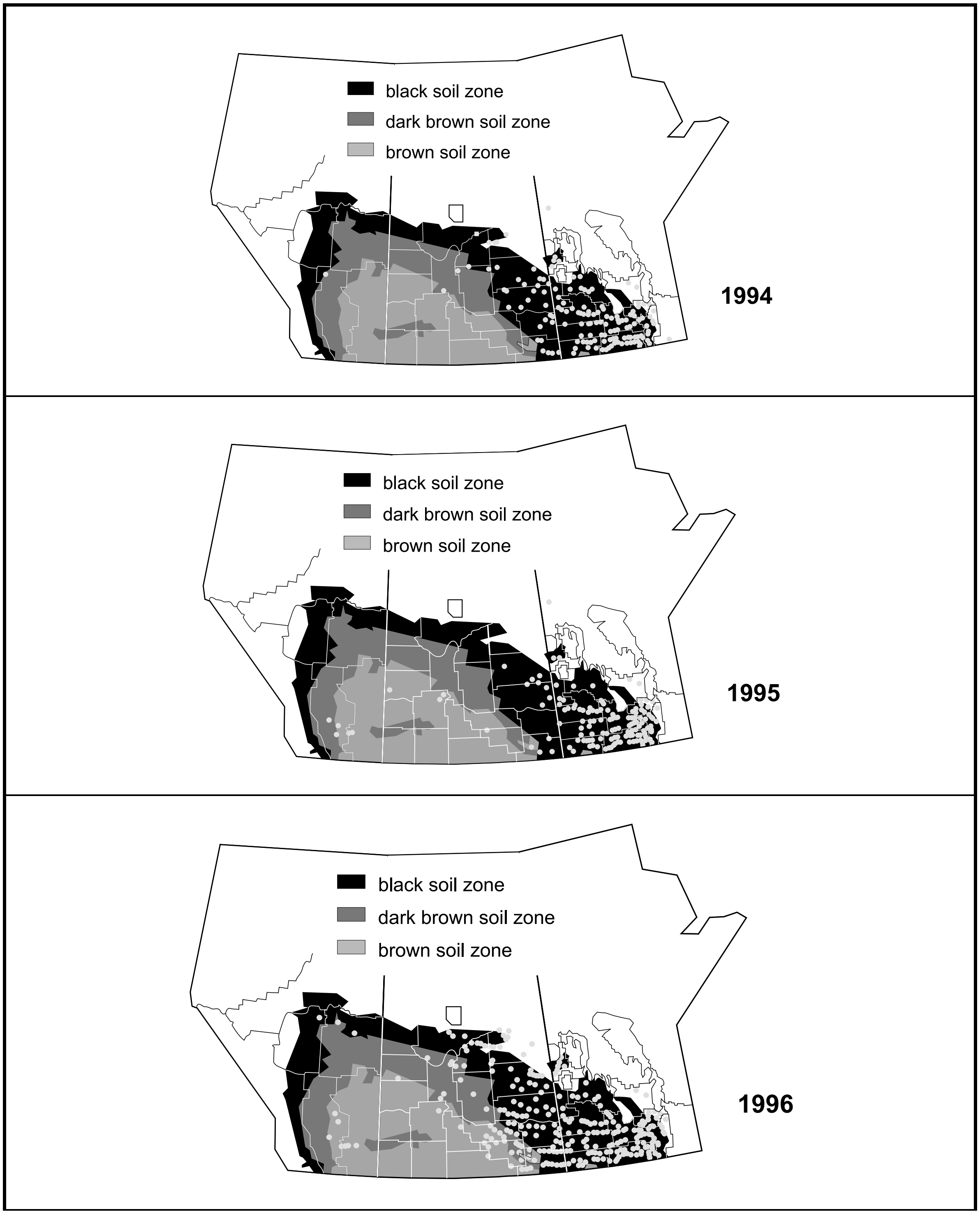


Figure 3. Individual locations where *Fusarium graminearum* was recovered from fusarium damaged kernels of wheat in 1997 and 1998, and their relationship to soil zones.

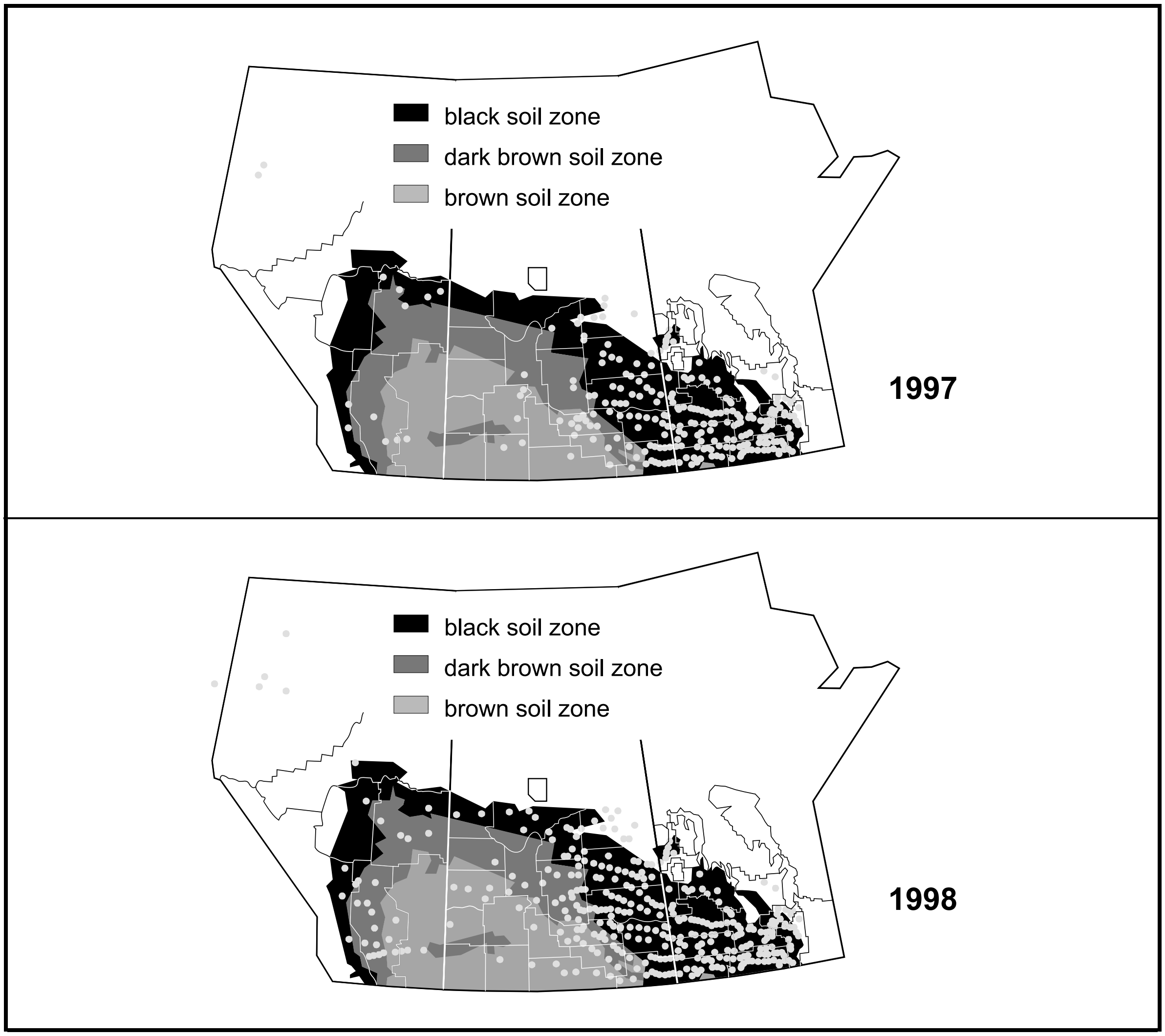
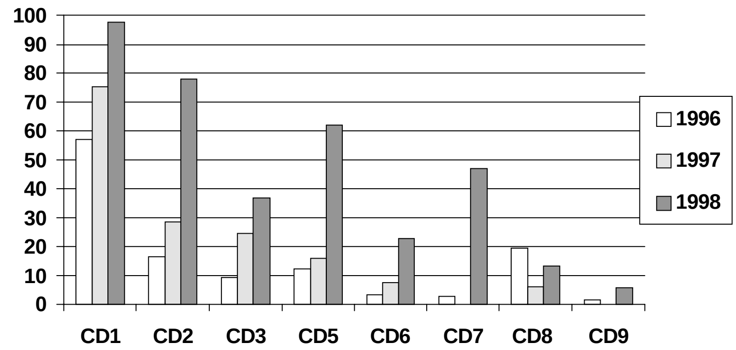


Figure 4. Percentage of fusarium damaged kernels in Saskatchewan crop districts infected by *F. graminearum*, 1996 to 1998.



(Note: Crop Districts 3 and 4 combined into CD 3)

Figure 5. Percentage of wheat samples on the prairies containing fusarium damaged kernels, 1996 to 1998.

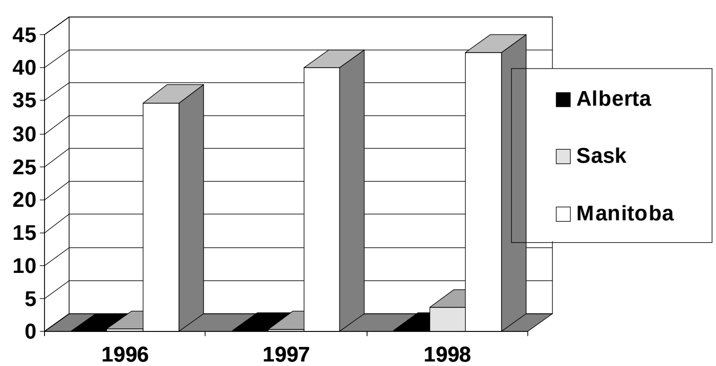


Figure 6. Percentage of barley seed on the prairies infected by *F. graminearum*, 1995 to 1997.

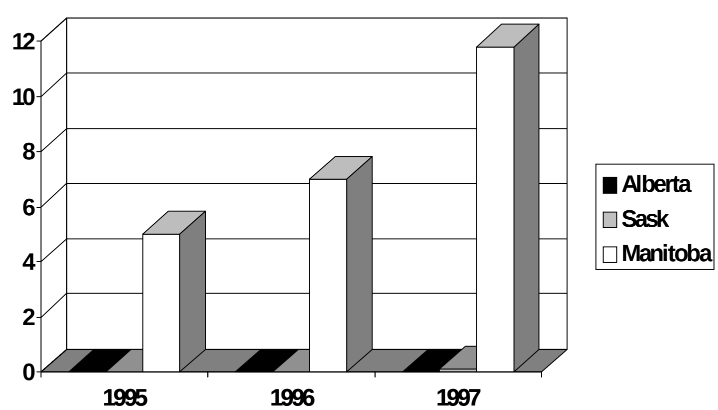


Table 1. Percentage of Saskatchewan wheat samples containing fusarium damaged kernels, arranged by crop district, in 1997 and 1998.

Along the Alberta Border*			Central Saskatchewan			Along the Manitoba Border		
CD	1997	1998	CD	1997	1998	CD	1997	1998
9B	<0.0	<0.5	**9A**	<0.0	2.1	**8A**	0.3	1.7
7B	<0.0	<0.0	**8B**	<0.0	0.4	**5B**	<0.0	4.3
7A	<0.0	<0.0	**6B**	0.3	0.7	**5A**	<0.0	10.4
4B	<0.0	<0.0	**6A**	<0.0	1.2	**1B**	0.5	22.8
4A	<0.0	<0.0	**3B**	0.4	<0.0	**1A**	5.1	24.2
			3A	<0.0	<0.0			
			2B	0.8	0.9			
			2A	2.1	2.8			

* Crop Districts arranged in table by geographical position, north to south and west to east.

Table 2. Percent seed infection by *Fusarium graminearum* in Manitoba barley seed, according to crop district.

Crop District	1995	1996	1997
1	1	9.5	19.5
2	2	4.5	13
3	1	0.5	6
4	0	0	0
5	1.5	*	1
6	3.5	0	1
7	8	15	22.5
8	19	17	35.5
9 & 10	5	12	17.5
11	4.5	9	10
12	0.5	3.5	4

* No data.

Fusarium Head Blight of Barley: A Plant Pathologist’s Perspective

Andy Tekauz, Agriculture and Agri-Food Canada
Winnipeg, Manitoba, Canada

Introduction

Fusarium head blight (FHB) is the most important disease of barley in Manitoba, Canada. This also applies to Minnesota and North Dakota, making FHB of regional and international concern. Since FHB was practically absent in barley as recently as five years ago, its current predominance here represents an extraordinary transformation.

The contemporary ‘epidemic’ of FHB in cereal crops in Manitoba, and which now may include parts of Saskatchewan and Alberta, can be traced to 1984. That year, two grain samples of wheat from the southern Red River Valley were found to contain ‘tombstone’ kernels and detectable levels of ‘vomitoxin’ – both are diagnostic for FHB (Clear and Abramson, 1986). Today, these ‘symptoms’ are usually referred to as ‘FDK’ (fusarium damaged kernels), and ‘DON’ (deoxynivalenol). Systematic field surveys for FHB in cereal crops in Manitoba were initiated in 1986 and have continued since. The results are published annually in the Canadian Plant Disease Survey.

It is intriguing that while FHB has been detected in wheat since 1984, it wasn’t observed in barley until 1993, and did not occur at appreciable levels until 1994. In 1998, after only five years, FHB was found in every barley field surveyed in Manitoba and damage was as high as in wheat. Clearly, barley initially was not the favoured host for the FHB pathogen, but now is as vulnerable as wheat. This may reflect a fundamental change in the pathogen population, or in the conditions promoting development of disease.

Fusarium head blight affects cereals crops in several ways. Infection results in small or thin, shriveled and discolored kernels replacing normal ones. The smallest infected kernels usually are lost during harvest, contributing to yield reduction. Others retained in the grain may contain DON, toxic to humans and livestock at higher concentrations, and contribute to grade/quality loss as FDK. Such kernels, and those otherwise normal in appearance but infested by Fusarium, if subsequently used as seed, may fail to germinate or the germinated seedlings may not emerge from soil (Gilbert and Tekauz, 1995). Furthermore, the integrity and reputation of the region and its crops will be compromised. The effects of FHB are additive, and during severe epidemics, can be devastating.

Because FHB was essentially a ‘new’ disease to barley in Western Canada, it presented an unique opportunity to deploy the range of disciplines comprising ‘plant pathology.’ These include: epidemiology, mycology, symptom expression, inoculation and rating protocols, host reaction, resistance sources (and crossing of these into adapted cultivars), biotechnology, surveys and disease management. More often, pathologists’ research has a narrow focus, and the chance to employ a broad approach is seldom presented.

Much of the research on FHB done in Western Canada in the past 10 years was made possible by support from the Western Grains Research Foundation. This support has been

both timely and visionary, as it began ca. 1988, FHB's 'early years.'

A brief summary of findings relating to FHB in barley, follows.

Disease Occurrence and Spread

Fusarium head blight was first observed in barley in Manitoba in 1993 (Tekauz et al., 1995), but was neither widespread nor severe that year, despite this being the worst epidemic of FHB to date. Losses in wheat that year were estimated at $75M in Manitoba (Gilbert et al., 1994), while total losses to the industry in the US approached $1 billion (McMullen et al., 1997). Comprehensive annual surveys since 1994 have shown FHB to be present in 50 to 100% of barley fields in southern Manitoba (Tekauz et al., 1995).

As in wheat, FHB in barley in Western Canada has been most prevalent and damaging in the Red River Valley region between Winnipeg and the US border. In 1997, severe levels of FHB were encountered for the first time in western regions of Manitoba south of Brandon (McCallum et al., 1998b). This re-occurred in 1998 and spread to areas north of Hwy. #1 (McCallum et al., 1999). At the same time, barley fields in eastern Saskatchewan were diagnosed with FHB, albeit at much lower levels than in Manitoba (Celetti et al., 1998, Fernandez et al., 1999). Precipitation plays a key role in FHB epidemics, with normal to above-normal levels contributing to general infection and subsequent diseases spread. Since 1993, FHB has been of lesser concern only in 1995, a relatively dry year.

Damage to barley crops can be estimated by calculating an average 'FHB Index,' and this value has risen in the past three years from 2% to 6% (loss of yield only) (McCallum et al., 1999). Yield losses now approach those in wheat, estimated at 7% in the last two years (Gilbert et al., 1999). In barley, disease incidence (% heads affected) tends to be higher than in wheat, while severity (% of head with symptoms) is usually less. In summary, FHB in barley has moved westward, become more severe, and has gone from being unreported to documented in all Manitoba fields, in just five years.

Causal Organism(s)

Fusarium head blight of wheat in Canada is associated almost exclusively with *Fusarium graminearum*, a highly pathogenic and deoxynivalenol (DON) producing species (Wong et al., 1992, 1995). Likewise, this species is most often isolated from infected barley, however, other species, including *F. poae*, *F. sporotrichioides,* and *F. avenaceum*, also are found (Tekauz et al., 1995). The latter species do not produce DON, but may give rise to other mycotoxins (Wong et al., 1995). A change in species ratio occurred in 1998, and *F. graminearum* dominated in barley, as it has always done in wheat (McCallum et al., 1999). *Fusarium graminearum* initially may not have been adapted to barley, but now can infect barley as readily as wheat. The high degree of variability in the *F. graminearum* population (McCallum and Tekauz, 1998a) likely facilitated the rapid selection of pathotypes virulent on barley. In future, damage to barley may remain high, as in wheat.

Disease Symptoms

Symptoms of FHB in barley are similar, but not identical to those in wheat. Affected spikes are discolored at mid-dough, rather than their normal green, when infection by Fusarium has occurred. In these, one or more spikelets will be tan to brown-coloured, sometimes with an orange tinge, and often will be 'flattened' or thin, in comparison to healthy spikelets/kernels which are plump and green. In wheat discoloration is usually a light tan, and orange-pink sporodochia (masses of Fusarium spores) at glume bases and margins, are more common. At maturity, symptoms of FHB in barley are more difficult to diagnose with accuracy, particularly if brown, as this discoloration may also be caused by leaf spot pathogen invasion (i.e. *Pyrenophora teres* - net blotch, *Cochliobolus sativus* - spot blotch), and/or weathering, exacerbated by saprophytic field fungi such as *Alternaria* and *Cladosporium*.

In harvested grain, identification of FHB in barley is based on the presence of FDK, kernels having fungal mycelium in the dorsal crease and orange-pink sporodochia and/or erumpent black spots (pseudothecia, the fruiting bodies of Fusarium) on their surface (Symons et al., 1997). These kernels may not necessarily be smaller, thinner nor shriveled, as are FDK (tombstone) in wheat. The proportion of FDK is a quality factor, with levels of >1% (by weight) reducing grade in barley from 'select' to 'sample.' For 'Special Select' 2- and 6-row barley, FDK tolerance is zero.

Testing Protocols

Inoculation of barley spikes with macroconidia of *F. graminearum*, leading to typical disease development, has been successful using both spray and injection techniques (McCallum and Tekauz, 1998b). Timing of inoculation is not as critical as in wheat (where infections at flowering lead to greatest damage), and in barley, successful infection can take place over a two-week span with similar results. Inoculation with other species of Fusarium also leads to FHB, but the damage is reduced. Visual symptoms and other parameters can be used to rate severity of disease.

Cultivar Reaction

Reaction (resistance or susceptibility) of barleys to FHB varies. In general, 2-rowed cultivars are less susceptible than 6-rowed types. Head architecture may play a role. Multi-year testing of registered Canadian cultivars in inoculated FHB Nurseries and 'natural' field trials, has identified cultivars consistently more or less affected by FHB. Most affected (susceptible) cvs. include: AC Lacombe (6-row feed); and Falcon (6-row hulless). Least affected ones, possibly 'moderately resistant,' include: AC Oxbow and AC Metcalfe (2-row malt); Tankard (6-row malt); and CDC Silky (6-row hulless). This information was first included in the '1998 Manitoba Seed Guide.' First-year results from the 1998 FHB Nursery at Glenlea Manitoba for a second group of cultivars are shown in Table 1. The wide, but incremental range in visual reactions, suggest additive levels of resistance to Fusarium. Knowledge of cultivar performance to FHB is useful in implementing an integrated approach to FHB management where cultivar selection plays a vital role.

Identification of Resistance and Transfer Into Adapted Genotypes

Resistance in barley to *F. graminearum* has been reported from different parts of the world. Resistance is based on low levels of visual FHB and other parameters such as low DON or Fusarium kernel infestation. Putatively resistant genotypes include: Chevron (USA), Svanhals (Sweden), Zhedar 1 (China), Gobernadora (CIMMYT) and Seijo II (Japan). An additional group of 145 genotypes from diverse origins has been tested at CRC and the most promising ones forwarded to breeders for use as parents (McCallum et al., 1998a). Resistance was mainly found in 2-rowed genotypes. Crosses made at the AAFC Brandon

Research Centre include TR232/Zhedar 1, TR232/Chevron and TR251/AC Sterling. F3 progeny from these crosses were screened in the FHB Nursery in 1998, and the best are being increased in the winter nursery for re-testing in 1999. Despite 'fast-tracking' it will be several years before adapted barleys with significantly improved levels of resistance become available.

Table 1. Reaction of Barleys to Fusarium Head Blight in the FHB Nursery at Glenlea, Manitoba in 1998.

Cultivar					
CDC Lager	2.2* a**	AC Metcalfe	4.3 abcd	BT950	16.2 de
Harrington	2.5 a	AC Rosser	5.1 abcd	AC Bacon	17.7 de
AC Sterling	2.9 ab	AC Oxbow	5.3 abcd	Stander	23.9 e
CDC Stratus	3.2 abc	Condor	5.5 abcd	AC Lacombe	24.1 e
		CDC Earl	5.8 abcd	Falcon	44.9 f
		CDC Gainer	6.0 abcd		
		CDC Dawn	6.2 abcd		
		B1602	6.3 abcd		
		Foster	7.1 abcd		
		CDC Silky	9.2 abcd		
		Robust	9.6 abcde		
		Excel	14.7 bcde		
		CDC Sisler	15.6 cde		
				Average	10.8

* Based on 'FHB Index' (% incidence x % severity / 100); range 0 - 100%; artificially inoculated.
** Means followed by the same letter are not different at P<0.05

Relationships Between Parameters Used to Measure FHB

Evaluating damage from FHB is most readily done by visual estimation, using a rating scale such as '0 to 5,' representing a healthy head to one totally affected (blighted) by FHB. More accurate, but more labour intensive, is the calculation of visual damage based on incidence (proportion of heads affected by FHB) and severity (proportion of the head affected by FHB) which, combined, provide an 'FHB Index.' This is a measure of the total spike/head area affected by disease. As an example, a crop with 20% of heads with FHB symptoms, in which average severity is 50% of the head affected, would have an FHB Index of 10% (20 x 50 / 100). However, FHB can also be measured in other ways such as % FDK in harvested grain,

% Fusarium seed infestation, and level of DON.

Ultimately, and because of its potential impact on human and animal health, the DON level in the grain may be key. Unfortunately, this determination is time and labour intensive as well as costly. The same applies to Fusarium species determination in seed. Assessment of FDK can be faster, but is more challenging in barley because such kernels are not as distinguishable as in wheat. In wheat, these measurable parameters are correlated and each can provide a valid count of FHB (Tekauz et al., 1997). In barley, the relationships are less clear, but may also prove true (Tekauz and McCallum, 1998). Results of a trial are shown in Table 2. Here, correlation coefficients are significant for DON vs total *Fusarium* spp. (0.77) or *F. graminearum* (0.75), total *Fusarium* spp. vs *F. graminearum* (0.94) and FDK by number vs weight (0.97). If cvs. CDC Guardian and Manley, in which high infestation by *Cochliobolus sativus* may have confounded visual scores and *Fusarium* recovery from seed, are removed from the analysis, the remaining 14 cultivars additionally are correlated for FHB Index vs DON, *Fusarium* spp. and *F. graminearum*.

Notwithstanding, data from single cultivar/genotype tests should be interpreted with caution and include comparisons with checks, as FHB is variable. While correlations among measurable FHB parameters may exist in a genotype group, any single data set may be an 'outlier' that does not conform to the relationships validated for the whole.

Management of FHB

Minimizing damage from FHB is desirable to maintain producer profitability, the viability of the food and feed industries, and the integrity of exports. Cereal crops with an FHB Index as high as 50% have been observed in Manitoba. In such cases, yield losses would approach 40% and the grain contain high levels of DON. Until fully resistant cultivars are available, other management approaches must be pursued. These include rotations and tillage to reduce primary inoculum residing in overwintered straw and stubble (Miller et al., 1998), staggered seeding or the planting of cultivars of differing maturities to prevent wholesale infection, optimal field drainage to reduce puddling and high humidity conducive to disease, selection of cultivars of lower susceptibility, and use of seed treatments and 'foliar' fungicides. In combination, these measures would greatly reduce FHB. However, not all may be tenable, and currently no fungicide(s) is registered in barley for control of FHB. Under conditions leading to severe epidemics of FHB, as experienced in Manitoba in 1993 and 1994, no available management strategies may work. This places increased urgency on the deployment of resistance.

Table 2. Reaction of Barley Cultivars to Fusarium Head Blight at Carman Manitoba in 1997.

Cultivar	Type	FHB Index[b] %	*Fus.* spp. %	*Fus. gram.* %	C. sat. %	FDK no. %	FDK wt. %	DON ppm
Falcon	6r, hl[c]	2.9	21.5	6.0	11.0	2.9	2.1	1.3
CDC Guardian	2r, f	12.4	8.0	2.5	90.5	2.3	1.6	1.8
AC Oxbow	2r, m	3.3	27.0	13.0	32.0	0.4	0.3	2.0
AC Metcalfe	2r, m	3.4	35.5	15.0	34.0	0.8	0.5	3.4
Manley	2r, m	12.8	25.0	2.5	62.0	5.1	3.5	3.8
Bridge	2r, f	4.0	35.5	24.0	32.0	2.2	1.4	4.1
Duke	6r, f	6.1	64.5	52.0	8.5	3.3	2.9	5.1
Tankard	6r, m	4.9	56.0	28.5	17.5	1.0	1.0	5.2
AC Lacombe	6r, f	9.4	50.5	23.0	13.0	1.8	1.5	5.5
CDC Earl	6r, f	12.0	61.0	39.5	20.5	1.5	1.1	6.6
Bedford	6r, f	7.5	58.0	37.5	9.5	4.1	3.8	6.7
CDC Silky	6r, hl	1.9	28.5	18.5	6.0	2.7	2.4	6.8
Heartland	6r, f	9.7	62.5	51.5	22.0	3.1	2.6	7.2
Stander	6r, m	7.1	67.0	46.0	13.5	2.4	1.9	10.1
Argyle	6r, m	5.2	54.0	41.5	6.0	2.0	1.6	10.4
AC Rosser	6r, f	11.1	67.5	45.5	11.5	3.4	2.4	14.2
LSD (0.05)		*3.4*	*21.6*	*17.6*	*12.4*	*2.5*	*1.7*	*7.2*
Average		7.1	45,1	27.9	24.3	2.4	1.9	5.9

[a] ranked by inceresing level of DON
[b] FHB Index = % incidence x % severity / 100
[c] 2r = 2-rowed; 6r = 6-rowed; f = feed; hl = hulless; m = malt

Summary

The current research effort on FHB at many laboratories is unprecedented and attests to the global significance of the disease. In Canada, producer awareness and concern over FHB, and industry's resolve to eliminate the problem, are likewise unparalleled since the rust epidemics of the early to mid 1900's. The concerted research efforts of the past few years are beginning to bear fruit. Cultivars with improved FHB resistance have recently been released (eg. Bacup wheat, MNbrite barley – U of Minnesota), and previously-developed cultivars with partial resistance to FHB have been identified (eg. AC Metcalfe, AC Oxbow, Tankard barley; AC Barrie, AC Cora, AC Majestic, Gunner, Pioneer 2375 wheat). Future cultivars will have much improved FHB resistance, along with all other traits (agronomic, quality and other disease resistance) required for superior performance.

While FHB is doubtless a 'dark cloud' for agriculture, it does have a 'silver lining' – albeit visible only to the 'blighted' eye of a plant pathologist! The disease has given many of us in the profession the opportunity to utilize our training in the fullest, broadest sense. New and exciting research has resulted, with rewards and the pay-off coming soon.

References

Celetti, M. et al. 1998. Can. Plant Dis. Surv. (electronic) 78:78-79.

Clear, R.M. and Abramson D. 1986. Can. Plant Dis. Surv. 66:9-11.

Fernandez, M. et al. 1999. Can. Plant Dis. Surv. (electronic) 79:xx.

Gilbert, J. and Tekauz, A. 1995. Can. J. Plant Pathol. 17:252-259.

Gilbert, J. et al. 1994. Can. Plant Dis. Surv. 74:77-78.

Gilbert, J. et al. 1999. Can. Plant Dis. Surv. (electronic) 79:xx.

McCallum, B.D. and Tekauz, A. 1998a. Can. J. Plant Pathol. 20:125-126.

McCallum, B. and Tekauz, A. 1998b. Can. J. Plant Pathol. 20:215-216.

McCallum, B. et al. 1998a. Can. J. Plant Pathol. 20:215.

McCallum, B. et al. 1998b. Can. Plant Dis. Surv. (electronic) 78:74.

McCallum, B. et al. 1999. Can. Plant Dis. Surv. (electronic) 79:xx.

McMullen, M. et al. 1997. Plant Disease 81:1340-1448.

Miller, J.D. et al. 1998. Can. J. Plant Pathol. 20:95-103.

Symons, S.J. et al. Grain Biology Bulletin No. 2. GRL, Canadian Grain Comm., Winnipeg MB.

Tekauz, A. et al. 1995. Can. Plant Dis. Surv. 75:113-114.

Tekauz, A. et al. 1997. Cereal Res. Comm. 25 (3/2):821-822.

Tekauz, A. and McCallum, B. 1998. *In*, Proceedings 7th ICPP, Edinburgh UK, abstr. no. 8.6.

Wong, L.S.L. et al. 1992. Can. J. Plant Pathol. 14:233-238.

Wong, L.S.L. et al. 1995. Can. J. Plant Sci. 75:261-267.

Is Harrington Showing Its Age?

T.Kelly Turkington, Agriculture and Agri-Food Canada
Lacombe, Alberta, Canada

K. Xi, Alberta Agriculture
Lacombe, Alberta, Canada

P.A. Burnett, Agriculture and Agri-Food Canada
Lethbridge, Alberta, Canada

G.W. Clayton, Agriculture and Agri-Food Canada
Lacombe, Alberta, Canada

The malting barley variety Harrington has been registered for production in Western Canada since 1981. Although the variety is almost 20 years old, it is still one of the most common barley varieties grown by producers, especially in Alberta and Saskatchewan. In some areas of these provinces, Harrington accounts for 50 to 60% of the total area seeded to barley (Edney and Tipples 1997). Producers are attracted to this variety due to its potential for a malt premium and because it is still one of the most popular malting varieties among malting and brewing companies. In addition, barley is considered a dual purpose crop – so if the producer's crop is not selected for malt, it can be marketed domestically or internationally as feed barley (Edney and Tipples 1997). However, concerns about the disease susceptibility of Harrington have caused some producers to avoid production of this variety. Our focus for this presentation will be primarily from a plant disease perspective, looking at how changing tillage practices, crop rotation, seed-borne disease, and disease resistance influence diseases like scald and net blotch of barley and their subsequent impact on productivity and quality of a susceptible variety like Harrington. However, other diseases including common root rot, smuts, rusts and fusarium head blight may also have a significant impact on the productivity and quality of susceptible varieties.

Changing Tillage Practices

Over the past decade, conservation tillage has become a routine practice for many farmers in Western Canada. From 1991 to 1996, the amount of land where most crop residue was incorporated into the soil with tillage has been decreasing, while the acreage of zero tillage has increased (Table 1, Anon. 1997). Furthermore, in an Alberta survey conducted by McLelland (1992), an average of 36% of producers surveyed grew barley on barley with the proportion increasing to 75% in the western parts of central and southern Alberta. The combination of increased adoption of conservation tillage and the continued lack of rotation to non-hosts by some producers has prompted concerns regarding the impact of residue-borne diseases like net blotch and scald, especially with susceptible varieties like Harrington. Increased levels of these diseases could affect yield and quality as well as our ability to meet domestic and international demand for high quality malting barley. In 1995, 1996 and 1997, an Alberta barley leaf survey was undertaken to assess the impact of tillage regime, crop rotation, and variety resistance on scald and net blotch of barley.

Table 1. Trends in tillage practices for Alberta, Saskatchewan and Manitoba, 1991 to 1996, Census of Agriculture, Statistics Canada (Anon. 1997).

	% change in area where most residue was incorporated into soil with tillage	% change in zero tillage acreage	Area of zero tillage 1996 (millions of ha)
Alberta	-25	+215	0.8
Saskatchewan	-27	+117	2.9
Manitoba	-10	+70	0.4

A total of 99, 148 and 88 barley fields were surveyed during the summers of 1995, 1996 and 1997, respectively. Average levels of scald on the flag and flag - 1 leaves remained below 4% leaf area diseased (PLAD) under zero, minimum and conventional tillage in all three years. Net blotch severity on the flag -1 leaf was highest in 1995 (7.5% PLAD), lowest in 1997 (2.5% PLAD) and intermediate in 1996 (4.2% PLAD). Overall, trends associated with tillage and rotation were limited. In 1996 and 1997, scald and net blotch severity were similar among the tillage systems and in fields planted to barley the previous year compared with fields planted to a non-host. In 1995, when net blotch severity was increased, disease levels tended to be highest for those fields under minimum and zero tillage. Disease severity was also increased when barley in 1995 was preceded by barley in 1994, especially for net blotch. Survey results from 1995 indicated that increased net blotch levels under zero or minimum tillage may be reduced to levels comparable to those observed under conventional tillage by the use of resistant varieties or by not planting barley on barley residue. Results from the leaf survey regarding the impact of tillage are similar to more recent results from an experiment at the Lacombe Research Centre investigating the effect of cultivar, fertilizer placement and tillage on barley production (Clayton et al., personal communication). In 1997 and 1998, scald and net blotch levels on Harrington were not significantly different under direct seeding compared with conventional tillage (Clayton et al., unpublished data).

Crop Rotations and Seed-Borne Disease

Shortened rotations or continuous barley production can be risk factors with regard to scald, net blotch, spot blotch and various root diseases. Accordingly, pathologists recommend an interval of 1 to 2 years between barley crops to help minimize disease. However, extended rotations may not always reduce a producer’s risk of disease. In the Alberta barley leaf survey, described previously, substantial levels of both scald and net blotch developed in fields not planted to barley or forage grasses for the previous four years. Average PLAD in each year ranged from 0.9 to 3.2% and 3.5 to 9.9% for scald and net blotch, respectively. However, in some individual fields scald and net blotch levels exceeded 30 and 50% PLAD, respectively. Most of the high levels of disease, especially for net blotch, occurred in fields of Harrington. One potential source of disease in these fields may have been seed-borne inoculum.

The fungi that cause scald and net blotch are both seed-borne and residue-borne. The importance of seed-borne scald and net blotch as a source of disease in Western Canada is not well understood. In Alberta, Skoropad (1959), Lee et al. (1998), and Xi and Burnett

(1997) found that *Rhynchosporium secalis*, the causal agent of scald, infected barley awns, lemmas, paleas and pericarps. The movement of scald into scald-free areas via infected seed has been suggested (Habgood 1971, Reed 1957 and Skoropad 1959). Several reports have indicated the level of seed infection with scald observed in a number of countries. In Alberta, Skoropad (1959) found that seed samples collected randomly from barley crops had from 1 to 10% scald infected seed with an average of 2.0%. During the summer of 1996, seed from a regional variety trial located at Westlock, Alberta was found to have scald infection levels that ranged from 0 to 10% infected seed (T.K. Turkington, personal communication). Jackson and Webster (1976) in the early 1970's, looked at seed from a number of fields in California and found from 0 to 36.5% seed infection with an average of 5.3%. In the United Kingdom, Kay and Owen (1973) reported a range of 0 to 14.5% infection with an average of 0.9%. Research in the 1950's and 1970's demonstrated transmission of *R. secalis* from infected seed to seedlings mainly under greenhouse conditions (Habgood 1971, Jackson and Webster 1976, Kay and Owen 1973, Reed 1957 and Skoropad 1959). Reed (1957) also observed that infected seed that remained on the soil surface after seeding could act as a source of inoculum.

In some countries, including India, New Zealand and England, seed-borne inoculum of net blotch is considered to be an important source of disease (Hampton 1980, Jordan 1981, Sheridan et al. 1983, Shipton et al. 1973, Singh and Chand 1985). At Lacombe, Alberta, Piening (1968) studied seed to seedling transmission using seed that was covered with cultured net blotch mycelium or ground net blotch infected leaves. In the field, seedling infection levels were 0.5 to 1.5% and 0 to 0.15% for infested and control seed, respectively. Piening (1968) also looked at disease development resulting from seed to seedling transmission and found that 28 days after emergence plots where infected leaves had not been removed had twice as many infected plants as compared with plots where infected leaves were removed.

The presence of fungal pathogens, such as net blotch, on barley seed may also be of concern with regard to grain quality. Recent seed surveys (Turkington et al. 1996, T. K. Turkington and R.M. Clear, unpublished data) have shown that over a three year period from 1995 to 1997 between 71 and 97% of barley grain samples in Alberta had detectable levels of infection with *Pyrenophora teres*, the causal agent of net blotch (Figure 1). Samples from 1995, 1996 and 1997 had overall average seed infection levels of 7.1, 12.1 and 22.6%, respectively. The maximum observed seed infection levels were 82, 81 and 89%, for 1995, 1996, and 1997, respectively. The frequency and level of infection tended to be higher for 2-row barley samples compared with 6-row samples. Based on results from Edney and Tipples (1997) the majority of 2-row samples would likely be the variety Harrington. *Cochliobolus sativus*, a pathogen commonly associated with kernel discolouration in barley (Mathre 1997), was undetected in seed samples from 57 to 86% of fields. Yearly averages of 0.3, 1.0 and 0.6% seed infection were recorded for 1995, 1996 and 1997, respectively. Although not frequently isolated in the Alberta survey, this pathogen is among the most common fungi isolated from barley in Manitoba and eastern Saskatchewan (R.M. Clear, personal communication). Another pathogen not commonly associated with barley, *Septoria nodorum*, was observed in almost all samples from each year with average seed infection levels of 19.5, 10.7 and 16.6% for 1995, 1996 and 1997, respectively (Fig. 1). Maximum observed levels of this pathogen were 45, 59 and 61% for 1995, 1996 and 1997, respectively.

The potential impact of significant levels of seed-borne *P. teres, S. nodorum*, and *C. sativus* is not clear, especially with regard to malt barley acceptance and quality in Western Canada. Edney et al. (1998) found that kernel discolouration was correlated with in-crop net blotch severity levels, but only for 6-row barley varieties. High levels of seed infection with these pathogens likely indicate significant disease levels in the growing crop, which would have a negative impact on overall crop yield and kernel plumpness. Basson et al. (1990a) found differences in malt quality between sound and black-end barley kernels and attributed this to higher nitrogen levels in the black-end kernels. Gyllang et al. (1977) demonstrated that *Aspergillus* spp. occurring during germination in the malting plant caused gushing beer. They also demonstrated that these *Aspergillus* spp. as well as *Rhizopus oryzae* had an impact on several malt quality parameters. Flannigan and Healy (1983) also demonstrated that microbiological analysis of barley samples and comparison of relative levels of field (*Cladosporium* spp.) and storage fungi (*Aspergillus* spp. and *Penicillium* spp.) could be used to indicate whether previous on-farm “heating” had occurred prior to delivery.

Disease Resistance

Resistant varieties are one of the main management tools for foliar diseases in barley, especially for feed barley production. Currently, most commercially available malt barley varieties are completely susceptible to scald, although some varieties with interim registration have increased levels of resistance. Intermediate levels of net blotch resistance are available in some of the malting barley varieties. Unfortunately, the scald resistance of some feed varieties appears to be breaking down. This has occurred mainly in Alberta, but during the summer of 1997, significant levels of scald on a resistant cultivar were reported in the Medstead area of Saskatchewan (E. Seidle, personal communication).

Scald reaction data from 6-row and 2-row regional trials at Lacombe and Edmonton from 1995 to 1997 are reported in Table 2 (T.K. Turkington, P.A. Burnett and K. Briggs, unpublished data). From 1995 to 1997 at Lacombe, scald severity ratings as a percentage of Harrington were relatively high for several resistant varieties including CDC Dawn, CDC Earl, CDC Guardian, Falcon and AC Lacombe. For some of these varieties, the ratings as a percentage of Harrington increased from 1995 to 1997. In 1995, there appeared to be somewhat of a differential reaction for some of these varieties when comparing ratings from Lacombe and Edmonton. Ratings as a percentage of Harrington for some of the resistant varieties tended to be higher at Lacombe compared with Edmonton (Table 2). However, by 1997, these ratings were similar for both sites. In general, the resistance in varieties like Kasota, CDC Dolly and Seebe seemed to hold up reasonably well from 1995 to 1997. Overall, regional trial results indicate the development and increased influence of more virulent races of the scald pathogen at the Lacombe and Edmonton screening sites. In addition, significant levels of scald on varieties classified as resistant have been observed over the past several years in commercial fields and various variety trials across Alberta (T.K. Turkington and K. Xi, personal communication).

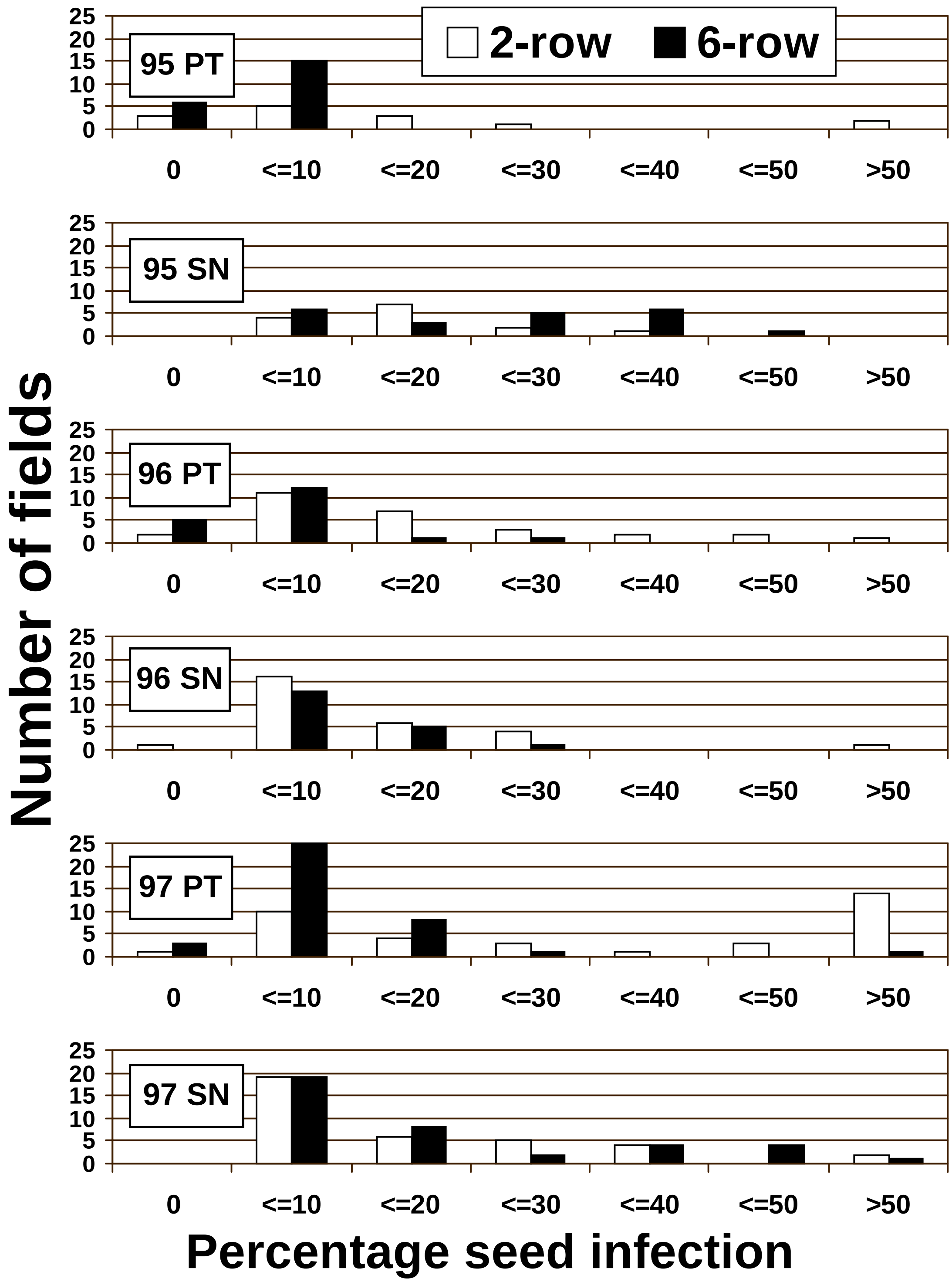


Figure 1. Frequency of seed infection with *Pyrenophora teres* (PT) and *Septoria nodorum* (SN) for 2-row and 6-row barley varieties, Alberta 1995, 1996 and 1997 (Turkington et al. 1996, Turkington and Clear, unpublished data).

Table 2. Scald severity ratings as a percentage of Harrington, 6-row and 2-row regional barley trials Lacombe and Edmonton, 1995 to 1997.

Variety	Lacombe			Edmonton		
	1995	1996	1997	1995	1996†	1997
6-row trial						
AC Lacombe	79	76	87	35	32	51
CDC Earl	36	76	93	14	21	71
Harrington	100	100	100	100	100	100
Kasota	12	0	0	28	21	36
2-row trial						
CDC Dawn	40	64	93	67	33	100
CDC Dolly	13	36	21	13	67	92
CDC Guardian	53	46	93	13	67	100
Falcon	67	73	64	20	67	83
Harrington	100	100	100	100	100	100
Seebe	20	0	0	13	67	75

† Overall disease levels were low at Edmonton in 1996.

The breakdown in scald resistance observed in Alberta has typically occurred where a particular resistant variety has been grown in the same field for several years in a row. Under these conditions, there is a tremendous selection pressure placed on the scald pathogen to develop and/or increase the level of more virulent races able to overcome the disease resistance that is present. However, significant levels of scald have also been observed on varieties registered within the last couple of years (T.K. Turkington and K. Xi, personal communication).

Recently, severe levels of net blotch (net-form) were observed in agronomic plots planted to AC Lacombe, a variety with an intermediate response to this disease, especially in the field. This experiment was located on land that has been planted to AC Lacombe silage barley for several years in a row (G.W. Clayton and T.K. Turkington, unpublished data). In the same experiment, plots seeded to Falcon barley, a variety with a similar intermediate response, had less severe disease levels. Perhaps with continuous production of AC Lacombe there had been selection for more virulent races of the net blotch pathogen able to cause more extensive disease on this variety.

Summary

Barley diseases can have a significant negative impact on crop productivity and quality, especially with a susceptible variety like Harrington. Yield losses in barley of around 20% or more as a result of net blotch and scald infection have been reported (Buchannon, and Wallace 1962, Mathre 1997, McDonald and Buchannon 1964, Skoropad 1960)**.** Recent fungicide studies with Harrington have demonstrated yield reductions due to foliar disease of over 20% and that fungicide application could be used to increase yield, thousand kernel weight and kernel plumpness (Orr and Burnett 1995, Orr and Turkington 1997, Kutcher and Kirkham 1997). However, limited information appears to be available regarding the impact of diseases or application of foliar fungicides on malt barley quality (Basson et al. 1990b). Scald, net blotch and spot blotch reduce green leaf area, resulting in less plump kernels, but the fungi causing these diseases are also seed-borne (Mathre 1997, Skoropad 1959). Net blotch has been shown to reduce carbohydrate and malt extract levels in barley grain (Kamal and Naguib 1957, Shipton 1966). Nutter et al. (1984) also found a reduction in malt extract of malting barley after field inoculation with *C. sativus*, the causal agent of spot blotch. Likewise, barley yellow dwarf virus has been shown to reduce malt extract, and to raise protein levels and diastatic power (Steffenson et al. 1990). In a study investigating the impact of take-all on malting barley, Cunningham et al. (1968) concluded that this disease "had no pronounced or consistently adverse effects" on quality. In a fungicide study, Basson et al. (1990b) found little or no effect of application of registered foliar fungicides, including propiconazole (Tilt) on malt quality, although they did find a significant positive effect on kernel plumpness. More recently, Newton et al. (1998) also found no significant effect of fungicide application on hot water extract of winter malting barley.

From a disease standpoint, the increased adoption of conservation tillage by western Canadian producers will likely not have a pronounced influence on barley productivity and quality. In general, other factors such as environmental variation, rotation, seed-borne inoculum and variety will have a much larger impact on disease and crop productivity than just the tillage system used by a producer. Significant levels of some pathogens on barley grain are a concern. For pathogens such as net blotch, seed-borne inoculum may act as an important source of disease when rotations with several years between barley crops are used. Furthermore, there is no clear indication of the significance of the foliar or seed-borne phases of diseases like scald, net blotch, spot blotch or septoria on malt barley quality and acceptance. A better understanding is needed of the potential impact of seed-borne and foliar diseases on malt barley quality, combined with continued refinement of management strategies to reduce disease levels. This will assist western Canadian producers to more consistently obtain malt grades and provide malting and brewing industries with a consistent supply of high quality malting barley.

The goal of incorporating disease resistance into suitable barley varieties is to provide long-term disease management and reduced reliance on chemical pesticides. However, plant pathogens will adapt to the varieties being grown and perhaps even to the pesticides that are being used. Results from scald screening nurseries, variety trials and commercial fields in Alberta have illustrated the increased prevalence of more virulent scald races. As a result of these races, the resistance genes in varieties like CDC Earl, CDC Dawn and Falcon may no longer be effective at certain locations in Alberta. In addition, they may not represent effective sources of resistance to incorporate into adapted varieties by western Canadian barley breeders. Work by Penner et al. (1996) has suggested that there may be a limited

number of resistance genes present in western Canadian barley varieties, while Tekauz (1991) and Xi (unpublished data) have demonstrated tremendous variability in the scald pathogen. This may explain the breakdown in barley scald resistance that is occurring in Alberta and western Saskatchewan. There is also interest in the potential of barley varieties with a slow-scalding response. With this type of response scald symptoms develop, but the disease does not build up to high levels on the upper leaves, potentially translating into reduced yield losses. Furthermore, slow-scalding may help to reduce the selection pressure on the scald fungus for changes in virulence. This type of disease reaction could represent a source of intermediate resistance that may be effective for a longer period of time compared with the resistance that is present in a variety such as CDC Earl.

As we continue to see the breakdown of scald resistance in Alberta and western Saskatchewan, there is potential for a similar scenario with net blotch in Western Canada. Tekauz (1990) found more extensive variability in the net blotch pathogen compared with previous studies and demonstrated the occurrence of isolates virulent on several sources of resistance. He also suggested that “future cultivars with improved net blotch resistance may select for and increase these more virulent pathotypes.” Research by Ho et al. (1996) has shown that some sources of resistance may be conditioned by 1 to 3 genes. Observations from agronomic trials at Lacombe (Clayton et al. unpublished data) suggest the appearance of more virulent races of this pathogen.

Although scald and net blotch resistance may be incorporated into current and future malting barley varieties, changing pathogen virulence patterns may reduce the effectiveness of these sources of resistance. As a consequence, these varieties may suffer from the same disease-related disadvantages that currently affect Harrington. Moreover, as long as Harrington has similar agronomic and quality characteristics compared with newer varieties, and remains popular among farmers, malting companies and brewers, it may prove to be truly an ageless variety.

Acknowledgements

The assistance of technical staff of Agriculture and Agri-Food Canada (AAFC) at Lacombe and Beaverlodge and of Alberta Agriculture, Food and Rural Development (AAFRD) at Lacombe is gratefully acknowledged. The collaboration of Dr. K.G. Briggs, University of Alberta, Dr. J.H. Helm, AAFRD Lacombe, Dr. B.G. Rossnagel, University of Saskatchewan, Dr. W.G. Legge, AAFC Brandon, and R.M. Clear and S. Patrick of the Grain Research Laboratory, Canadian Grain Commission, Winnipeg, is also gratefully acknowledged. The assistance of AAFRD Cereal/Oilseed Specialists and Conservation and Development Technologists and Technicians and cooperating barley producers with the barley leaf and seed surveys and conversations regarding Harrington is also gratefully acknowledged. Funding for the scald resistance screening project was provided by the Alberta Barley Commission.

List of References

Anonymous. 1997. Census of Agriculture, Statistics Canada.

Basson, A.B.K., O.T. de Villiers, and C.J. Rabie. 1990a. ASBC Journal. 48: 8-13.

Basson, A.B.K., and G.J. Greeff. 1990b. S. Afric. J. Plant Soil 7:244-246.

Buchannon, K.W., and H.A.H. Wallace. 1962. Can. J. Plant Sci. 42:534-536.

Cunningham, P.C., P.A. Spillane, B.T. Foreman, and D. Conniffe. 1968. Ir. J. Agric. Res. 7:183-193.

Edney, M.J., T.M. Choo, D. Kong, T. Ferguson, K.M. Ho, K.W. May, and R.A. Martin. 1998. Can. J. Plant Sci. 78: 217-222.

Edney, M.J., and K.H. Tipples. 1997. ISSN 1182-4417 Crop Bulletin No. 235. Grain Research Laboratory, Canadian Grain Commission.

Flannigan, B., and R.E. Healy. 1983. J. Inst. Brew. 89: 341-343.

Gyllang, H., L. Satmark, and E. Martinson. 1977. Proc. Eur. Brew. Conv. Congr., Amsterdam, 245-254.

Habgood, R.M. 1971. Plant Pathol. 20: 80-81.

Hampton, J.G. 1980. N.Z. J. Exp. Agric. 8: 297-299.

Ho, K.M., A. Tekauz, T.M. Choo, and R.A. Martin. 1996. Can. J. Plant Sci. 76: 715-719.

Jackson, L.F. and R.K. Webster. 1976. Plant Dis. Reptr. 60: 233-236.

Jordan, V.W.L. 1981. Plant Pathol. 30: 77-87.

Kay, J.G., and H. Owen. 1973. Trans. Br. Mycol. Soc. 60: 405-411.

Kamal, M.A.M, and M.I. Naguib. 1957. Ann. Agric. Sci., Cairo 2: 95-103.

Kutcher, H.R., and C. Kirkham. 1997. Pest Management Research Report – 1997.

Lee, H.K., J.P. Tewari, and T.K. Turkington. 1998. Seed Sci. Tech. In press.

Mathre, D.E. 1997. APS Press, St. Paul, Minnesota. 90 pp.

McDonald, W.C. and K.W. Buchannon. 1964. Can. Plant Dis. Surv. 44: 118-119.

McLelland, M.B. 1992. Alberta Agriculture, Food and Rural Development, Field Crop Development Centre. 24 pp.

Newton, A.C., J.S. Swanston, D.C. Guy, and R.P. Ellis. 1998. J. Inst. Brew. 104: 41-45.

Nutter, F.W., V.D. Pederson, and R.E. Pyler. 1984. Brewers Digest 25-28.

Penner, G.A., A. Tekauz, E. Reimer, G.J. Scoles, B.G. Rossnagel, P.E. Eckstein, W.G. Legge, P.A. Burnett, T. Ferguson, J.H. Helm. Euphytica 92: 367-374.

Orr, D.D. and P.A. Burnett. 1994. Pest Management Research Report.

Orr, D.D. and T.K. Turkington. 1997. Pest Management Research Report.

Piening, L. 1968. Can. J. Plant Sci. 48: 623-625.

Reed, H.E. 1957. Bull. Univ. Tenn. Agric. Exp. Stn. No. 268.

Sheridan, J.E., N. Grbavac, and L. Ballard. 1983. Proc. 36th N.Z. Weed and Pest Control Conf. 242-246.

Shipton, W.A. 1966. Aust. J. Exp. Agric. and Anim. Husb. 6: 437-440.

Shipton, W.A., T.N. Khan, and W.J.R. Boyd. 1973. Rev. Plant Pathol. 52: 269-290.

Singh, M. and J.N. Chand. 1985. Indian Phytopath. 38: 659-661.

Skoropad, W.P. 1959. Phytopath. 49: 623-626.

Skoropad, W.P. 1960. Commonw. Phytopathol. News 6: 25-27.

Steffenson, B.J., M.C. Edwards, and P.B. Schwarz. 1990. Phytopath. 80: 1021 (Abstr.).

Tekauz, A. 1990. Can. J. Plant Pathol. 12: 141-148.

Tekauz, A. 1991. Can. J. Plant Pathol. 13: 298-304.

Turkington, T.K., P.A. Burnett, R.M. Clear, G.W. Clayton, A. Olson, K. Olson. 1996. Seed-borne cereal disease survey: Alberta 1995. Proceedings of the 1996 Plant Pathology Society of Alberta annual meeting, November 4-6, 1996, Lacombe, Alberta. 12 (Abstr.).

Xi, K. and P.A. Burnett. 1997. Biotechnic & Histochemistry 72:173-177.

Hulless Barley – The Barley of the Future?

Brian Rossnagel, University of Saskatchewan
Saskatoon, Saskatchewan, Canada

Canadian Hulless Barley History

Prior to the early 1970's hulless barley was a curiosity in Canadian barley research and development (R&D). A few cultivars were released from 1920 to 1980, but added feed value was not recognized nor realized.

In the late 1960's and early 1970's an effort was launched to investigate overall improvement of feed grains for Western Canada, with an emphasis on barley for export and domestic use. Key players in these ground breaking steps were D.R.Metcalfe (AAFC), C.Brown (CWB), and J.Sibbald (AAFC). Others included: M.Bell, R.Bhatty, I.Christison, J.Berdahl & B.Harvey, (U. of Sask.), E.Stringam & L.Campbell (U. of Man.), K.Buchannon, R.Wolfe & V.Bendelow (AAFC), D.Laberge & A.MacGregor (CGC). Key leadership came from D.R. Metcalfe who first made a presentation about breeding and improving feed grains (especially barley) at the Canada Committee on Grain Breeding (CCGB) meeting in February of 1968. He followed by organizing and chairing an ad-hoc feed grains improvement committee through the mid-1970's making a significant report to the 1973 CCBG meeting. As a result of these efforts, and specific investigations by the Eastern Prairie Barley Project group (AAFC, Wpg & Bdn & the Univ. of Sask. & Man.), a majority of the barley R&D community agreed that a road to improvement lay in the development of commercially acceptable hulless barley cultivars. This would improve energy for poultry and swine and make export barley more competitive with the international feed standard corn.

The first breeding project to respond and undertake a significant, concerted effort on hulless barley development for Western Canada was the feed barley program, Crop Development Centre (CDC), University of Saskatchewan, where J.Berdahl (followed by B.Rossnagel in 1977) and R.Bhatty began serious breeding and selection in 1973. The program was based on crosses introgressing the hulless trait into local germplasm made by B.Harvey in the late 1960's. From the outset the program collaborated with nutritionists in the University of Saskatchewan, Animal & Poultry Science Department to improve nutritional quality. Basic donor hulless parents were Hulless Betzes from R.Eslick, Montana State for 2-rows and the US variety Godiva for 6-rows. First results were the release of the 2-row variety Scout (1982) and the 6-row Tupper (1984). Ten hulless varieties have been released through 1999.

The second major effort was that by the Alberta Department of Agriculture, where J.Helm began dedicating significant effort to the hulless type in the late 1970's. This program has contributed significantly to the short history of hulless with the release of the 2-row variety Condor (1988) and the 6-row Falcon (1992). To date, three more varieties have since been released.

The first hulless genotypes appeared in the western barley Coop tests in 1980 and a separate western Hulless Barley Coop trial was established in 1988. Eighteen varieties have been registered since 1982.

Commercial production of hulless barley became notable in the late 1980's, especially in Alberta. While difficult to obtain accurate data, it is generally agreed that western Canadian acreage reached some 750,000 acres in 1997, having doubled annually from 1993 to 1996. While acreage dropped in 1998, primarily because producers were not realizing sufficient price premiums, and the current hog industry downturn may depress 1999 acreage, it should recover by 2000 and continue long term growth after that.

Present Canadian Hulless Barley R&D Activity

Hulless Barley Development

Eastern Canada

While the bulk of hulless barley R&D is in Western Canada, programs in Eastern Canada do have an interest. The primary goal is development of hulless for feed markets.

***Public Programs*:** The McGill University program currently does not work on hulless, but the cultivar Oxford was released in 1933. The AAFC Ottawa/Charlottetown program has not worked with hulless extensively until recently, but registered a doubled haploid cultivar, AB168-11, in 1998. The University of Guelph program works on hulless in collaboration with the University of Saskatchewan and genotype SB90594 may be released in 1999.

Private Programs: W.G. Thompson and Sons and C&M Seeds collaborate with the University of Saskatchewan with annual evaluations in Ontario. Neither program has a specific hulless effort.

Western Canada

The bulk of Canadian hulless R&D has and does take place on the Prairies. While the major goal is feed, limited sustained effort has been placed on the food and industrial markets, and recent efforts have begun re hulless for malting/brewing.

Public Programs:

AAFC Brandon: This project has been in and out of hulless barley R&D since the early 1980's, but since 1988 has dedicated significant effort to the type. Hulless now represents 40% of the feed barley effort with both feed and food components. Emphasis is on feed, especially for swine. Cultivars released include AC Hawkeye and AC Bacon, both 6-rows. The malting barley program has recently begun a limited effort re 2-row hulless malting development.

Crop Development Centre, University of Saskatchewan: This program has the longest ongoing hulless barley development program with breeding dating back to the late 1960's and a concerted effort beginning in the mid 1970's. CDC hulless entries first appeared in the Western Two-Row and Six-Row Coop Tests in 1980 and 1981, respectively. The first 2-row variety registered was Scout in 1982 with the first-6 row Tupper in 1984. While the program emphasizes the development of hulless for monogastric and poultry feed, a sustained food/industrial breeding effort has been ongoing since the early 1980's with emphasis on specialty starch and high beta-glucan types. Since the early 1990's, an additional objective has been the evaluation and development of hulless for malting and brewing. Ten varieties released include: 2-rows – Scout (1992), CDC Richard (1990), the waxy type CDC Candle (1995), CDC Dawn (1995), CDC Gainer (1997), CDC Freedom (1998) and HB335 (1999); 6-rows – Tupper (1984), CDC Buck (1990) and the semi-dwarf CDC Silky (1994).

Agronomic emphasis has been for improved yield, threshabilty, straw strength and disease resistance, while low beta-glucan and acid extract viscosity for feed use and the opposite for food/industrial use have been primary considerations from a quality viewpoint.

Field Crop Development Centre, Alberta Agriculture Food & Rural Development, Lacombe: While this second major effort has been ongoing since the 1970's, concerted efforts began in the early 1980's. FCDC hulless entries first appeared in the Western Coop Trials in 1985. The program has emphasized the development of cultivars for the feed industry, with main selection criteria being yield and energy digestibility. The program collaborates with the CIMMYT program on the development of food types for developing countries. Varieties released include: 2-rows – Condor (1988), Phoenix (1993) and Tercel (1997); 6-rows – semi-dwarfs Falcon (1992) and HB608 (1998).

***Private Programs*:** Alberta Wheat Pool/Agricore: Collaboration with Western Plant Breeders, Bozeman, MT on waxy hulless for food/industrial markets. Varieties: Merlin and HB803 in 1995.

Feed Quality R&D

Initial and past activity primarily in Western Canada at the University of Saskatchewan, Alberta., Manitoba and British Columbia directed at swine and poultry nutrition and enzyme addition to ameliorate limitations due to NSP's. Feed research groups at AAFC Agassiz (poultry), Brandon (swine) and Lethbridge (ruminants) have recently become active.

Food/Industrial R&D

Initial and past activity primarily at the University of Saskatchewan in collaboration with the Canadian Grain Commission's Grain Research Laboratory, followed by the University of Alberta and, most recently, the University of Manitoba.

Current & Future Issues/Opportunities

Agronomic or Performance Traits

Threshability

***Current*:** Since hulless barley with hulls does not have superior feed quality and the feed industry has established a maximum level of 15% adhering hulls as a "quality" criteria, threshability has been an over-riding issue from a practical production viewpoint. With initial varieties it was difficult to achieve the 15% target, however, selection to improve this trait has been successful, especially in 2-rows. This is still an issue for 6-rows.

Future: Improve threshability in 6-rows and maintain levels of most recent 2-row varieties. Asian germplasm may assist. Vigilant of possible shattering losses in easy to thresh germplasm and of embryo damage for malting.

Straw Strength

Current: Initial releases were generally weak and there was an association of weak straw with the hulless trait, especially in 2-rows. Selection has ameliorated this. The development of semi-dwarfs has assisted in the 6-rows.

Future: Continued selection for strong straw "normal" height types and development of semi-dwarf 2-rows. Using growth regulators to maintain straw strength is possible, but not economic.

Disease Resistance

Current: Disease resistance in hulless is no different than in hulled barley, with the exception of the smuts, where hulless are more susceptible and scab, where hulless may have an advantage. Progress in developing hulless with disease resistance has been good. Recent hulless 2-rows have the best net blotch, scald and rust resistance combinations available for any 2-row varieties. Since most fusarium and accompanying toxins are on the hull, which is left in the field at harvest, hulless may have an advantage in areas subject to scab. However, breeders and pathologists will need to select for fusarium resistance to keep this advantage.

Future: While significant improvement in disease resistance has been made, breeding must continue since pathogens evolve and overcome resistance. Fusarium will need more emphasis as will scald, where several current resistance sources are breaking down. Once resistance gives better "control" of net blotch and scald, other leaf diseases such as septoria may become problematic. The lack of "complete" covered and false loose smut resistance, with hulless being more susceptible, mean this area requires more effort. Genetic transformation offers promise to bring in resistance from related species and genes for novel resistance (e.g. anti-fungal proteins) or by regulating existing resistance genes. Molecular marker assisted selection (MMAS) will improve the breeding/pathology/biotechnology team's effectiveness in developing varieties with resistance/tolerance to multiple diseases and with multiple and more stable resistance to individual pathogens.

Yield

Current: As with any germplasm improvement effort, increased yield per unit area has been an important objective in hulless development. New varieties out-yield originals by 20% or more.

Future: Yield increases will be ever more difficult. The key will be to maintain yield increases consistent with those made in hulled barley.

Quality or Output Traits

These can be broken down into sub-sections within each of several end-use areas. End-use areas include: feed vs. food/industrial vs. malting/brewing. Sub-sections within those include: physical vs. intrinsic/chemical traits, processing vs. nutritional characteristics; and in the feed area – livestock type: ruminant vs. monogastric vs. poultry vs. fish.

Physical Traits (hull adherence, embryo damage, test weight, grain size, plumpness, uniformity, colour)

Current: Physical trait needs are generally similar regardless of end-use, although end-uses which require processing have specific limitations. While ease of threshing (discussed above) is and will remain the key physical trait of importance, uniformity and plumpness are key as they affect storage, handling and processing for many end-uses.

Future: Increased emphasis on uniformity. Possible special emphasis on grain colour for the food/industrial sector. Greater concern re embryo damage for malting end-use.

Intrinsic/Chemical Traits (starch content and type, non-starch polysaccharides (NSP's), fat, protein, enzymes, minerals)

Processing Characteristics

Current: To date little attention has been given to processing characteristics.

Future: Importance depends on end-use. In feed, processing is important for ruminants, poultry and fish; where rolling, pelleting or extrusion are used, but not for monogastrics where most feed is ground. Since hulless offers little advantage for ruminants, rolling is not a concern. For pelleting or extruding (poultry and fish) future hulless barley will need to be tailored for these processes. While all intrinsic chemical traits are involved in "processability", starch type, NSP's and protein will be of most interest. The increasing importance of the fish feed sector with its special processing requirements needs to be recognized and capitalized upon if possible.

Nutritional Factors – Feed

Current: The main value of hulless is high energy and low fiber, thus all programs emphasize low hull adherence. For monogastrics and poultry the CDC program has also developed varieties with low levels of beta-glucan and other NSP's, and with high starch content, and has begun to develop low phytate materials. The FCDC program uses NIR to screen for improved digestibility. Hulless offers little advantage for ruminants, thus has not been designed for cattle. Early feed research suggested poor protein digestibility, however, that has been refuted.

Future: Continued selection for high starch level and digestibility with low NSP's. Selection for feed intake. Increased fat content. Lower total protein with increased protein digestibility. Possible development of hulless types tailored for high energy dairy rations. Development of low phytate hulless. Combination of feed needs with malting/brewing needs.

Nutritional Factors – Food/Industrial

Current: Primarily development of waxy starch types with elevated levels of NSP's, especially beta-glucan. Recent developments include waxy lines with pure amylopectin starch at the CDC. These parameters affect nutritional/health benefits and processing/functional characteristics.

Future: Refinement of waxy and 100% amylopectin types. Development of high amylose types and other novel starch type combinations, including fractured starch, with potential functional novelty from processing, nutritional and functional viewpoints. Increased interest in anti-oxidant levels and specific NSP's. Novel industrial use of hulless barley derivatives. Segregation of food barley designed for markets in developed countries (health food) vs. markets where barley is used as a staple food.

Malting/Brewing

Current: Evaluation of hulless for malting/brewing has been stimulated by the development of pressure mash filters so hulls are no longer needed for filtration in brewing. The >5% increase in malt extract per unit of barley is attractive to brewers, thus hulless has the potential to be the barley of choice for that industry. Work has been done re the use of hulless for food malt production and advanced hulless lines have been regularly evaluated for malting quality for the past several years. Two breeding programs are specifically selecting for improved malting quality in hulless.

Future: While initial results are promising, several issues must be overcome before the use of hulless becomes a reality. Embryo damage during harvest and handling leading to reduced germination percentage is a major physical issue, and relatively high protein content leading to poor malt friability, appears to be the major chemical issue. Evidence from GA addition indicates that current cultivars can also be improved regarding enzyme activity. Canada has a distinct advantage vs. international competitors since we have hulless up and running and the feed industry will continue to provide demand. Should the use of hulless barley for malt become routine the face of western Canadian barley production will change dramatically.

Summary

Hulless barley is established as a crop type in Western Canada and will be a major part of the future of the barley crop. The "pull" from the domestic monogastric and poultry feed industries has and will continue to be the driving force behind hulless barley use and development. As a result, Canada has a competitive advantage should hulless market demand in the international feed or malting and brewing industry develop increasing market pull. Not only will we have an experienced R&D community and product, but most critically we have an experienced production community able to produce to that demand. Since other competing barley producing areas of the world do not and will not have a feed industry pull, due to the availability of alternative high energy feedstuffs, it is unlikely that hulless will become important in those areas. That will change only if the use of hulless for malting and brewing becomes established.

Predictions

As hulless becomes the feed grain of choice for swine, and as we see increased use in poultry rations, 25 to 30% of western Canadian barley acreage will be hulless.

Now that hulless is established as a crop alternative, quality refinements will lead to specific varieties for specific end-uses. Much of the production will be identity preserved. Quality refinements will include higher energy, lower protein with improved biological value, lower phytate, and alterations to improve feed processing and feed intake.

Fish feed quality requirements will be determined and hulless will need considerable alteration if it is to find a fit in that market. Hulless barley with slower digestion rates designed for high energy dairy rations may be developed, but competition from other feeds will generally keep hulless barley out of ruminant diets.

Food and industrial use of hulless will increase, but will not likely occupy more than a few 100,000 acres. Despite relatively limited acreage, this production will be important and a significant portion of it may be organically produced, driving an even greater need for disease resistance, especially to smuts.

"IF" hulless barley breaks through for use in malting and brewing, the majority of barley acres could be hulless – with as much as 75% of the area planted to hulless.

Challenges in Breeding Feed Barley

James Helm, Alberta Agriculture
Lacombe, Alberta, Canada

The number one challenge or problem in breeding feed barley has been to define what feed barley is. To most, the definition has been "barley that doesn't make malt," and the primary quality factor, as defined by the livestock industry, has been "price, price, price." There have been years when feeders have used low quality frozen wheat at an equal price to good quality barley and put up with the lower animal performance because there is a perception that even low quality wheat is better than good barley.

In spite of these problems, the last twenty five years has shown a trend to grow more feed varieties (Tables 1a and 1b). Yield is the primary factor that has caused this switch from both the 6-row and 2-row malting types. However, standability and disease resistance are also major factors.

In addition to yield, disease resistance and lodging resistance of the feed types over the malting varieties, we have seen the traditional price advantage of the malting varieties erode to the point that this year, in Alberta, feed barley is priced better than malt barley. As changes in grain transportation shift the cost to producers, we will continue to see growth in the livestock industry. This growth is expected to make Alberta a feed deficit area by 2002 (Toma & Bouma 1996). When the importation of feed grain begins, it will drive up the local prices. This will also drive up the demand for high yielding feed barley varieties.

Table 1a. Percent of Barley Production in Western Canada over the past 25 years.*

Year	6-Row Malt	2-Row Malt	Feed Varieties
1970	65.0	18.3	16.7
1975	55.7	18.7	25.6
1980	49.3	31.1	19.6
1985	35.4	30.3	34.3
1990	23.2	43.6	33.2
1995	23.0	51.0	26.0

Table 1b. Percent of Barley Production in Alberta over the past 25 years.*

Year	6-Row Malt	2-Row Malt	Feed Varieties
1970	57.4	22.6	20
1975	53.8	22.7	23.5
1980	45.7	36.2	18.1
1985	22.8	32.2	45.0
1990	16.5	39.3	44.2
1995	14.6	48.0	37.3

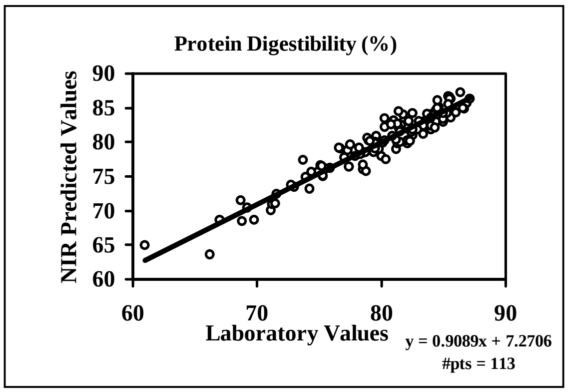
*Production numbers from BMBRI

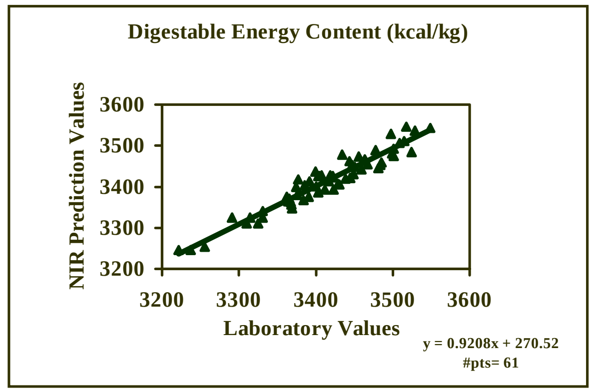
Science has made several important gains in technology in the last 20 years toward defining quality. We are beginning to understand the starch, protein, fiber and mineral components of the animal's diet more every day. We are to the point of using genetics to develop functional foods.

Over the last 30 years I have seen the quality focus of the industry change from protein to lysine and threonine, to digestible protein, to digestible energy and now a renewed interest in amino acid digestibility and phytate bound phosphorus (Michal et al 1998, Rock et al 1997). Besides animal performance, we are also looking at environmental impact. We are also dealing with animal genetics which has changed significantly over the same period.

Science has experienced a tremendous technology revelation that has made the measurement of components in the laboratory both rapid and accurate (Figure 1). This computer technology allows us to rapidly determine intrinsic quality of whole grain.

Figure 1. Examples of NIR predictions vs. Laboratory Values of Protein Digestibility in a Pig and Digestible Energy.





We began a large trial in 1993 to determine the G x E effects on as many feed quality factors as we could. This was done on ten varieties grown at ten locations of the Hulless Barley Coop test in 1993, 1994 and 1995 with Harrington as a hulled barley check. Our preliminary results (unpublished) indicate that the genetic component is significant for all characteristics except for Gross Energy (Table 2).

Table 2. Significance of Varieties for Quality Characteristics Measured on Ten Varieties Grown at Ten Locations from 1993 to 1995.

Quality Characteristics	Variety	Location	Year	L x V	Y x V
Crude Protein	**	*	NS	NS	*
Gross Energy	NS	NS	NS	NS	NS
Protein Digestibility	**	NS	**	NS	*
Energy Digestibility	**	NS	**	NS	**
Digestible Energy Content	**	NS	**	NS	**
Pentosans	**	NS	*	**	**
Lipids	**	NS	NS	NS	*
B-Glucans	**	NS	NS	NS	**
Starch	**	*	*	*	NS
Ash	**	NS	NS	*	NS
Soluble Fiber	**	NS	NS	NS	NS
Insoluble Fiber	**	NS	NS	NS	**
Total Fiber	**	NS	NS	NS	**

**Significant at $P \leq 0.01$ *Significant at $P \leq 0.05$ NS Not Significant

We also see that Year had a more significant effect than location. The Year x Variety interaction disappeared when Harrington was removed from the calculation for all but Digestible Energy, Pentosans, Beta-Glucan, Insoluble Fiber, and Total Fiber. The genetic differences for Pentosans also disappeared when Harrington was removed. While we can not say the heritability is high for these characteristics, we can say that there was significant genetic variability (Figures 2 and 3). This leads me to the conclusion that we can change these characteristics by breeding.

The problem remains that we do not have a usable definition based on an economic model to determine what quality is and what its dollar value is for the livestock producer. I think that the factors that will eventually be defined as economical will be those factors that increase the productivity and health of the animal and those that reduce the environmental costs. To do this we need to increase nutrient density and or nutrient utilization, energy, protein and minerals.

Two other factors must also be considered. The first is processing. We know that processing plays a major role in defining nutrient availability in all types of animals. As feed and environmental costs rise, we will see processing become an economical way of achieving the results we need. The second factor is palatability and feed intake. If we have achieved the development of a nutrient dense highly digestible feed that the animal will not eat – we have achieved nothing.

If I were to speculate on what this all means, I would say that Digestible Energy and % Digestibility of the protein will be the primary areas that will define feed quality. The third area will be the increased utilization of phosphorus from the grain. The first two are the direction we decided to go in the mid-1980's working with Dr. R. Beames at UBC and Dr. B.O. Eggum from the Danish Institute of Animal Science. Using rats, we found that the barley germplasm had a very wide range for these traits. We have since revised the procedures and, using the pig nylon bag procedure developed by Dr. Willam Sauer, analyzed over 300 samples of grain representing variety x location x year and developed a new screening test using NIR (Figure 1). Since we began this testing we have seen the selection level rise by over 6% for digestible energy and % digestibility of the protein. Our screening of germplasm indicates that we have the potential of increasing DE by another 200 Kcal and protein digestibility to over 90% in a pig (Figure 2).

Figure 2. Range of Constituent Values for Hulless Samples.

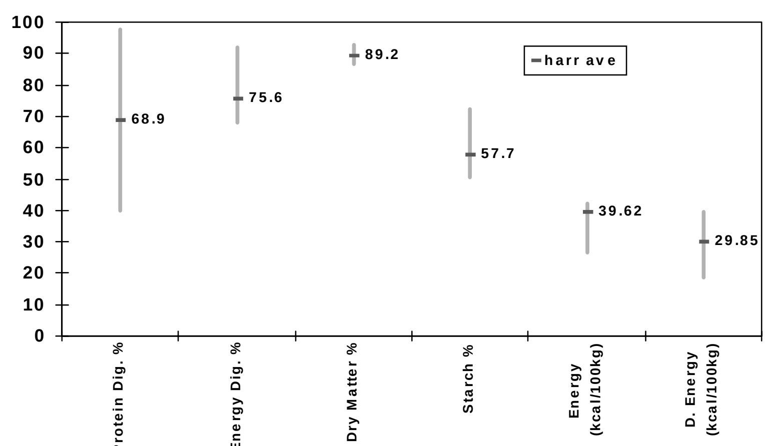
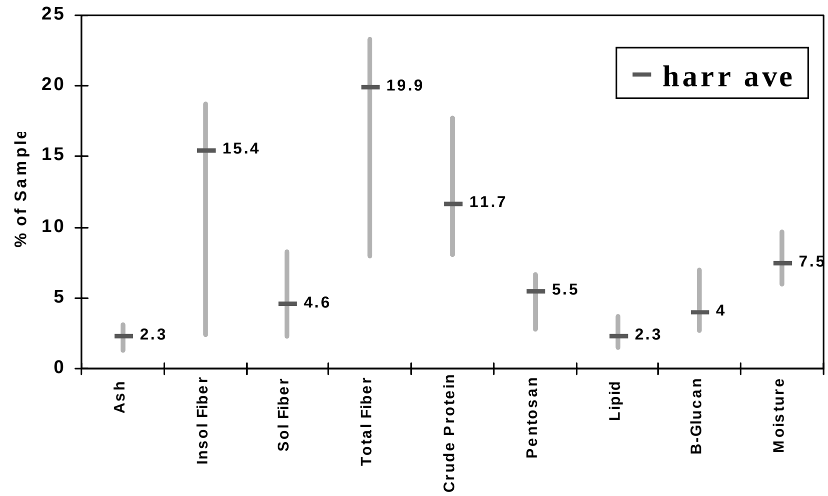


Figure 3. Range of Constituent Values for Hulless Samples.



References

Helm, J.H., W.C. Sauer and L.A. Helberg (1996) VII International Barley Genetics Symposium Proceedings, Page 123.

Michal, J.J., J.A. Froseth, N.O. Ankrah, M.A. Davis, C. O=keefe and C.E. Hosthether (1998) Washington Swine Information Day Proceedings, Vol. 13.

Rock, M.J., J.J. Michal, N.O. Ankrah, M.D. Davis, C.E. Hostetler, and J.A. Froseth (1997) Washington Swine Information Day Proceedings, Vol. 12.

Toma and Bouma Management Consultants (1997). Alberta Agriculture, Food and Rural Development, Consultant report.

Canadian Malting Barley Varieties for the Future

Michael J. Edney, Canadian Grain Commission
Winnipeg, Manitoba, Canada

Introduction

In recent years Canadian 2-rowed malting barley has become renowned for its high quality. In the past, though, Canada was thought of as a producer of high protein, 6-rowed barley. The severe weather of Western Canada with its short, hot, dry summers was thought to negate any possibility of producing the plump, low protein, 2-rowed barley demanded by a majority of brewers around the world. In contrast, demand for malting barley in the United States has been and continues to be for high protein, 6-rowed barley. Over the past 10 years this market has also shown increased demand for Canadian malting barley.

The increased demand for Canadian malting barley, especially 2-rowed, has resulted from new varieties with good quality. Dedicated breeders and a varietal registration system that emphasizes quality have been key in developing varieties that are now considered standards for quality around the world. As the growers of the new variety, Canadian barley producers also played a role in this rise to prominence. The varieties, though, had to have the agronomics and disease resistance that made them economical to grow, traits that once again trace back to successful breeding programs.

However, breeding of Canadian malting barley has not become stagnant since the first success of our varieties on the world market. New breeding objectives for quality have come from the domestic malting and brewing industries as well as from overseas customers of Canadian malting barley. Feedback from the farming community has indicated which aspects of agronomics and pathology need attention in breeding programs. The information has allowed breeders to develop varieties with improved agronomics and disease resistance for specific areas of Western Canada. Since Harrington’s first appearance, more than ten 2-rowed varieties have been registered. These varieties have better yields and disease resistance combined with malting quality equal to or better than Harrington. As well, a number of newer lines are presently in the final stages of testing and these all show specific improvements over Harrington. The new varieties should help maintain Canada’s position as a source of quality malting barley.

Quality of Present Day 2-Rowed Malting Varieties

Developing a 2-rowed malting barley with world class quality had been a dream for many barley workers in Western Canada. The first big break came with the development of Klages, a 2-rowed variety out of the USA. This variety did not have great agronomics or disease resistance for Western Canada but it did show improvement over earlier varieties. More importantly, it provided proof that top quality 2-rowed malting barley could be grown in Western Canada. It did not take long before a Canadian 2-rowed variety was developed from Klages. Harrington showed better agronomics and better quality than Klages. Extract levels in Harrington malt were higher than Klages and far superior to those seen in

Hannchen, the predominant 2-rowed variety prior to Klages (Table 1). Enzyme levels in Harrington were also superior to Klages and Hannchen.

In the 10 years subsequent to Harrington's release, an array of varieties have been released with quality similar, if not slightly better, than Harrington. These include Ellice, Manley, Stein, AC Oxbow and B1215. These varieties, as well as Harrington, all have the potential to produce world class malt. Their extract levels approach those seen in European and Australian malts despite the fact that protein levels are still at the high end of the acceptable range (Figure 1). The higher protein levels, though, add a quality edge to the Canadian varieties, higher enzymes levels and adequate levels of soluble protein (Figures 2 and 3) combined with acceptable levels of extract. These latter traits have been especially appreciated by adjunct brewers who require the higher enzyme levels and extra soluble protein.

Despite similar quality and the better agronomics and disease resistance of the newer varieties, Harrington has remained king. This variety malts easily and a good overall quality can be obtained under almost any conditions. Fifteen years of experience with Harrington has also left maltsters and brewers leery of moving on to newer varieties. However, Harrington is not without its quality concerns. The recent move to micro-filtration in breweries around the world has resulted in a need for reduced levels of ß-glucan in malts. Harrington, along with most of the other varieties from this generation, often require 4 to 5 days of germination to reach the modern specifications for malt ß-glucan. As a result, soluble protein levels are often too high for today's brewer. The maltster, therefore, is often faced with the dilemma of holding soluble protein levels down while dealing with high levels of ß-glucan.

Quality of Future 2-Rowed Malting Varieties

In the most recent generation of Canadian malting varieties, breeders have concentrated on the problems of ß-glucan and soluble protein as well as agronomics and disease resistance. The next harvest in Western Canada should produce commercial quantities of this next generation of varieties. They show much better yields in the field, due somewhat to better disease resistance, and quality superior to anything we have seen from Canada.

New varieties are coming out of the Agriculture and Agri-Foods Canada Research station in Brandon and from the Crop Development Centre at the University of Saskatchewan. The varieties include AC Metcalfe, CDC Stratus, CDC Lager as well as TR 139, TR 145, TR 243 and the American-bred Merit. Malting quality of these new varieties show further increases in levels of extract and enzymes while ß-glucan levels have been reduced (Table 2 and Figure 4). The improved agronomics and disease resistances of these new varieties should help to increase the area grown to barley and thus there is a potential for greater amounts of selectable barley in Western Canada. Selectable quality has been a limiting factor to further expansion of markets for Canadian malting barley. Therefore, Canada will not only continue to be a supplier of good quality malting barley but its market share will expand.

Quality of Present Day 6-Rowed Malting Varieties

Increased demand for Western Canadian 6-rowed malting barley in the USA was brought about by a major outbreak of Fusarium. Beginning in the 80's, the American Midwest, the heartland for American 6-rowed barley, was struck hard with Fusarium or scab, a disease that severely restricts the selectability of barley. Canadian 6-rowed barley filled the void but this was only possible because we had the varieties and quality demanded by the American malting and brewing industries.

Canadian 6-rowed malting barley had seen limited demand in the USA until the arrival of the American-bred variety, B1602. Prior to 1989 all 6-rowed barley grown in Western Canada had to have a blue aleurone if it was to be graded as malting barley. This trait was unacceptable to the Americans who preferred white aleuroned barley. B1602 was the first white aleuroned, 6-rowed barley that was registered as a malting barley for Western Canada. Several other American 6-rowed malting barley varieties were soon to follow. These included Robust, Excel, Stander and Foster. All of these varieties have quality similar (Figures 5 and 6) to Tankard, the last blue-aleuroned, 6-rowed malting barley to be fully registered in Canada. The American varieties, when grown in Canada, are somewhat plumper than the Canadian varieties, although the Canadian varieties still have equal levels of extract. Demand for American varieties grown in Canada has also been stimulated by their tendency to be plumper when grown in Canada.

Quality of Future 6-Rowed Malting Varieties

All of the 6-rowed, white aleuroned, malting barley varieties that presently have full registration in Canada, were bred in the USA for American growing conditions. However, there is now a sustained effort to develop varieties specifically for Canada. This will lead to varieties that are more economic to grow than the 6-rowed, white aleuroned varieties presently available. Improvements in malting quality are also likely. Breeding programs are in place at both the Agriculture and Agri-Foods Canada Research Station in Brandon and the Crop Development Center at the University of Saskatchewan. Varieties also continue to be introduced from American breeding programs.

CDC Sisler, a white-aleuroned, 6-rowed variety, is the Canadian-bred variety closest to commercial production. This variety is very similar to Tankard but with the white aleurone. Quality is somewhat better than the 6-rowed, white aleurones presently registered for malting in Canada. CDC Sisler shows higher levels of extract and DP and yet acceptable levels of soluble protein (Figures 5 and 6). The Canadian brewing industry has shown interest in CDC Sisler and production trials are continuing. There has also been some industrial testing of this variety in the USA.

The future holds promise for more 6-rowed Canadian varieties. Several promising lines are at the later stages of testing and their registration will further increase producers' options. Similar to the 2-rowed situation, these increased options will widen the area on the Prairies where selectable quality can be grown, resulting in more Canadian barley with acceptable quality.

Objectives for Future Varieties

Canada is well set for the near future, having a series of malting varieties with a range in quality. However, improvements in agronomics and disease resistance can always be sought and some quality concerns continue to linger. The development of the next generation of Canadian malting barley is underway. In terms of quality, peeling has been identified by the Brewing and Malting Barley Research Institute (BMBRI) as the most important problem to address. The problem of ß-glucan breakdown versus excess soluble protein must continue to be addressed. The amount of extract a variety's malt can produce in the brewhouse will always be a concern as that directly affects the bottom line of brewers. These characteristics are the top three concerns on the desirable traits list of the BMBRI (Table 3).

Quality objectives have also come from overseas users of Canadian malt and malting barley. For example, interest has been expressed for a more European-type barley from Canada. European-type barley is known for low protein levels and a malt with high extract and low enzyme levels. In contrast, Canadian barley has high protein levels which result in reduced extract and increased enzyme levels. Preliminary research suggests that some progress could be made in improving Canadian malting quality by breeding for a European-type barley. However, improvements would be limited because of the key role environment plays in determining barley quality. As well, breeding for a European-type barley is not a new direction for Canadian malting barley. The BMBRI's desirable list has always stressed low barley protein levels, high extract and constant enzyme levels, all European-type traits.

Overall, the breeding community is well-informed on what will further enhance the reputation of Canadian malting barley. In fact some lines with lower protein levels and better resistance to peeling are already being tested in the field. These are the varieties of the next generation of Canadian malting barley.

Recommended Varieties List

The number of registered malting barley varieties for Western Canada will further increase with all the new varieties coming through the system. Producers will have a long list of options from which to select a malting variety to grow. As well, decisions will be more complicated as newer varieties will have niche markets and specific areas on the prairies where they can best be grown. Communication on which varieties to grow in which locations will be essential.

The past 2 crop years have seen the establishment of a list of Recommended Malting Barley Varieties. The list was established by the Malting Barley Industry Group, a group of representatives from producer organizations, grain companies, malting companies the Canadian Wheat Board and the Canadian Grain Commission. The list of varieties is based on the group's sense for markets in the coming crop year.

The value of the recommended list will be even greater in the future as changes are made to the registration system. However, it will still be only one source of information available to producers. They should continue to seek advice from more traditional sources such as their provincial agriculture representative and their elevator manager. Other sources of information on varieties will also be available at producer meetings, in the farm press and in special bulletins form the Malting Barley Industry Group. Communications of this sort will be essential if Canada is to continue to be the proud suppliers of top quality malting barley to a thirsty world.

Table 1. Comparing the malting quality of Harrington with earlier 2-rowed varieties.

	Fine Extract (%)	Diastatic Power (° Lintner)
Hannchen	76.2	123
Klages	78.7	146
Harrington	79.4	161

Table 2. Comparing malting quality of Harrington with the coming generation of 2-rowed malting varieties.

	Fine Extract (%)	Diastatic Power (° Lintner)
Harrington	79.1	113
CDC Stratus	79.7	122
AC Oxbow	80.6	141
CDC Lager	80.9	153
AC Metcalfe	81.4	175

Table 3. Desirable traits in malting barley.

Characteristic	Priority
Hull Adherence	1
ß-Glucan / Soluble Protein	2
Carbohydrate Extract	3
Modification	4
Varietal Identification	5
10.0 - 12.5 % Barley Protein	6
Slight Dormancy	7
Low DMS	8
Long Term Germination	9
Hulless Barley for Malting	10

Source: Brewing and Malting Barley Research Institute

Figure 1. Comparing fine extract and barley protein levels in Canadian and some world class 2-rowed varieties.

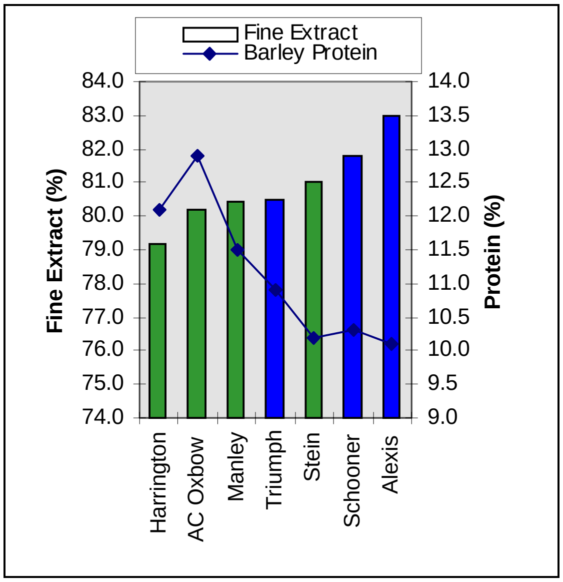


Figure 2. Comparing diastatic power and protein levels in Canadian and some world class 2-rowed varieties.

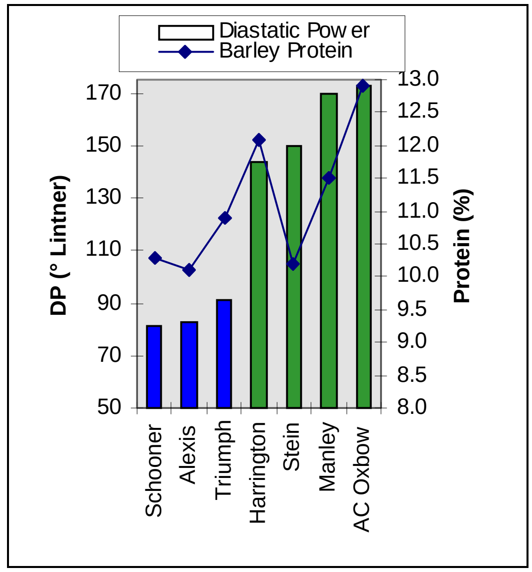


Figure 3. Comparing soluble protein and barley protein in Canadian and some world class 2-rowed varieties.

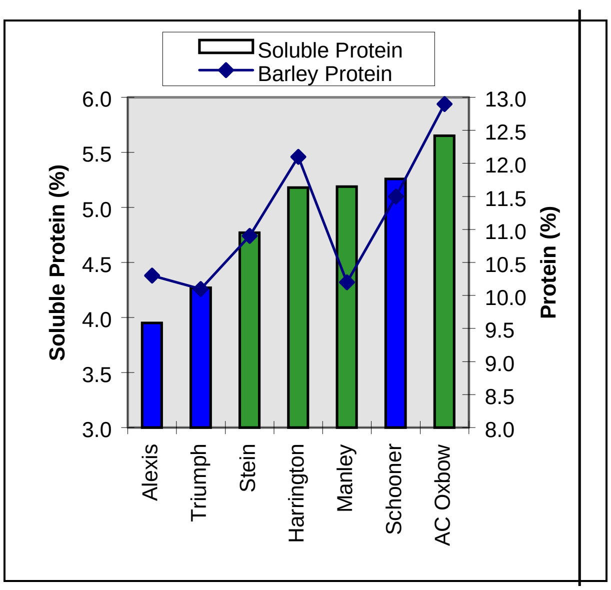


Figure 4. Soluble protein and ß-glucan levels in Harrington and newer 2-rowed varieties.

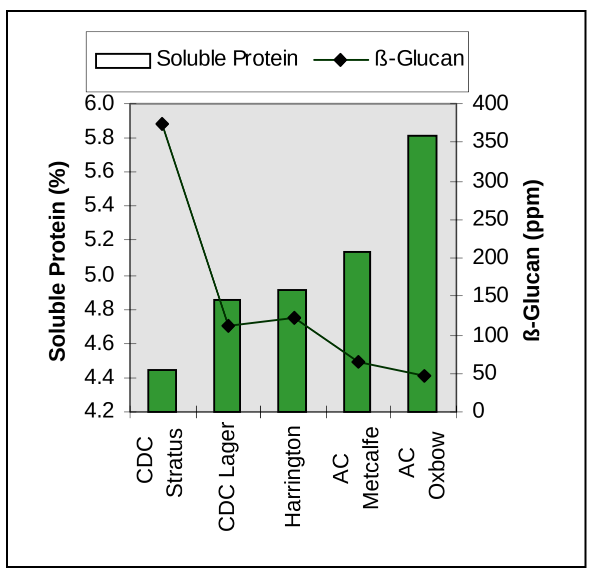


Figure 5. Comparison of extract and plumpness levels in Canadian and American 6-rowed varieties.

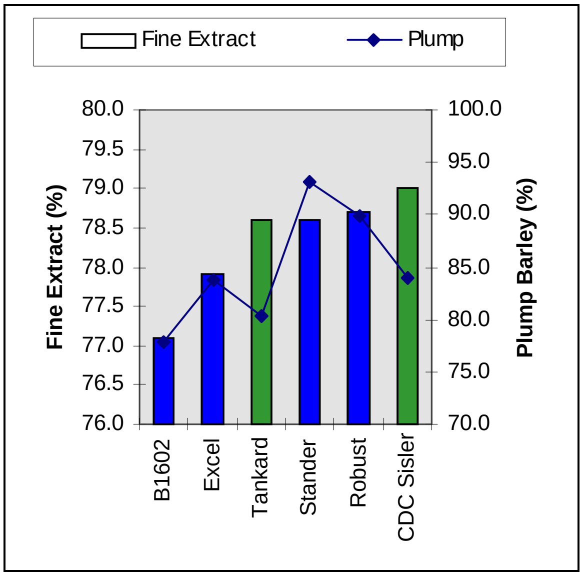
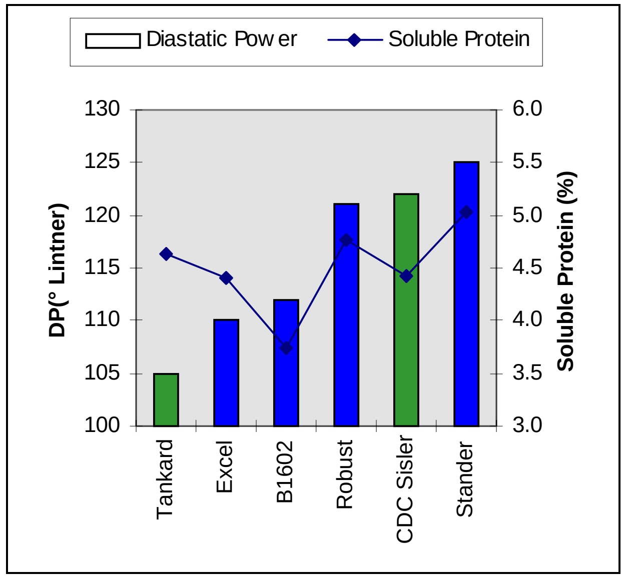


Figure 6. Comparison of soluble protein and diastatic power in Canadian and American 6-rowed varieties.



Marketing Genetically Enhanced Barley

Earl Geddes, Canadian Wheat Board
Winnipeg, Manitoba, Canada

Good afternoon.

Let me begin by congratulating the organizers and participants of this event for the quality of the information that has been prepared and delivered. It could be characterized by "everything you wanted to know about barley and then some." The topics on biotechnology certainly fall into this characterization, as I know many people feel a little overwhelmed by the technology and the issues that are raised.

I appreciate the opportunity to discuss some of the issues involved in the marketing of genetically enhanced barley. I will tackle this task by focusing on the two basic principles of the market, "supply and demand." In doing so, I will assume that farmers will create the supply based on the profitability of producing barley versus other crops for a customer who is always right.

We have heard a great deal about the use of biotechnology in the development of new and better barley varieties for the feeding and malting industries. This relatively new science has developed many new varieties of other crops and will generate new barley varieties sooner than some may expect. It is important that we understand the implications this will have for the market.

I would like to start with customer demand for genetically enhanced or "transgenic" barley. In marketing, the customer is always right and will dictate the acceptance/rejection and value of a new product. The Canadian and American customers' choices will have a significant effect on the marketing of transgenic barley.

The Customer

Farmers are the first customers of transgenic crops. Barley will be no different. With the increasing demand for more sustainable agricultural production systems, farmers will welcome new crops that reduce the use of chemicals, improve disease resistance and increase the net return per acre. Life Sciences companies are turning out new transgenic crops on a regular basis and finding farmers to be willing customers for the seed.

Livestock feed manufactures are looking for disease-free grains to carry the nutrients in their rations. With an increased focus on feeding in Western Canada and especially hog feeding, fusarium-resistant feed barley would find a ready market. Globally, the livestock feeding sector is using genetically enhanced corn, soybeans and canola meal in their rations.

Demand from the malting industry for clean, plump, disease-free barley is steady and growing. Increased extract and soluble protein would make transgenic malting barley very attractive. The maltster, however, must be sure that the customer (the beer industry) is a willing customer for malt produced from a transgenic barley.

The brewer wants consistent high quality malt that will make a clear and appealing beer. Malt made from fusarium-free malting barley would be appealing to the brewing industry. The beer industry may already be using as an adjunct corn grits that were produced from a transgenic corn plant.

The international livestock feeding industry is already using rations that contain transgenic soybeans and corn. It is not clear what the camels and goats in Saudi Arabia will think of transgenic feed barley but, if a seed that does not discolour because of weathering can be developed, it is a sure thing that Canadian feed barley will be easier to market.

As for consumers, especially in North America, we are just plain looking for the best steak and beer in town, confident that it is safe and nutritious.

What is at issue in today’s discussion is whether or not the end consumer, we beer drinkers and meat eaters, are prepared to accept as “safe” the food products that are derived from transgenic crops.

CWB Customer Survey

In order to understand the marketing challenges that transgenic barley will raise, the CWB is conducting a survey on a number of its international customers. As I said earlier, the customer is always right and their views will influence how transgenic malting barley is introduced into production in Western Canada.

Customer concerns are generally focused on issues relating to safety. Issues of allergic reactions, long term health effects and possible effects on bio-diversity are raised as factors that will determine the acceptance of these new crops. The customers for western Canadian barley are generally the domestic and international malt plants and livestock feed manufacturers who, in turn, have customers who will have to accept that processed products made from transgenic barley are safe.

The livestock feeding industry has said “okay” to genetically-enhanced crops with their acceptance of transgenic corn, soybeans and canola in the rations of livestock worldwide. One would expect that transgenic feed barley would be accepted as soon as there are varieties registered for production.

If the worldwide brewing industry chooses to use malt made from transgenic barley there will be very little market disruption. However, if the international brewing industry says no to transgenic barley malt, the malting industry will have no choice but to insist that the barley varieties they are buying from farmers for the purpose of malting will have to be non-transgenic. This will have significant logistical implications for marketing. If only the North American industry decides to avoid transgenic barley, the marketing implications are magnified greatly.

The current bulk handling system in Canada relies on some level of kernel visual distinguishability to separate one class of grain from another. With the advent of transgenic barley varieties that are indistinguishable one from another, it will be very difficult to provide assurances to customers that they are receiving transgenic or conventional barley through the bulk handling system.

The CWB and Canadian Grain Commission are leading an industry effort to raise funding for the Rapid Instrumental Objective Testing (RIOT) research project.

This critical project is designed to develop the rapid instrumental capacity to identify varieties of grain at the elevator driveway. This ability is necessary to make an identity preservation system work.

In order to provide quality service in a situation where not all customers will accept transgenic wheat and/or barley, the CWB is working with the grain handling industry to develop identity preservation (IP) systems. Well-developed IP systems assist in the segregation of genetically enhanced wheat and/or barley and conventional wheat and/or barley to meet customers needs.

Without technology to assist in the rapid identification of varieties, it becomes difficult to assure customers that visually similar varieties of malting barley are either transgenic or non-transgenic. The cost of providing both classes of malting barley will have to be born by the industry including, but not only, farmers.

Let's leave the customer here and assume that there will be some reluctance at least in some counties to accept beer made from transgenic malting and food barley.

The Supply

The other side of the market equation is supply.

Farmers are early adapters. Increasingly, farmers will adopt new technology as soon as it is proven safe and effective. Just look at how quickly the acreage of transgenic canola, corn, soybeans, potatoes and cotton have taken off in North America.

If barley follows other crops, it will offer farmers greater disease and insect resistance. As well, it will provide a greater range of in-crop weed control using less expensive chemicals. Experience so far has been that transgenic seed costs have risen significantly absorbing any saving that were realized in lower chemical costs.

With the introduction of genes that would increase the value of malting barley to the malting industry there is also the chance that farmers could expect to receive more for their production.

The key factor in a farmer's decision making when it comes to growing any particular crop is the return to his/her bottom line. The current shift to spring wheat, away from malting barley, in Alberta is a result of a greater return per acre for growing spring wheat. The risk of having malting barley accepted/rejected is too high for many farmers when the margins are as low as they are.

If genetically-altered feed barley provides a significantly greater yield and lowers production costs, the shift away from malting varieties will escalate. Similarly, if other biotechnology enhances the profitability of growing crops like wheat, canola, flax and peas, farmers will drop the production of malting barley.

The rate of introduction of transgenic crops other than malting barley will create some uncertainty of supply as well. The growth of the Canadian malting barley and malt industry has been based on three key factors: world demand, a high quality product and a secure supply of malting barley from which to draw. World demand is expected to continue to increase and Canadian breeders will develop varieties equal to or better than Harrington. The question is whether farmers will continue to grow malting barley if other transformed crops show less risk and higher profitability. Price premiums for non-transgenic malting barley may have to increase to attract growers to this crop.

The Competition

The final issue that must be considered from a market supply standpoint is what the competition is going to offer. Let’s assume that the brewing industries in China, Japan and Latin America are willing to use transgenic barley to make beer. As well, it is safe to assume, from earlier presentations today, that genetic enhancement of the malting and brewing characteristics of malting barley are possible and likely. If the Australians produce a variety before Canada we could see our market share in the consuming countries drop.

If the enhancement of the malt characteristics is significant we might even see the competitiveness of our malting industry challenged. Canada’s ability to maintain its current level of malt exports and malting barley exports would be at stake.

Let’s return to the customer. The key concern of the customer, whether it is a beer drinker or a feedlot steer, is knowing that what is going into the body is safe. The malting/brewing industry will need to be sure that there is not a negative reaction, in any of their markets, to beer that is made from transgenic barley.

The regulatory systems in North America, Japan and Europe should be able to provide this assurance. Consumers in North America and Japan have confidence in their regulatory systems. The same can not be said for consumers in Europe where more trust is placed in retailers than in regulators. In many cases, less developed countries do not have the capacity to regulate let alone monitor the issues that genetically enhanced crops may raise.

In a number of countries, labeling of food products containing genetically enhanced ingredients is becoming a mechanism to assure that consumers have a choice. The CWB agrees that the customer is always right and has a right to know what they are eating. The CWB is also supportive of sound scientific fact being the driving force behind regulation and labeling issues.

The CWB is involved in the product labeling issues along with trade concerns raised by the Bio-Safety Protocol. The CWB has and will continue to take an active part in the international trade discussions that relate to the trade of genetically enhanced crops.

Through communication with biotechnology companies, the CWB will also monitor the development of new varieties to ensure that varieties are not registered for agronomic characteristics alone. It is important that new varieties add value to the consumer. This is a critical point as farmers can only expect to achieve market success if the customer is receiving the quality and consistency that they expect.

Conclusions

In conclusion, let me bring back the key points that I see for the marketing of genetically enhanced barley.

The customer is always right and the CWB is developing a clear understanding of where each of its customers stands relative to the introduction of transgenic crops.

Farmers will adopt genetically-enhanced crops that provide them with a greater return for their labor and investment. This includes trasgenic feed and malting barley varieties.

If the North American beer industry chooses not to use transgenic malting barley it will be necessary to secure stocks of barley through variety specific contract programs.

If the global beer industry chooses not to use transgenic malting barley varieties it will be increasingly difficult to encourage farmers to grow traditionally bred varieties without a larger price spread between feed and malting varieties.

International trade and food labeling laws will need to reflect the realities of international trade. Just because an ingredient of a food product is derived from a transgenic crop should not be enough reason to block its entry into a market. There must be a scientific basis to regulations governing the trade of genetically enhanced barley.

The CWB will be actively involved in the marketing issues raised by transgenic barley making sure that the impacts on both farmers and customers are respected.

Methods for Assuring Varietal Purity in Barley

Randal W. Giroux, Canadian Grain Commission
Winnipeg, Manitoba, Canada

Introduction

Barley germplasm has been developed to produce a variety of end-use products. The two major markets for barley (malting and feed) each demand unique quality characteristics and, as such, barley varieties are developed, sold and marketed as either feed or malting barley. The ability of the grain industry to distinguish varieties or cultivars provides a valuable indicator of grain quality and end-use properties.

The need for varietal identification (VID) in malting barley has become increasingly significant in the last five years because of increased demands for varietal purity from the malting barley export market and domestic malthouses. Transforming barley into malt is a complex biochemical process and the art of the maltster is to produce a homogeneous product of consistent quality. Since each variety responds to the malting process in a unique way, the presence of multiple varieties in a barley shipment can have significant effects on uniform germination and the production of high quality malt and malt extract.

Currently, export and domestic customers demand in excess of 90% varietal purity. To support this specification, a number of methods have been developed to quantify the level of varietal purity present in a barley cargo. This survey of VID methods will show that in the rapidly evolving barley industry, some of the visual VID methods have been lost, a number laboratory approaches continue to support VID, and new DNA-based methods are being developed.

Visual Distinction and KVD

In the recent past, most barley varieties were identified visually by examining a specific set of kernel characteristics. With this specific set of qualifiers, most barley kernels could be placed into sequential sub-groups leading to varietal distinction. The first major distinction is between 2- and 6-row barley. Based on the 6-row barley architecture, varieties possess twisted lateral kernels in 2/3 of the seeds. While this characteristic is useful to distinguish a pure line, during cargo inspection 1/3 of the 6-row kernels are straight and could be indistinguishable from the 2-row barley kernels.

To keep the feed and malting varieties separate in the grain handling system, mandatory visual characteristics (Kernel Visual Distinguishability or KVD) has been required to register barley varieties in Canada. These characteristics were valuable indicators for segregating barley varieties. In 2-row barley, long rachilla hair was used to distinguish malting varieties from short-haired feed varieties. As of this year, rachilla hair is no longer required for registration and this useful indicator has been lost. For 6-row barley, blue aluerone has provided a fast and useful tag to distinguish malting varieties from feed. This distinguishing characteristic was abandoned with the registration of “B1602” (a 6-row American variety) in Canada. As such, blue aluerone can no longer be used to distinguish malting from feed. Loss of these valuable visual qualifiers has made varietal identification more difficult and complex.

In addition to rachilla hair and aleurone colour, a specific set of characteristics are used to classify individual varieties. Grading these characteristics can be quite difficult and requires considerable practice and skill because these characteristics are present in a continuum and some are affected significantly by the environment. As such, it can be quite difficult for grain inspectors to objectively and accurately determine varietal composition of barley shipments. Laboratory test methods have been developed to support the VID inspection requirement.

Methods for Varietal Identification

VID methods which are applicable to the operational environment of the grain handling industry must be fast, simple and robust seed-based tests. While many laboratory tests have been developed for distinguishing varieties, some of these tests do not meet the basic requirements of the operational environment. Useful VID tests should include: 1. high degree of discriminatory power; 2. ability to perform rapid analyses; 3. ability to accurately quantify varietal composition of a seed lot; and 4. provide clear discrimination of results.

1. Discriminatory Power

VID testing methods must have a level of variability which allows each individual variety to be clearly discriminated from one another. This variability must be managed against methods which provide excessive amounts of information making a particular test unmanageable or too cumbersome.

2. Rapid Aanalysis

It is imperative that VID testing be rapid and simple. While laboratory-based methods may be suitable for assessing variety in a some instances, VID in the grain handling industry demands a rapid assessment of variety within minutes to hours. This significant time constraint dictates the use of seed-based methods to discriminate variety.

3. Ability to Distinguish Varietal Composition

A major focus of VID is to support the delivery of variety-specific grain shipments to barley end users. For the malting barley industry, varietal purity is a prerequisite for cargo acceptance and, as such, methods to quickly determine the varietal composition of the cargo are required. Currently, the degree of varietal purity is determined by identifying the variety of individual kernels in a sub-sample. To confirm delivery of 95% varietal purity, a minimum of 100 kernels must be examined to provide a statistical significance result (Wrigley and Baxter, 1974). For limits over 95%, the number of kernels required quickly jumps to a minimum of 500 individual varietal identifications and this becomes prohibitive for most single kernel methods. Since a larger sub-sample provides a more accurate estimate of cargo composition and allows varietal purity measurement above 95%, a single discriminatory test which can analyze a ground sample is preferred by the grain handling industry. This single sample test must be quantitative and accurate. This type of test is not currently available to the grain handling industry.

4. Clear Discriminatory Results

Any testing method which requires subjective interpretation is undesirable. Tests which provide an objective assessment of variety composition are essential to consistently and accurately distinguish variety. For example, KVD for varietal identification requires the subjective assessment of a number of visual qualifiers, and assessment of cargo compositions can vary widely between grain inspectors. The future development of rapid tests with clear discriminators will increase the consistency and objectiveness of assessing cargo composition.

Protein Fingerprinting

Protein fingerprinting represents a traditional laboratory technique for determining grain varietal identification. There is no doubt that gel electrophoresis of the alcohol-soluble hordeins from seed represent the most widely used and successful method for identifying barley varieties. More than sixteen published techniques are reported for the separation of the barley hordeins, of which most are variants of acid polyacrylamide gel electrophoresis (A-PAGE) and sodium dodecylsulfate (SDS)- PAGE (Cooke, R.J., 1995).

Protein fingerprints have been developed at the GRL for all registered Canadian varieties. This project has been successful in distinguishing a majority of the 2-row malting varieties and a limited number of 6-row varieties. The 6-row barley varieties have been particularly difficult to distinguish because of the narrow breeding focus of some of these programs. Protein fingerprinting using electrophoresis does not show the discriminatory power required to differentiate a majority of the interim varieties which are seeking registration in Canada. To augment electrophoresis, high performance liquid chromatography (HPLC) has been utilized by the GRL to increase the discriminatory power required for analyzing protein fingerprints in barley.

Reversed-phase (RP-HPLC) methods provide excellent separation of barley hordeins and provide opportunities for detailed computer analysis of the protein fractions. Since RP-HPLC separates protein based on hydrophobicity instead of size, this technique offers alternative protein properties for separating varieties. RP-HPLC has proved to be an excellent technique to augment electrophoresis at the GRL. In some cases, it has been able to distinguish varietal differences which are not apparent using SDS PAGE. More significantly, RP-HPLC permits analysis of a single ground sample and subsequent measurement of varietal-specific peak areas. This single sample test allows an estimate of varietal purity and can distinguish the presence of contaminating varieties. Unfortunately, this test is limited in the number of varieties it can clearly distinguish.

Digital Imaging

Identification of barley variety by appearance is highly subjective and requires considerable training and experience. The use of digital image analysis offers a objective and quantitative alternative to visual grading and has the ability to be both accurate and consistent. While the use of digital imaging for wheat class discrimination and quality evaluation shows strong potential, the potential of digital imaging for varietal identification in barley remains unclear. The most significant factor that limits imaging is the large variability in seed characteristics within a pure line and the significant effects of environment on some of these seed characteristics. Efforts to develop barley seed recognition using two malting varieties (TR118 and Harrington) and a feed variety (CDC Guardian) showed limited success. Digital imaging was able to distinguish malting (TR118) from feed at a 15% error rate and at this level of discrimination was not able to distinguish Harrington (Romaniuk et al., 1993). At the present time, varietal identification of barley using digital imaging does not demonstrate the level of accuracy required by the grain handling system.

DNA-Based Methods

DNA-based varietal ID has strong potential to provide testing methods which meet all of the basic criteria required by the grain handling system. DNA-based tests are immune to the confounding effects of environment, the large genome of cereals provide an unprecedented wealth of polymorphisms to discriminate varieties, the methods provide clear results which are easily scored, and new technologies are rapidly reducing the time required to complete the test. Two major approaches for DNA-based varietal identification have the potential to meet the industries needs for a fast, simple and robust seed test.

1. Genotyping with Amplified DNA Polymorphisms

Each barley variety represents a unique genomic combination of DNA sequences. Genotyping with amplified DNA polymorphisms exploits each varieties unique combination of sequences and characterizes, by size, a series of genomic fragments which distinguish one variety from another. In general, these approaches involve PCR amplification and subsequent analysis of random or specific genomic regions to show differences in the banding patterns which exist between varieties.

RAPDs: Randomly Amplified Polymorphic DNAs are now a commonly used tool for the molecular analysis of genomes. This PCR test is based on the use of a single oligonucleotide primer of arbitrary sequence that will amplify genomic DNA sequences whenever they find regions of homology at a favorable distance and in converging orientation on the two DNA strands. This technique is well suited for rapid genomic analysis and has been successfully used in barley to distinguishing barley inbred lines (Tinker et al., 1993) and some 6-row varieties (Hoffman and Bregitzer, 1996). To maintain a high degree of reproducibility, RAPDs require highly accurate and standardized testing procedures and reaction conditions. Since many variables can affect the RAPD banding patterns, reported difficulties in maintaining reproducibility restrict this technique's applicability for rapid routine screening.

AFLPs: The amplified fragment length polymorphisms (AFLP) protocol is based on the selective amplification of genomic restriction fragments produced by a double digestion with rare and frequent cutter restriction enzymes onto which known sequence adapters are ligated. This method produces a large amount of information content and to date, AFLP is the superior method for providing genomic information which distinguishes one variety from another (Powell et al., 1997). Unfortunately, AFLPs are not suitable for routine barley identification because this procedure requires the isolation of highly pure genomic DNA and the protocol requires a minimum of two days to complete. It does not meet the criteria for being rapid and simple.

Microsatellites: Microsatellites or simple sequence repeats (SSRs), are tandemly arranged repeats of two to six nucleotides (e.g. ATC**ATC**ATC) located within conserved flanking sequences. The number of repeat units can be variable between varieties and this variation in length can be identified by amplifying the repeat region using PCR with primers that correspond to the conserved regions flanking the repeat. Microsatellite markers are currently used extensively in human genetic diagnostics and are rapidly becoming the desired marker technology for virtually all species because of their simplicity, low cost of analysis, and their ability to detect genetic differences among closely related individuals. In addition, large numbers of microsatellite regions are dispersed throughout the genome and inherited in a codominant Mendelian fashion making them ideal for genome mapping. Because of this ideal nature as molecular markers, a large number of microsatellite loci have been identified in barley (Sanghai Maroof et al., 1994; Robbie Waugh, Scottish Crops Research Institute; Henrietta Giese, RISO) offering a large and continually growing supply of potential markers for varietal identification. Microsatellites have been useful for distinguishing closely-related malting barley varieties (Williams et al., 1997). Analysis of the major 2-row and 6-row Canadian varieties has shown that most varieties can be distinguished with three to four microsatellite loci (R.W. Giroux, unpublished results). To exploit this technology, a microsatellite fingerprint database of all registered barley varieties is being developed at the GRL to distinguish the full range of registered germplasm. Microsatellite genotyping is rapid and discriminatory but is limited to genotyping single seeds in the analysis of cargo composition.

2. Sequence-Based Varietal Identification

Application of sequence-specific varietal identification involves discriminating varieties based on differences in DNA sequence that exist between individual varieties. One potential method is to characterize the sequence polymorphisms that differentiate varieties from one another in a specific DNA fragment. An alternative to routine sequence analysis is the use of sequence-specific hybridization probes which either: hybridize to each varieties DNA in unique combinations; or amplify a specific set of PCR fragments based on the sequence differences which exist between varieties. The sequence-specific hybridization methods have strong potential to be used on ground samples and provide a test which is highly discriminatory and rapid.

Sequence Polymorphisms: The most direct strategy for distinguishing sequence differences between registered varieties is to sequence a defined region of the genome and align the orthogolous regions from each of the varieties. This type of analysis is a highly reproducible and informative method which can be adapted to different levels of discriminatory potential by choosing appropriate regions of the genome. Sequence polymorphisms are mainly used for medium and long distance relatedness studies but need not be restricted to this type of analysis. Application of the sequencing process has been greatly facilitated by the advent of PCR-based cycle sequencing and the use of automated DNA sequencers. These technologies allow the routine sequencing of large numbers of samples and long stretches of DNA. The potential of direct sequencing in barley identification is illustrated in the work of Chee et. al. (1993) where differences in genomic sequence were used to differentiate barley varieties. In these experiments, differences in sequence were detected by restriction enzyme analysis in ten genomic regions. This work suggests that full length sequencing of specific regions would be a useful tool for varietal identification and could offer increased resolving power for separating varieties. Finding useful genomic regions which have a manageable level of variability within and amongst varieties may prove to be a daunting challenge for this approach.

Sequence-specific Hybridization: The use of sequence-specific oligonucleotides to detect varietal composition offers greatest potential for being a simple and rapid seed-based test. The use of oligonucleotides for hybridization fall into three major categories: i. use as PCR primers for amplifying variety-specific fragments; ii. use as fluorogenic probes to detect specific sequences; and iii. use as capture molecules to anchor specific fragments in a solid-phase detection.

i. Sequence-specific amplicons (SSAs): This technique involves the use of sequence-specific PCR primers which amplify a specific fragment of DNA in single variety or subset of varieties. This method demands a plus/minus PCR result for each primer set if it is to be rapidly screened by either fluorometry or colorometric methods. In this test, the presence or absence of amplified DNA for a specific combination of primer sets is used to distinguish variety. The use of SSA is highly reproducible and discriminatory since longer primers (20-mers) are used. This technique has been employed successfully in barley to distinguish disease susceptibility (Mohler and Jahoor, 1996; Penner and Legge, 1995). Preliminary application of this technique to barley identification (Baum et al., 1998; Penner, G.A., personal communication) show this technique has potential. The requirement to run multiple agarose gels and characterize fragment size, limits these preliminary approaches to a slow single seed analysis. The future development of strict plus/minus primer sets should permit quantitative analyses of ground samples by fluorometry or colorometric analysis. This would be a rapid and simple seed-based test.

ii. *Fluorgenic probes*: Fluorogenic probes are based on the fact that one fluorescence molecule can be either excited or quenched when it is located in close proximity to another molecule. Hybridization of a oligonucleotide primer(s) to sequences found in specific PCR product either bring the two molecules together or separate them spatially (Figure 1).

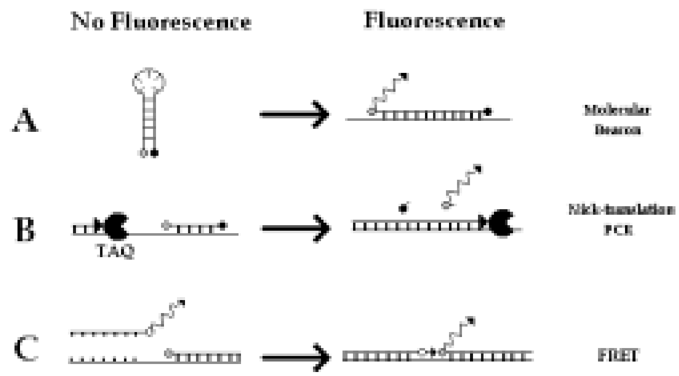


Figure 1: Fluorogenic probe strategies for detecting sequence-specific differences between varieties. Grey circles (◎) indicate a fluorogenic molecule; black circles (●) indicate a quenching molecule; and white circles (○) indicate a second "donor" fluorescent molecule.

One approach is to place a fluorescent molecule in close proximity to a quenching molecule (no fluorescence) (Figure 1. A,B). During PCR, hybridization of the dual-labeled oligonucleotide to the developing PCR strand results in either: A. separation of the fluorescent molecule from the quenching molecule; or B. cleavage of the oligonucleotide by exonuclease activity of the TAQ enzyme (Figure 1). Both methods liberate the molecules fluorescence and this fluorescence can be measured in real-time (Woo et al., 1998).

With fluorescence resonant energy transfer (FRET), two short oligonucleotide probes are brought in close proximity by hybridization to specific sequences (De Silva, et al., 1998) (Figure 1. C) Each probe has an attached fluorescence molecule and when one is excited it “donates” its fluorescent energy to the other molecule which fluoresces at a different wavelength. This fluorescence can be measured in real time.

For all of the fluorogenic probe methods, by quantifying the fluorescence of the excited molecules against a control using real-time PCR, quantitative estimates of varietal composition should be possible. Real-time PCR monitors the amplification of DNA during each PCR cycle. This type of analysis allows for the detection of the “log-linear” portion of the PCR reaction. The “log-linear” phase appears at higher cycle numbers as the amount of template decreases and differences between the unknown variety DNA and control DNA concentrations can be quantified by this method. This approach shows strong potential for a quick seed-based test.

iii. *Solid-phase capture*: This technique represents the reverse technology to traditional membrane hybridization or blotting. Traditionally, genomic fragments are immobilized to a membrane and specific oligonucleotide sequences (probes) are washed across the membrane to see what genomic regions hybridize with the probe. In solid phase capture, it is the oligonucleotides which are immobilized to the substrate (solid phase) and specific genomic fragments (PCR products) are “captured” by the oligonucleotide sequence. By attaching a specific set of oligonucleotide sequences to the substrate, in a single hybridization reaction an entire series of sequences can be analyzed at once. Usually the hybridizing fragments are labeled with a fluorescent tag and the location and intensity of fluorescence is measured for each oligonucleotide attachment site. This “DNA-chip” technology is now available and is being applied in large arrays to monitor differential gene expression (Schena et al., 1995) and for genetic analysis (Saiki et al., 1989). With the development of variety-specific oligonucleotides, this technology has the potential to support the detection of variety-specific amplicons and/or direct sequence analysis. This technique has strong potential for a quantitative rapid seed-based test.

References

Baum, B.R., Mcchanda, S., Penner, G.A., and Ednie, A.B. 1998. Establishment of a scheme for the identification of Canadian barley (Hordeum vulgare L.) six-row cultivars using RAPD diagnostics bands. Seed Sci. Technol. (in press)

Chee, P.W., Pederson, L., Matejowski, A., Kanazin, V., and Blake T. 1993. Development of polymerase chain reaction for barley genome analysis. Am. Soc. Brew. Chem. 51(3): 93-96.

Cooke, R.J. 1995. Identification of Barley Varieties. *In:* Identification of Food-Grain Varieties, *Ed.* C.W. Wrigley, American Association of Cereal Chemists. St Paul, USA. pg 224-227.

De Silva, D., Rieser, A., Herrmann, M., Tabiti, K., Wittwer, C. 1998. Rapid genotyping and quantification on the Lightcycler™ with hybridization probes. Biochemica 2: 12-15

Giese, H. 1998. RISO, Denmark. http://www.risoe.dk/pbk/pls/projects/symbioses.html

Hoffman, D.L. and Bregitzer, P. 1996. Identification of reproducible PCR-RAPD markers that enable the differentiation of closely related six-row malting barley (Hordeum vulgare L.) cultivars. J. Am. Soc. Brew. Chem. 54(3): 172-176.

Mohler, V. and Jahoor, A. 1996. Allele-specific amplification of polymorphic sites for the detection of powdery mildew resistance loci in cereals. Theor. Appl. Genet. 93: 1078-1082.

Penner, G.A., Stebbing, J-A., and Legge, B. 1995. Conversion of a RFLP marker for the barley stem rust resistance gene Rpg1 to a specific PCR-ampifiable polymorphism. Mol. Breeding 1: 349-354.

Powell, W., Thomas, W.T.B., Baird, E., Lawrence, P., Booth, A., Harrower, B., McNicol, J.W., and Waugh, R. 1997. Analysis of quantitative traits in barley by the use of Amplified Fragment Length Polymorphisms. Heredity 79: 48-59.

Romaniuk, M., Sokhansanj, S., and Wood, H.C. 1993. Barley seed recognition using a multi-layer neural network. Presenttion at winter meeting of the American Society of Agricultural Engineers, Chicago, Dec.14-17.

Saiki, R.K., Walsh, P.S., Levenson, C.H., Erlich, H.A. 1989. Genetic analysis of amplified sequence-specific oligonucleotide probes. Proc. Natl. Acad. Sci. 86: 6230-6234.

Sanghai-Maroof, M.A., Biyashev, R.M., Yang, G.P., Zhang, Q., and Allard, R.W. 1994. Extraordinary polymorphic microsatellite DNA in barley. Species diversity, chromasomal locations and population dynamics. Proc. Natl. Acad. Sci. 91:5466-5470.

Schena, M., Shalon, D., Davis, R.W., Brown, P.O. 1995. Quantitative monitoring of gene expression patterns with a compementary DNA microarray. Science 270: 467-470.

Tinker, N.A., Fortin, M.G., and Mather, D.E. 1993. Random amplified polymorphic DNA and pedigree relationships in spring barley. Theor. Appl. Genet. 85:976-984.

Waugh, R. 1998. Scottish Crops Research Institute http://www.scri.sari.ac.uk/pmb/plantmol.html

William, M., Dorocicz, I., and Kasha, K.J. 1997. Use of microsatellite DNA to distinguish malting and non-malting barley cultivars. J. Am. Brew. Chem. 55(3): 107-111.

Woo, T.H.S., Patel, B.K.C., Smythe, L.D., Norris, M.A., Symonds, M.L., and Dhont, M.F. 1998. Identification of pathogenic Leptospira by TaqMan Probe in a Lightcycler. Anal. Biochem. 256: 132-134.

Wrigley, C.W. , and Baxter, R.I. 1974. Identification of Austrailian wheat cultivars by laboratory procedures. Grain samples containing a mixture of cultivars. Aust. J. Agric. Anim. Husb. 14: 805-810.

Strengths and Weaknesses of the Current Handling/Transportation System

Pat Rowan, ConAgra Grain
Winnipeg, Manitoba, Canada

Thank you for asking me to join you today to address the issues in the grain handling and transportation sector. I think the trends we need to cover today are bigger, faster, and more cost efficient. There are steps Canada is already taking to meet these challenges, but the job is not yet done. Market pressures are furthering the need for change, causing the system to evolve rapidly – and that's not about to stop.

Specifically, we'll be assessing the consequences on transportation and handling where the barley market is concerned. It is important to remember that barley holds a time-honoured place in the Canadian grain economy. Statistics Canada estimates the 1997 harvest tipped the scales at 12.6 million tonnes, 14% less than 1996 but more than enough to hold the position as the number two crop grown in Canada.

Alberta and Saskatchewan are the leaders in Canada's barley production (see Figure 1). Production estimates were slightly lower for 1998 than in 1997.

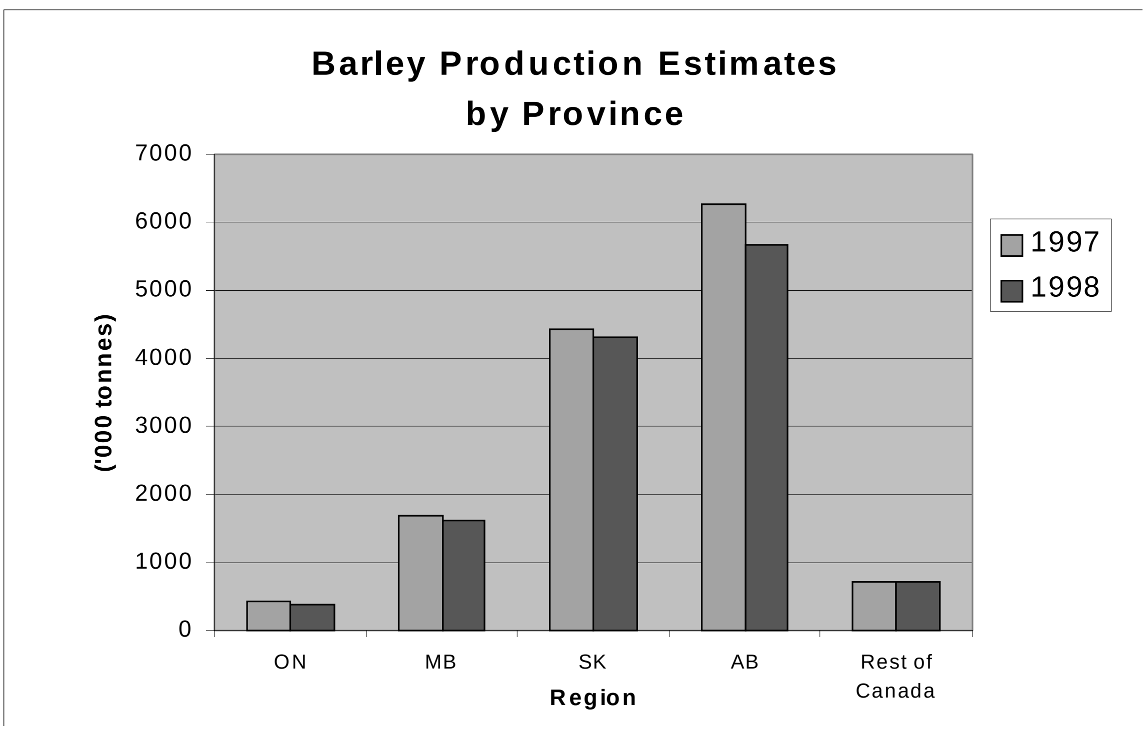


Figure 1. Barley Production Estimates by Province.

Freight costs to get barley to export locations make domestic barley trade more attractive and create highly competitive prices for prairie feed users. Feed has traditionally been the largest market for Canadian barley.

But what Canadian wouldn't take pride in the other famous use for our barley? Beer. Malt barley must meet strict quality standards and is a higher value commodity than feed barley. It also represents a large proportion of our exports. In the 1997/98 export year, 70% of the barley exported was either malt or malt barley.

Other uses for the crop are also being examined which may see it used for more human consumption purposes. Preliminary testing shows barley can be made into pasta and the beta-glucans found in this grain make a good additive for beverages.

Although there is a large domestic consumption of barley, 20% of total production is exported. Due to the relatively low prices for barley, freight costs to get the crop to export locations are problematic. This furthers the need for a more cost-effective approach to grain handling and transportation on the Prairies.

So, let's examine the state of the transportation and handling system in Canada. Today, six major domestic companies make up the majority of the grain trade in Canada (see Figure 2). Agricore (the combination of Alberta Pool and Manitoba Pool) has almost 27% of the market, about the same as Saskatchewan Wheat Pool. United Grain Growers has almost a 17% market share. Pioneer, owned by James Richardson and Sons, has a 12% share, and Cargill has over 7%. All others comprise 9% of the market.

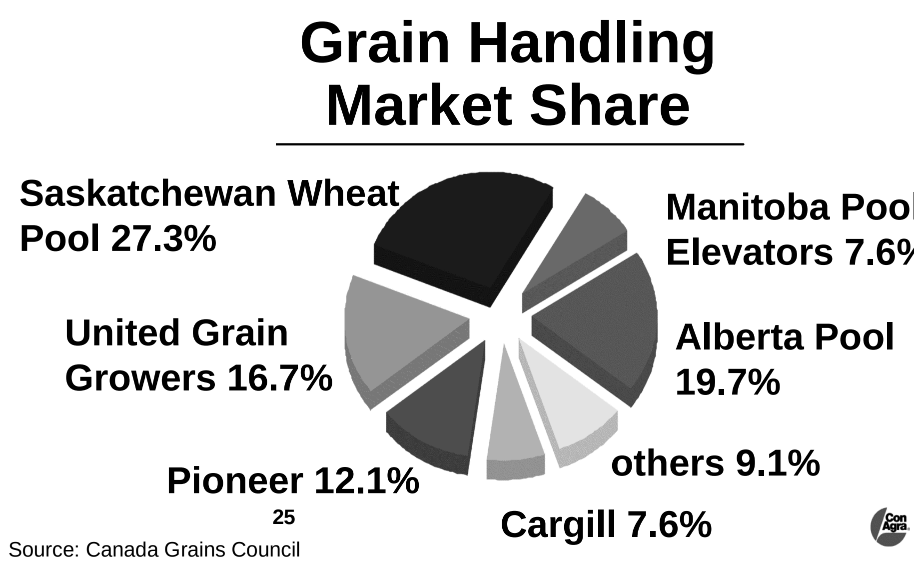


Figure 2. Grain Handling Market Share.

Most of the existing players in Canadian grain handling are not linked to value-added processing. The companies are beginning to make adjustments for their new environments, however. In the past few years, two major co-operatives, Saskatchewan Wheat Pool and United Grain Growers, have made public stock offerings to raise capital. As well, Manitoba and Alberta Pool attempted a hostile takeover of United Grain Growers, but they did it without the assistance of their long-time partner Saskatchewan Wheat Pool. Canadian grain handlers have recognized that they will need huge influxes of cash to operate in a more competitive environment, and need to rebuild the necessary infrastructure to ship efficiently.

Canadian grain handling companies have an extraordinary number of facilities, most of which are completely out-of-date. With over 1,000 wooden elevators in operation (see Figure 3), there must be a massive reconstruction of infrastructure to bring their handling capacity up to today's standards – never mind tomorrow's.

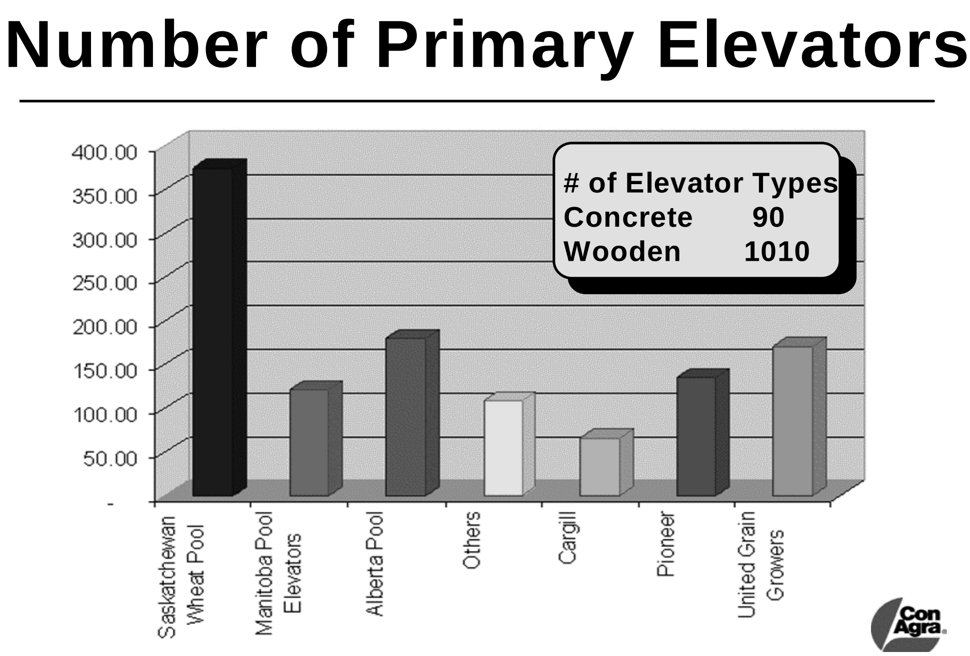


Figure 3. Number of Primary Elevators.

Grain handlers are now operating in a new competitive environment. Until recently, the small provincial and regional companies were almost the only grain buyers and handlers operating on the Prairies.

Now, Western Canada real estate has altered significantly in the past five years, with the advent of state-of-the-art high-throughput terminals, each capable of handling in excess of 10 million bushels. New construction persists, and numerous announcements for future construction will radically change grain handling on the Prairies.

To me, there cannot be a clearer indication of the potential of the Canadian market than to see so many new players become involved. And it is noteworthy that they are the leaders in the agri-food sector – companies with the global resources, networks, and knowledge to effect a real change.

Proof of the benefit of these changes is the increased efficiency that is being developed. The average elevator in Saskatchewan now handles 35% more barley per unit of capacity than 1990. Alberta facilities average 25% more; Manitoba, one-half less.

The construction of the new, large-scale grain handling facilities we are talking about is underway all over the Prairies. It is being done to better meet farmers’ needs for bigger, faster, more cost-efficient facilities. In fact, 49 concrete or steel facilities are slated for construction.

Certainly, some are expressing concerns about the extent of this new construction and whether the system will again be overbuilt. It is always fair to ask these questions and companies will certainly have to examine their decisions carefully. However, there is no question that modern facilities are essential to meet the needs of a new approach to grain handling. That means maximizing shipping efficiencies and handing multiple grains and grades.

It should be noted that the railroads, to no small extent, encourage this type of investment, by offering lucrative rate incentives at the high-throughput terminals.

One of the issues is that the rationalization of the old system is still not complete. Thousands of small wooden, crib elevators were littered throughout the countryside, built every few miles along the rail line to serve the needs of farmers delivering by horse and cart. Rapid attrition has already begun and they now number about a quarter of what they did even a decade ago. However, that process is by no means complete. Even today you can see the large number of facilities with 25 car sidings that remain in operation.

Massive numbers of small inefficient wooden crib elevators across the Prairies will have to be closed.

A factor in these changes is not only the need to have better infrastructure to serve farmers, but also increased cost pressure on the transportation system. This has been highlighted by the end of the Crow Rate subsidy.

Until 1994, the Canadian government had been providing massive support to subsidize the cost of transporting grains and oilseeds in Western Canada. A declaration of an end to this subsidy marked a historic turning point for Canadian agriculture. A $1.6 billion payment was made to farmers to replace the ongoing support the government offered to keep rail rates low by making payments to the railways for each tonne moved. For the next five years, until 1999, rates will continue to be capped, and then the system will move to a freer market. Already the effect of the change is being felt though, as rates to some off-shore markets have more than doubled.

The demise of this transportation support program was a big step towards a new vision of Canadian agriculture, which has helped farmers focus less on the export of bulk commodities and more on higher value crops and meeting the needs of specific markets.

It would probably be fair to observe that this has been a reason for the decline of barley production.

The changes to the operating environment have helped highlight the changes needed to the physical infrastructure system. Western Canada must deal with an extensive rail line network (see Figure 4) which requires rationalization. A number of light steel branch lines still exist, which are not capable of handling jumbo hoppers. On the other hand, most major production areas are served by both major Canadian rail lines, providing competitive markets.

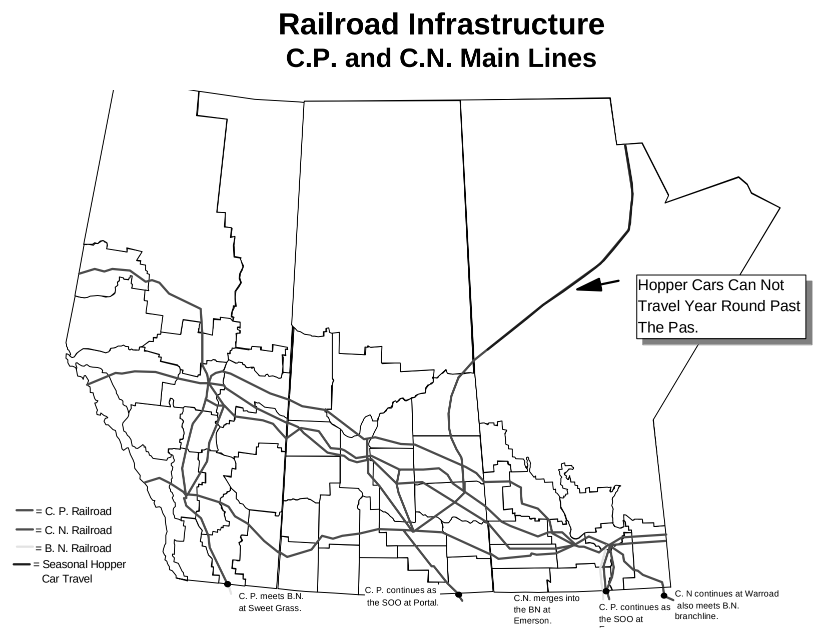


Figure 4. Railroad Infrastructure.

As we are adjusting the handling system to meet the needs of the modern agri-food network, the railways are also making their own changes. Unlike the U.S., where there are many players in the market, Canada has only two major railways – Canadian National and Canadian Pacific. Recently, Canadian National acquired Illinois Central in the U.S. The result is a railway which has a presence not only in Canada and the U.S., but also in Mexico. The railways clearly understand globalization of trade and are positioning themselves for changes in the marketplace.

Further changes are also likely to occur. Recently, a review of the operating system was conducted due to considerable pressures on the system. You might call it a Crow hangover!

The central question posed in the grain handling and transportation review was: what can be done to the administrative and commercial regulation of the grain industry in order to strengthen and enhance the position of Canada in the global grain market? Willard Estey’s report calls for increased accountability by ending Canadian Wheat Board regulatory powers over grain transportation, establishment of commercial contacts between shippers and railways, repeal of the freight weight cap in exchange for reduced freight rates, and opening of the rail system to competition. The increased accountability is predicted to create a more accountable system to avoid transportation disasters.

It is unclear, yet, whether the recommendations will be implemented, but it is clear that the transportation system will continue to be under pressure to adapt.

The move away from government subsidies to a more market responsive environment; the move away from an antiquated handling and transportation infrastructure to a modern, integrated system; and the move away from a simple commodity mentality to an interest in serving specific markets and specialty products are evidence. All indicate an interest in listening to market needs.

And as a major purchaser of grains and oilseeds, I can tell you ConAgra (see Figure 5) believes these market needs are shifting. The world is demanding more and better food. Markets must be allowed to operate in an open, competitive, and economically viable manner. This allows for clear signals to producers to grow the right crops profitably.

Figure 5. ConAgra Grain, Canada.

Recently, we have also begun to create a handling network in Canada. Our state-of-the-art grain-handling terminals in Nokomis, Corinne, and Yorkton, Saskatchewan, and now in Westman, Manitoba, enable ConAgra to provide direct access to our large value-added processing capacity (see Figure 6).

Each terminal is a high-capacity, high-volume facility. Each offers high-speed unloading, weighing facilities, cleaning capabilities, and the ability to efficiently load 100-car unit trains. This maximizes the efficiency of shipping grain, optimizes rail resources, and encourages efficient handling at the ports.

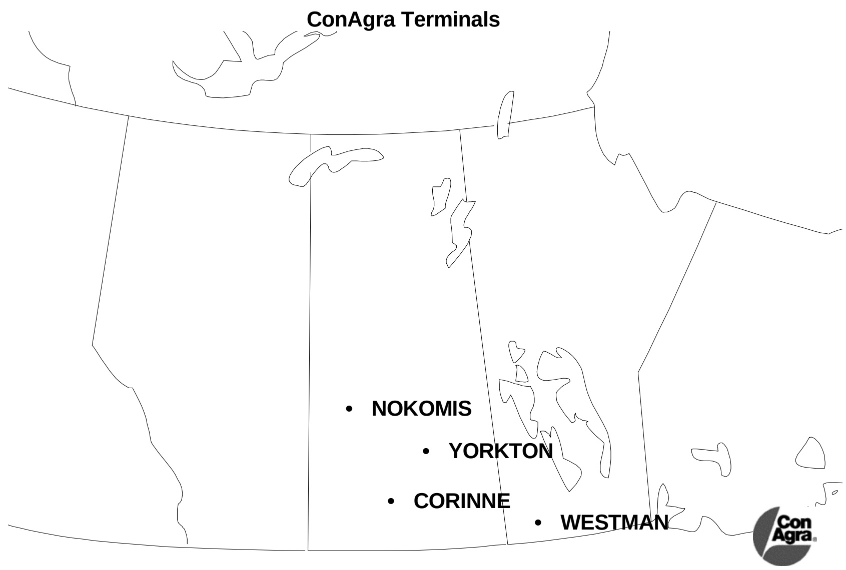


Figure 6. ConAgra Terminals.

The terminals are full-service facilities that can ship unit trains to ensure increased efficiency. The grain can also be dried, cleaned, graded, and be subject to many segregations. This approach ensures the handling system is meeting the needs of the end use customers.

In total, we believe these terminals represent the future of the handling system in Canada. These kind of large-scale facilities are precisely what's needed.

But in addition to the right kind of facilities, ConAgra adds another element to the mix. Value-added processing is perhaps ConAgra's biggest benefit to Canadian farmers. Working with ConAgra creates a link to the vast network of processing within ConAgra's food companies. The diversified nature of ConAgra's holdings offers significant value. Our company's oat mills, flour mills, malt plants, and food processing facilities create a large demand for grain.

Tying in to the processing sector means improved value to farmers.

There is a concrete example of this benefit. A new innovation in handling malt barley has been "Street Malt," a program that ensures gowers are paid for malt quality at the point of delivery rather than waiting until shipments are received by the processor. Therefore, growers see returns immediately.

In addition, shippers can now co-mingle malt deliveries, which makes it possible to ship unit multi-car trains.

Both small acreage farmers and high volume producers can take advantage of the benefits the system has to offer. This has eliminated the old system of consigned cars, delayed settlements, and delivery of carload quantities only. It provides the producers with the capturing malt price for the last 20 or 30 MT remaining and not been reduced to accept feed barley price.

It is clear how this approach better meets market demands and better meets farmer needs. The whole system must examine ways to better achieve both ends.

37% of the canola crop is processed in some way (see Figure 7). In excess of 50% of the 1 million metric tonnes of malt barley purchased by the domestic maltsters is processed and exported as malt. The preferred markets are Asia and South America. However, international markets are changing considerably.

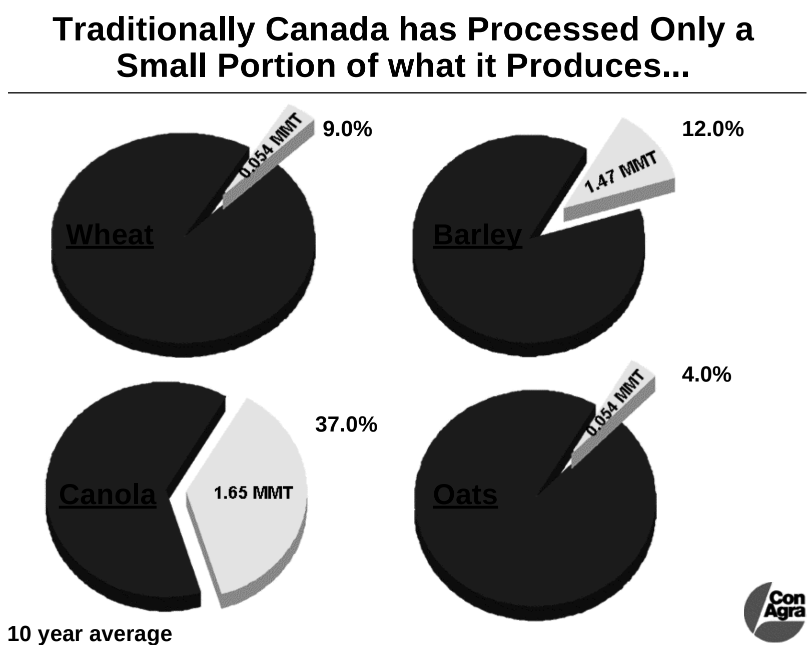


Figure 7. Processing.

Malt barley exports had projected to rise again, however, financial instability in the Asian and South American markets has tempered those expectations. Malt and malt barley exports may be lucky to reach the 1997/98 levels (see Figure 8). Long-term, we expect resumption of the malt barley exports, but these will be slower than the optimistic forecast that been outlined in the early 1990’s.

The markets being served are also changing (see Figure 9). The former Soviet Union and Europe, once large importers, now take virtually no Canadian barley. Asia continues to be an important market but it too has dropped its imports.

The one significant growth market for Canadian barley is the United States.

Larger Domestic Role

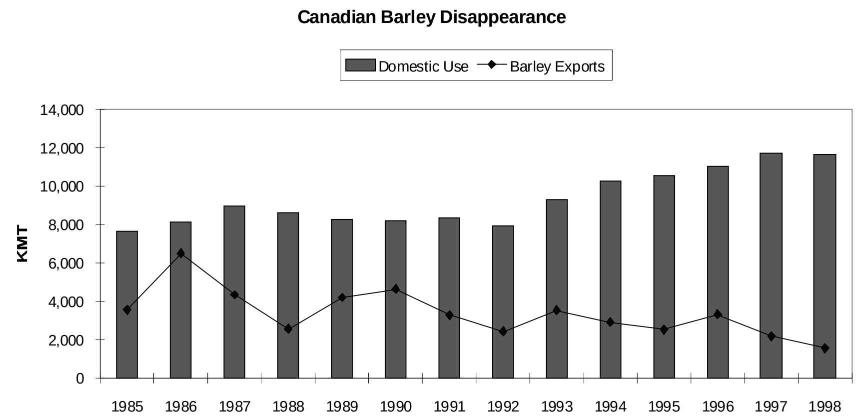


Figure 8. Larger Domestic Role.

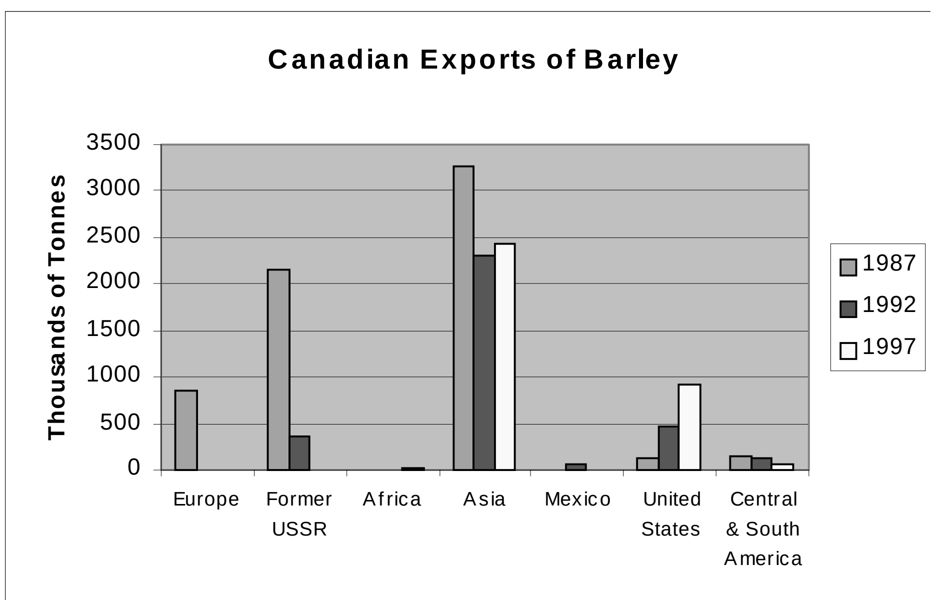


Figure 9. Canadian Exports of Barley.

It is leading to the question of whether the barley market is becoming more integrated within North America. Ups and downs within this market will continue to occur, but increasingly it seems the rise in North American demand over the past decade is consuming Canadian exports to a much greater extent (see Figure 10).

Greater Reliance on North America for Exports?

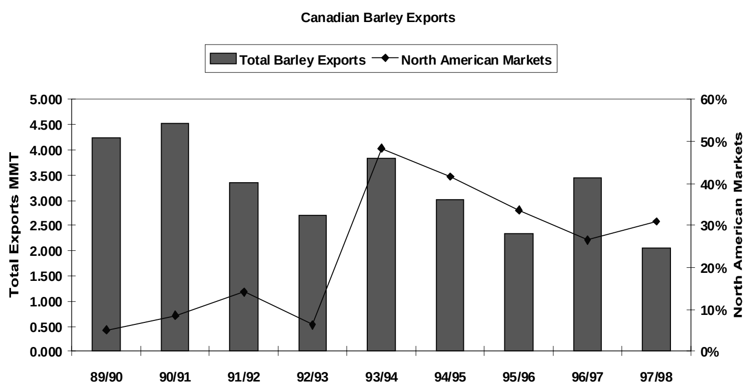


Figure 10. Greater North American Reliance.

Although Canada has always been a significant exporter of grain, further evidence of the changes in the marketplace was demand in Alberta. By year end, imports of U.S. barley into southern Alberta became significant for the first time. Imports of U.S. barley are predicted to reach 50,000 tonnes.

Feed demand in Alberta is great. Modern markets will move rapidly to meet demand and, if the North American market is more integrated, you can expect that farmers on all sides of the border will move to meet the demand.

Perhaps one of the reasons is the ease of access. But there are also other reasons why there will be more trade within North America. Although there are certainly some differences in the system, the fundamentals are there for both Canada and the U.S. to work together more effectively. If you consider the total share of world markets, Canada and the U.S. make a pretty formidable force. Together, we command over half to three-quarters of most agricultural trade. It is possible to add value to this considerable market share by adjusting agricultural practices.

Canada, Mexico, and the U.S. have geography, markets, and trade arrangements in common. It is likely the integration process will continue in all three countries. The geography, infrastructure, and mindset are already in place to make this a North American market.

We have already begun walking down the path of shifting trade policy. The North American Free Trade Agreement and CFTA are one step in this direction and it is making a difference. Figures tell the story. When you look at the shifts in trade since the North American Free Trade Agreement (NAFTA) was signed, it is clear NAFTA has meant dynamic opportunities.

The transportation and handling system needs to adapt to reflect these market realities. As I stated at the outset: that means bigger, faster and more cost efficient systems. You can see the Canadian infrastructure is already undergoing these changes. More are still to come.

In the end, the system will likely have fewer facilities but a great deal more services in place. It will also be more responsive to market needs. If my predictions are right, that means a greater attention to North American production and tighter ties to the end user.

Just like other industries – the agri-food sector is moving into an era that focuses on global demands and continental production capacity. Adjusting the system is just needed to get there in a way that maximizes returns for farmers.

Handling Malting Barley – A Producer’s Perspective

Bob McCallister, Producer
Portage la Prairie, Manitoba, Canada

Introduction

Thank you for the opportunity to share, as a producer, some experiences with barley production. For purposes of this presentation, I will focus mainly on the malt barley component although for us, as producers, the feed barley market has some very close ties. Though I can’t speak for the western area of the province, I feel our experiences reflect the general situation in the central and eastern areas.

As a little background, our operation is a partnership, diversified to the extent of including a small on-farm seed-cleaning plant and feedlot. We have approximately 2,700 acres with a variety of crops including barley, wheat, oats, flax, canola, peas and beans, and about 300 acres is used as hay and pasture. As well, our rotation once included sugar beets.

To analyze the barley situation, I would like to use the bicycle wheel as an analogy, keeping in mind the inter-relationships that exist in the factors I’m about to discuss.

Think of the centre axle as the sample, or lot, of barley. The hub and bearings represent a combination of factors that influence and form the lot (i.e. quality). If all the factors were placed on the rim and tire, and then tied to all the end products through the spokes, the inter-relationships and dependence on one another would be clearly seen. Failure at any point (or any one spoke) could mean collapse.

I will highlight some of the factors although, in our area, as I should point out, I believe the barley industry has already started to collapse.

I will group these “factors” into two categories – agronomic and economic.

Agronomic

Fusarium

The big F word! Fusarium (the white wall on the tire) has been the most significant contributor to lost markets and decline in acreage in the past few years. Barley failing to meet malt standards can find a place in the local feed markets, however, when the pork industry is unable to use Fusarium infected barley, and in the absence of a strong beef finishing industry, it means much of our barley has to be shipped Alberta way. Weight criteria and freight costs add significantly to reduced returns in an already highly competitive market. How ironic to see western barley with no Fusarium come back into Manitoba while our barley moves west. Great for back-haul!

Varieties

Demand for higher quality malts and higher test weights for feeds, coupled with a slow change from the 6-row blues to the 2-row whites, has not left us very competitive in the malt industry. To say the least, we’re scrambling to find a 2-row that has the straw strength and disease package that will give yields high enough to economically compete and give us a positive return. In terms of revenue per acre, I believe we have taken a major step backwards because we can’t consistently get yields. I have some options in terms of fungicides and growth regulators, but the wheel dictates. As well, I don’t feel these options are cost-effective when so many other factors are involved. I would much rather invest more in the variety to solve the problem of disease and lodging then in a pail of chemical.

Protein

Malt needs to be lower and feed needs to be higher – yet the balance isn’t there. Our old program put our malt barley on previous sugar beet crop land, but beets tended to leave the land in a moisture deficit. Subject to years when rainfall was short, this rotation worked quite well because the land had high levels of N in the top, but lower levels of soil were left somewhat deficient. Barley crops started well but finished short of N. Most often, this resulted in low proteins.

Beans and potatoes (surface feeders) are expanding on the good soils. The probability of increased nutrient levels will undoubtedly increase the risk of higher proteins in the malts. This will upset the straw/grain ratio of the feeds. We will try to capture the enhanced fertility with crops other than barley, like wheat and/or canola, where higher protein is a benefit.

Economic

Freight Rates

A number of years ago, before we lost the crow, I made a presentation to a group representing grain companies, railways and eastern shippers. The context dealt with how farmers could adjust and cope with changes – that is, increases in cost of freight. I suggested that we needed to haul less dockage and ship higher value products. Chemicals and cleaners have helped clean up our products.

At that time malt barley certainly fitted the higher value end of things. The enthusiasm in the pork sector of the livestock industry led one to believe that “feed the feed” and “ship the pork” was the way to go. When we lose our local (closer) malt markets and are forced to export, we must ensure that the relationship (between cost of freight and value of product) stays in balance. With current trends and lower values for our product, many feel it is already unbalanced. With Fusarium added to the equation, we are looking to alternatives.

Grading and Shipping

As we tie all these issues together, we need to strengthen our position to balance the weaknesses, all leading to the hub of quality barley I present to the marketplace. The storage, the sampling, the acceptance and/or rejection all rely on the grading (the grease to the wheel). Herein lies my greatest problem.

There is inconsistency in two areas – the quality level of the market demands at the current time, and the ability to define that quality in a sample at two different locations from one period to another. We make every effort to keep a good product in storage but things can happen over time. Once a sample is selected we need to know exactly the criteria that sample was based on. More importantly, we need to know all the factors, not just one, which categorize a sample that might be cause for rejection. All too often, the reason for rejection at one time isn’t the same reason six months later. I think it’s unreasonable (even though storage is paid), that a carlot, once accepted, should remain in farm storage more than two months.

Many producers are reluctant to grow for the malt market because of the risk of having the sample rejected upon delivery or, even worse, on unload at port.

As demands for quality malt and feed evolve, we see more specifics for each market. With fewer and larger delivery points, those of us in the marginal barley growing areas seem to be suffering from an elevator's desire not to handle individual carload lots. I can take my sample to the local elevator and have it rejected. Yet I can take the same sample to an elevator in another area moving lots of malt, and have it accepted! Been there – done that – then arranged loading at the local elevator.

We used to see unaccepted malt varieties enter the feed market. When the wheel turns full circle and we see varieties intended for the feed industry coming into export shipments of malt, we need to be concerned that the values and messages returned to the producer are in order.

They say “once you learn to ride a bike you never forget,” but if everything isn’t properly in place the ride is going to be pretty rough. I don’t have the answers to keep the wheel straight and true but, if the economics can’t justify the trip, I can take the easy way out – I won’t get on for the ride. We do the barley industry a great injustice and disservice if many forsake it for an alternative. We need better profitability to realize more dollars from our sales and reduce our costs.

Can it be done? I hope so. Where there is a will, there is a way. Thank you.