Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Bi-weekly Bulletin

July 8, 2005 Volume 18 Number 13

COMPARING THE YIELDS OF HARD RED SPRING WHEAT LINES FROM CANADA AND UNITED STATES

Canada is recognized in the international marketplace as a reliable supplier of consistent, high-quality wheat, a brand image that has been successfully developed since the early 1900s. Canada's success at wheat quality assurance is related to a complex set of institutional arrangements which have constrained the adoption of certain higher-yielding varieties. Some stakeholders in the grain industry are concerned that Canada's approach sacrifices too much yield to maintain this level of branding. This issue of the *Bi-weekly Bulletin* reports on the results of a statistical analysis that compared the yield and protein level of Canadian and United States (US) hard red spring (HRS) wheat lines grown side-by side in the Hard Red Spring Wheat Uniform Regional Nursery (HRSWURN) cooperative nursery program administered by the US Department of Agriculture (USDA). Data from 1995 to 2004 point to a yield advantage of 1.83 bushels per acre (bu/ac) or 3.68% for US HRS wheat lines but a protein advantage of 0.417% for Canadian HRS wheat lines. Given the well-known inverse relationship between protein content and yield, the results suggest that the US yield advantage is offset by the Canadian protein advantage.

INTRODUCTION

Some stakeholders in the Canadian grain industry believe that Canadian HRS wheat yields are significantly lower than those in the US. This difference is generally attributed to the commercialization of higher-yielding varieties in the US. Canada's strict variety registration system is often cited as a barrier to achieving higher yields; in particular, some believe that the quality and kernel visual distinguishability (KVD) requirements for the Canada Western Red Spring (CWRS) wheat class come at the significant expense of yield. However, a yield difference between Canadian and US HRS lines has not been conclusively documented in the literature.

Measuring and Explaining Yield Differences

Limited research in this area is related to the lack of adequate data. The wheat yield data that are released to the public through various established channels – including the USDA National Agricultural Statistics Service, the Statistics Canada Field Crop Reporting Series, and provincial crop-insurance authorities – can be used to measure yield differences at the aggregate level between locations with similar soil conditions and farming practices. However, such aggregated data sources are of limited use in establishing an unbiased measure of yield difference, since these data are not accompanied by quality parameters such as protein content that are known to affect yield. Protein content is an internationally accepted indicator of the end-use performance of the wheat in producing flour for bread dough, and is an important quality factor for HRS wheat since most of the varieties within this class are grown for bread production. Without protein information, the farm-gate difference in revenue between two varieties with different quality parameters cannot be accurately estimated. As a result, the value of cross-border yield comparisons at the aggregate level is limited.

In a study recently commissioned by the Canadian Grain Commission (CGC) entitled *Identifying the Benefits of Moving Away from KVD*, Dr. Brian Oleson identifies an alternative data source which appears to provide some basis for comparing the yield and protein level of Canadian and US wheat lines.[1] This data source is generated by the USDA-administered Hard Red Spring Wheat Uniform Regional Nursery (HRSWURN) cooperative nursery program, through which public and private sector wheat breeders freely submit promising lines for evaluation at several research farms in Canada and the US. Each year Agriculture and Agri-Food Canada's (AAFC) Cereal Research Centre (CRC) enters a small number of advanced breeding lines into the program, which are then randomly assigned to test plots and grown alongside American lines at several research farms throughout Canada and the US.

A broad sample of HRSWURN data from the northern plains region was used to estimate (a) whether Canadian and American HRS wheat lines differ in both yield and protein content, and (b) the magnitude of the difference. Summary statistics were calculated for the yield and protein content of Canadian and American samples spanning several years at five research farms – St. Paul, Minnesota (MN); Crookston, MN; Morris, MN; Williston, North Dakota; and Swift Current, Saskatchewan. In addition, two statistical procedures were employed to test the equality of mean, and median, yield and protein content of Canadian and American HRS wheat lines at each research location.

[1] Brian T. Oleson, "Identifying the Benefits of Moving Away from KVD, Section 2: Impact Analysis of Key Value Chain Segments, The Wheat Breeding Segment of the Value Chain, Quantification of KVD-drag: Supporting Analysis," 19 December 2003, <http://www.grainscanada.gc.ca/Pubs/committee_reports/ved/oleson_sec2_a_03-e.htm> (2 July 2005), Supporting Analysis: HRSWURN Data and Aggregate Yield Data.

WHEAT QUALITY ASSURANCE IN CANADA AND THE U.S.

This analysis did not undertake an assessment of the system of quality evaluation that is in place for spring wheat in either country. It is recognized that each country has different quality evaluation mechanisms in place and that new wheat varieties are subject to rigorous evaluations in both countries.

The Canadian System

In Canada, the federal government regulates grain classification and grading through the *Canada Grain Act* and the *Seeds Act*. The *Canada Grain Act* provides the CGC with the power to "establish and maintain standards of quality for Canadian grain and regulate grain handling in Canada, to ensure a dependable commodity for domestic and export markets."[2] The CGC maintains a broad set of quality standards for each class of wheat in its annual *Grain Grading Guide*, including minimum protein requirements for premium grades of wheat. The *Seeds Act* helps the CGC maintain these standards by regulating the import, export and sale of seed of non-registered varieties in Canada.

The Canadian Food Inspection Agency (CFIA) is responsible for the registration of wheat varieties for production. It takes roughly ten years to develop a new wheat variety for production in Western Canada, where 95% of Canadian wheat is grown.[3] The final stage of the registration process involves at least three years of nursery trials at various breeding centres across Canada, the recommendation of a CFIA approved recommending committee, and the final approval of the CFIA.[4] In order to be considered for final approval, new varieties must be "equal to or better than" a benchmark set by a group of three to five varieties for "agronomic performance, end-use suitability, and response to diseases."[5]

In Western Canada, wheat is classified according to visual characteristics (size, shape, and colour), with each class of wheat having its own unique visual profile. Known as KVD, this requirement provides a low-cost, efficient basis for segregating wheat classes in the bulk handling system. To prevent non-registered varieties with the CWRS kernel type but different quality parameters from compromising the integrity of the CWRS class as it moves through the bulk handling system, non-registered varieties are only eligible for the lowest possible grade for wheat, CW Feed, regardless of their quality profile. The presence of non-registered varieties beyond defined grade tolerances in a CWRS shipment will cause that shipment to be downgraded to the CW Feed grade.

The American System

In the US, on the other hand, the federal government does not maintain a compulsory wheat classification system based on specific end uses. However, minimum standards for wheat are defined in the *US Grain Standards Act*. This legislation is largely concerned with defining minimum thresholds for damaged kernels and foreign materials for a number of grade increments, leaving other quality and agronomic considerations to the discretion of the market and state regulatory authorities.

The US federal government also plays an important role in quality assurance. Four federal USDA-ARS (Agricultural Research Service) Wheat Quality Laboratories evaluate breeding lines for the respective market classes in which they specialize to ensure agronomic and end-product quality characteristics are maintained or improved. Both public and private breeding programs may freely submit samples to these labs for quality evaluation. Despite the voluntary nature of this program, over 95% of all HRS varieties in production in the US have been rigorously evaluated for quality at one of these Laboratories. At the state level, agricultural experimental stations and various state authorities play a role in approving the release of new varieties, and quality data from various sources are very important to local approval processes.[6] It is important to note, however, that variety approval processes in the US are not government mandated—a breeder may, if he wishes, release a variety without government consent.

Uncertainty Over Impact of KVD Requirements

Canadian wheat breeders face several requirements that can each have an impact on the yield potential of their lines. Each Western Canadian wheat class has a unique set of agronomic, disease-resistance, and end-use quality standards that must be met or surpassed in monitored breeding trials before a new line will be considered for registration by the CFIA.

Historically, Canada's reputation for high quality wheat has been sustained by legislative initiatives aimed at guaranteeing the excellent milling quality of Canadian HRS wheat. However, there exists a trade-off between quality and quantity in wheat production, as certain quality parameters, such as protein content, are inversely related to yield. Recent improvements in baking technology have lowered the wheat quality standards required for bread production, which has led some to charge that Canada's quality standards are sacrificing too much yield potential.

Further complicating this matter is the potential yield cost of KVD. This 'visual distinguishability' requirement does not exist in the US, Canada's biggest competitor in wheat markets, putting Canadian wheat breeders at a competitive disadvantage (all other factors remaining the same) relative to their American counterparts. The potential cost of KVD is largely one of opportunity. Firstly, Canadian breeders must expend a significant amount of time incorporating this requirement into their lines—time which could otherwise be devoted to improving yield or other performance measures. Secondly, promising lines are occasionally discarded on the basis of their appearance alone. And thirdly, KVD inhibits the adoption of improved lines from the US, since they are not bred for KVD and are therefore typically ineligible for registration in the milling classes of Western Canadian wheat.

---

[2] Government of Canada, *Canada Grain Act* (Ottawa: 2002), Article 11.

[3] Meristem Land & Science, *Canada in the Big Picture: Wheat Breeding Report* (2004), 22.

[4] Ibid, 23.

[5] Ibid, 22.

[6] Much of this brief overview of the US quality assurance system was provided by Dr. David Garvin, Research Geneticist, USDA-ARS and Coordinator of the HRSWURN nursery program.

The complex relationship between yield, quality, and the environment makes it difficult to isolate the specific yield cost of KVD. According to Dr. Oleson, the lost yield potential in the CWRS class that is attributable to KVD appears to be less than 5%. For other classes of Canadian wheat, however, the cost may be higher. He also notes, "As a rule of thumb, for current CWRS wheat varieties, it is generally accepted that, given time, if the protein were lowered by 1%, all else staying the same, yield could be increased by 10%."[7]

THE HRSWURN PROGRAM AND DATASET

HRSWURN, administered by the USDA, is a cooperative nursery program among public and private sector wheat breeders (including AAFC) that evaluates advanced breeding lines at multiple locations in Canada and the US as illustrated in the attached map. It is a voluntary program that can also be used as a vehicle for germplasm sharing among breeders. The program is coordinated by a research geneticist who is an employee of the USDA-ARS. Advanced lines for testing are chosen by the participating scientists, not the USDA-ARS. It should be noted that there is no intent to compare Canadian and US varieties per se under this nursery program as would be the case under a variety testing program. However, individual breeders may use the data on their promising lines in support of a potential variety release.

Limitations of the Data

The HRSWURN dataset provides a basis for comparing the yields of Canadian and American wheat lines. While it represents an improvement over other more aggregate datasets, some limitations still remain. The current analysis was undertaken to compare promising Canadian and American HRS wheat lines – the ones that are relatively well-tested and are either currently registered or are likely to be approved for production. In such an analysis, the preference is to base statistical tests on a representative sample of the entire population of such lines in Canada and the US, accounting for the full range of diversity within the class of HRS wheats itself, as well as the multitude of efforts from a large cross-section of breeding programs in each country.

Limitation 1: End-Use Class Information Not Available

Unfortunately, the HRSWURN sample does not meet this idealized standard. Most of the wheat lines entered in the HRSWURN program are in the late stages of the breeding process, and have thus not yet entered the production chain in either country. This fact severely limits the amount of information that can be inferred about each particular entry in the HRSWURN program. In most cases, there is only enough information to determine the wheat line's breeding program, from which its country of origin can be determined. While each HRSWURN entry falls under the broad HRS type, in most cases it is difficult to determine which particular class it would be registered into. In Canada, HRS varieties are sub-divided into three classes: CWRS, Canada Prairie Spring, and Canada Western Extra Strong; while in the US, HRS varieties are sub-divided into three classes as well: Dark Northern Spring, Northern Spring, and Red Spring. While it is reasonable to assume that entries in the HRSWURN program reflect the relative importance of each HRS class to each country, the assumption that the samples from Canada and the US contain a similar composition of higher quality and lower quality HRS lines may not hold. As a result, the statistical analysis cannot rule out the possibility that an observed yield or protein difference between the two countries may simply reflect different marketing considerations. For example, a sample from one country might have lower average yields simply because it contains a higher percentage of high-quality bread wheat, a fact that should be reflected in higher protein levels for that country as well. Consequently, it is difficult to isolate the potential yield cost of KVD with this data. However, given prior research results on the nature of the protein-yield tradeoff, it is plausible to use observed yield and protein differences to infer what part of a yield difference (if any) might be attributable to factors other than protein.

Limitation 2: Limited Canadian Participation

Another limitation of the HRSWURN dataset is that the Canadian sample is not representative of all breeding programs in the country, since AAFC is the only Canadian participant in the program. While in recent years private breeding programs have become more important to the Canadian wheat economy, AAFC varieties still account for roughly 82.5% of all seeded acreage of CWRS (Canada's dominant HRS class) on the prairies.[8] Therefore, it is important to note that the statistical inferences drawn by this study are based solely on the efforts of AAFC breeding programs. However, AAFC is still the dominant player in the Canadian HRS market, and thus for practical purposes this sample will continue to be simply referred to as Canadian.

The US sample, on the other hand, contains a diverse mix of public- and private-sector submissions. Publicly-funded US contributors include the University of Minnesota, North Dakota State University, Washington State University, South Dakota State University, Montana State University, and Idaho State University. Among the largest US private-sector HRSWURN participants are Western Plant Breeders, Agripro Wheat, and Trigen Seed. The US sample therefore appears to contain entries from a sufficient cross-section of US breeding programs to constitute a fairly representative sample of all US HRS wheat lines.

DATA ANALYSIS

The entire HRSWURN sample contains a total of 1275 yield and protein observations, 109 of which are from Canadian-made HRS wheat lines, spanning the period from 1995 to 2004 inclusive.[9] This sample was divided into five sub-samples by research farm, and then further subdivided by country of origin (Canada or US). The summary statistics for the yield and protein content of Canadian and US entries at each location are presented in Tables 1 and 2, respectively.

The summary statistics seem to confirm the conventional wisdom that HRS yields are higher in the US, but that protein content is higher in Canada. The mean yield of US lines is higher at four out of five research farms, while the mean protein content of Canadian lines is higher at four out of five locations. Median yield and protein content show similar patterns. The weighted average yield of Canadian and American lines is 49.73 bu/ac and 51.56 bu/ac, respectively – a difference of 1.83 bu/ac. The weighted average protein content of Canadian and American lines is 15.10% and 14.68%, respectively – a difference of 0.417 percentage points.

In addition, two statistical procedures (the Wilcoxon rank sum and two-sample t-test) were employed to formally test the observed differences at each location for statistical significance. At the 90% confidence level, both of these tests revealed a statistically significant Canadian protein advantage at three out of five locations. However, the Wilcoxon test found a statistically significant US yield advantage at only one location

[7] Oleson, Supporting Analysis: Expert opinion.

[8] Canadian Wheat Board, *2004 Canadian Wheat Board Variety Survey*, 2004, <http://www.cwb.ca/en/growing/variety_survey/pdf/2004_variety_survey.pdf> (2 July 2005).

[9] The Williston and Swift Current locations did not report results in some years during this period.

TABLE 1: SUMMARY STATISTICS FOR YIELD OF SELECTED HRSWURN ENTRIES, BY RESEARCH FARM AND WHEAT LINE'S COUNTRY OF ORIGIN

	St. Paul, MN		*Crookston, MN*		*Morris, MN*		*Williston, ND*		*Swift Current, SK*	
	Canada	US	**Canada**	US	**Canada**	US	**Canada**	US	**Canada**	US
	yield (bushels per acre)									
Mean	**48.55**	51.06	**54.77**	54.10	**48.47**	50.58	**48.46**	51.83	**46.57**	49.09
Median	**41.90**	48.70	**52.15**	53.45	**51.50**	51.00	**48.40**	51.40	**41.60**	44.50
Standard Deviation	**20.08**	15.63	**19.65**	18.65	**16.89**	16.81	**10.30**	12.32	**14.23**	16.76
Minimum	**25.80**	17.00	**17.20**	21.00	**18.40**	19.90	**29.10**	29.70	**26.90**	24.90
Maximum	**91.60**	91.70	**88.10**	97.70	**81.20**	92.60	**67.30**	83.60	**76.80**	94.80
Sample Size	**26**	285	**26**	286	**23**	257	**19**	183	**15**	155

TABLE 2: SUMMARY STATISTICS FOR PROTEIN CONTENT OF SELECTED HRSWURN ENTRIES, BY RESEARCH FARM AND WHEAT LINE'S COUNTRY OF ORIGIN

	St. Paul, MN		*Crookston, MN*		*Morris, MN*		*Williston, ND*		*Swift Current, SK*	
	Canada	US	**Canada**	US	**Canada**	US	**Canada**	US	**Canada**	US
	protein (%)									
Mean	**15.47**	14.91	**15.21**	14.79	**14.48**	14.55	**16.55**	15.78	**13.35**	12.98
Median	**15.95**	15.30	**15.40**	14.80	**14.70**	14.50	**16.20**	15.70	**13.30**	12.50
Standard Deviation	**1.58**	1.34	**1.00**	0.85	**1.62**	1.04	**1.37**	1.20	**2.38**	2.12
Minimum	**11.60**	10.10	**13.30**	12.50	**10.80**	11.80	**14.90**	13.10	**8.70**	8.60
Maximum	**17.40**	17.40	**16.90**	17.80	**17.40**	17.20	**19.40**	18.60	**16.40**	16.60
Sample Size	**26**	285	**26**	286	**23**	257	**19**	183	**15**	155

Source: USDA HRSWURN Program, 1995-2004

(St. Paul), and the two-sample t-test could not detect a statistically significant yield difference at any location.

CONCLUSION

While our summary statistics point to a noticeable yield advantage for US HRS wheat lines over their Canadian counterparts, statistical tests suggest that the US advantage is negligible. However, the tests do not permit us to rule out the possibility of a Canada-US yield difference entirely. Our inability to group wheat lines according to end-use class has contributed to large variances in the Canadian and US yield samples, rendering comparisons of average yield differences inconclusive. Further limiting the power of these tests is the large inequality between Canadian and US sample sizes.

The numbers in the summary statistics, themselves, strongly support the expected result of a US yield advantage, as both mean and median US yields are noticeably higher at four out of five locations. Therefore, if a US HRS yield advantage does exist, our best estimate is the difference between the weighted average yields of the two aggregate country samples, which amounts to a 1.83 bu/ac or 3.68% advantage for US lines.

On the other hand, both the summary statistics and the formal tests support the expected result of a Canadian protein advantage. Our best estimate of this advantage is the difference between the weighted average protein levels of the Canadian and US samples, which amounts to 0.417%. Therefore, if the 10% yield for 1% protein tradeoff cited in the Oleson KVD study is correct, then the observed US yield advantage of 3.68% in our sample can likely be fully explained by the 0.417% Canadian protein advantage.

For more information contact:
Grain Policy Division,
Marketing Policy Directorate,
Strategic Policy Branch

Adam Hendrickson,
Junior Policy Analyst
Phone: (204) 983-0575
E-mail: hendricksona@agr.gc.ca
or
Jürgen Kohler,
Policy Economist
Phone: (204) 983-0574
E-mail: kohlerj@agr.gc.ca

Electronic version available at
www.agr.gc.ca/mad-dam/

ISSN 1207-621X
AAFC No. 2081/E

Bi-weekly Bulletin is published by the:
Market Analysis Division,
Marketing Policy Directorate
Strategic Policy Branch
Agriculture and Agri-Food Canada.
500-303 Main Street
Winnipeg, Manitoba, Canada R3C 3G7
Telephone: (204) 983-8473
Fax: (204) 983-5524

Director: Maggie Liu
Chief: Fred Oleson

A/Editor: Glenn Lennox

To receive a free e-mail subscription to Bi-weekly Bulletin, please send your request to bulletin@agr.gc.ca.

Issued also in French under title:
Le Bulletin bimensuel
ISSN 1207-6228
AAFC No. 2081/F

While the Grain Policy Division assumes responsibility for all information contained in this bulletin, we wish to gratefully acknowledge input from the following:
United States Department of Agriculture-Agricultural Research Service, Canadian Grain Commission, Canadian Wheat Board, Agri-Food Chain and IRM Analysis (AAFC), Research Branch (AAFC), Semiarid Prairie Agricultural Research Centre (AAFC), Market and Industry Services Branch (AAFC)