2023 TALE #7 Archive PDF FINAL Glenlea story July 26 2023 (File name)

ABOUT TALES OF ALES:
Celebrating the Past, and Changing the Future: Stories about some University of Alberta Faculty of ALES Professors, Students and Alumni and their Achievements and Activities in the Past

The TALES are a series of stories written in retirement by Keith Briggs in 2021 – 2023 as Emeritus Professor of the Department of Agricultural, Food and Nutritional Science (AFNS), Faculty of Agricultural, Life and Environmental Science (ALES) at the University of Alberta. The TALES place into the record some notable agricultural science events and activities for the Archives, stories not previously told or elaborated that may be of interest to the academic, scientific and public communities. They feature Professors or other staff all found in the history of AFNS. The TALES have additional authors in some cases.

ABBREVIATED TITLE:
All about Keith Briggs University of Manitoba 1960's PhD project and the release of Glenlea spring wheat, and its related influences on subsequent spring wheat breeding methods and Canada Western Extra Strong spring wheat production in W. Canada

FULL TITLE:
Keith Briggs, with co-author Ron DePauw, describes his 1960's University of Manitoba research that led to the Canada Western Extra Strong (CWES) spring wheat crop for Western Canada, and the registration and production of the variety Glenlea.

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ACKNOWLEDGEMENTS:
This article describes the breeding and fortunes of the W. Canadian spring wheat variety Glenlea, a variety released to growers in 1972. All the players named in the story except Briggs have sadly passed away by 2023, but this story highlights one particular part of their lasting legacy in the world of spring wheat breeding technology. All of those players are recognized here for their significant roles in the story. The first author also especially welcomes Dr. Ron DePauw as a second author for this story and the extra information that was added because of his review and extensive contributions to the text. The authors also wish to acknowledge the valuable review provided by Dr. Brian Beres, Senior Research Scientist, AAFC, Adjunct Professor at the University of Alberta, and 2011-2014 Chair of the Prairie Recommending Committee for Wheat, Rye and Triticale. Briggs especially acknowledges the invaluable PhD project supervision provided by Dean Leonard Shebeski during his PhD studies, and additional guidance provided by project colleagues Laurie Evans, Bob McGinnis and Didzus Zuzens, that led to many favorable research outcomes.

INDEX:

ABSTRACT:

TALES OF ALES #7: Keith Briggs (with Ron DePauw as co-author) describes the mid 1960's spring wheat research and related R&D of his University of Manitoba PhD program that developed the 25% higher yielding spring wheat variety Glenlea. A new Canada Western Extra Strong (CWES) wheat market class was created to market this new Glenlea quality type which possessed increased flour gluten strength better suited for use as a blending wheat in many novel markets. Subsequent changes to the Western Canadian wheat breeding and variety selection methods are also described, that were supported by many of the research findings in this project where Glenlea was selected. Glenlea itself was produced commercially on from 0.25 to 0.65 million hectares per year for its remarkable 32 year production run in the W. Canadian Prairies, with an estimated farm gate value for the entire period of perhaps $2 billion Canadian.

Please scroll down……….Thank you !

TITLE:

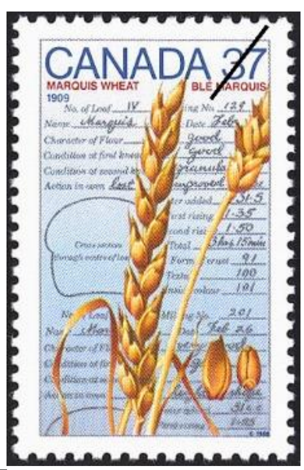
Keith Briggs and Ron DePauw describe1960’s University of Manitoba research that led to the Canada Western Extra Strong (CWES) spring wheat crop for Western Canada, and the registration and production of the variety Glenlea.

(Photo sources: unsplash.com; CPO)

Seeding

Harvesting

Prairie wheat fields



Marquis CWRS wheat 1904

TALES of ALES, TALE #7: Part (A)

The Canadian CWRS Wheat Crop in the 1960's and 1970's: The 'Government Crop' – "14.5% Protein and 85.5% Politics"

The target subject of this mainly autobiographical story is the wheat variety Glenlea, which was a direct physical outcome of the PhD wheat breeding methods research project of the first author. Briggs started his graduate studies program at the University of Manitoba in 1965, after completing his earlier genetics, agricultural and plant breeding studies at the University of Cambridge, and at the UK Plant Breeding Research Institute, also at Cambridge. To be fully understood this story requires a rather lengthy background to be described about how varieties for the W. Canadian spring wheat crop were bred, managed and marketed in W. Canada during the 1960's.

The W. Canadian wheat scene in 1965

In 1965 wheat was still the most important crop in acreage and economic return in western Canada but was at that time limited to very few approved types of wheat, specifically the top four listed in Table 1 below. Both Canada Western Amber Durum (CWAD) and Canada Western Red Spring (CWRS) wheat had been grown for many years in W. Canada, but CWRS wheat had reached domination in production because of its high protein content and its special flour gluten properties, and high value . This large acreage was because of large market demand at a premium price for CWRS that was commanded by its' superior milling and baking quality, its' guaranteed protein levels, and specifically for the consistent gluten properties of all varieties of CWRS. That was all based on the first CWRS variety Marquis, which was released by Charles Saunders in 1904. By 1965 there were many Federal controls put in place to continuously maintain this high quality package in CWRS wheat, so much so that Canadian wheat was sometimes referred to as a 'Government crop'. By 1965 all wheat marketing in Canada was still solely controlled by the Canadian Wheat Board (CWB), created for that purpose in 1935, although the CWB was terminated in 2012, resulting in a very controversial change in marketing procedures for many wheat growers. Because the CWB controlled all the marketing of W. Canadian wheat it also determined and had a profound effect on what different kinds of wheat growers should produce. For this purpose, Government defined market classes were put in place to keep the wheat quality types separate and to avoid the mixing of grain of different quality types that could destroy the inherent integrity and value of each type. Any new variety proposed for registration by a breeder always had to meet the quality standards of the Class for which it was intended.

Table 1 Western Canadian Spring Wheat Classes and Insured production Acreages ('000, for various selected years)
(Sources: Canadian Grain Commission Reports; Country Guide. March 2, 2021)

			Acreage '000, by selected years		
Wheat Marketing Class	First Prodn. ***	Name*	1965	Average 1974-1987	2020 **
				(Data for CU + CWES)	
Canadian Western Red Spring	1842 (Red Fife)	CWRS	17,312		11,206
Canadian Western Amber Durum	Pre 1930	CWAD	6,185		3,739
Canadian Western Soft White Spring	1930's ?	CWSWS	< 300		242
Canadian Western Red Winter	1918 ?	CWRW	< 300		118
Canada Utility	1972	CU	0	682	0
Canadian Western Extra Strong****	1993	CWES	0	0	0.9
Canada Prairie Spring Red	1985	CPSR	0		580
Canada Prairie Spring White	1988 ?	CPSW	0		< 200?
Canadian Northern Hard Red	2016	CNHR	0		198
Canadian Western Special Purpose	2016	CWSP	0		116
Canadian Western Hard White Spring	2003 ?	CWHWS	0		12

* Names used in the text ** Reduced acreage due to severe drought *** Approx. year of first production
**** Initially marketed as the Canada Utility (CU) Class;

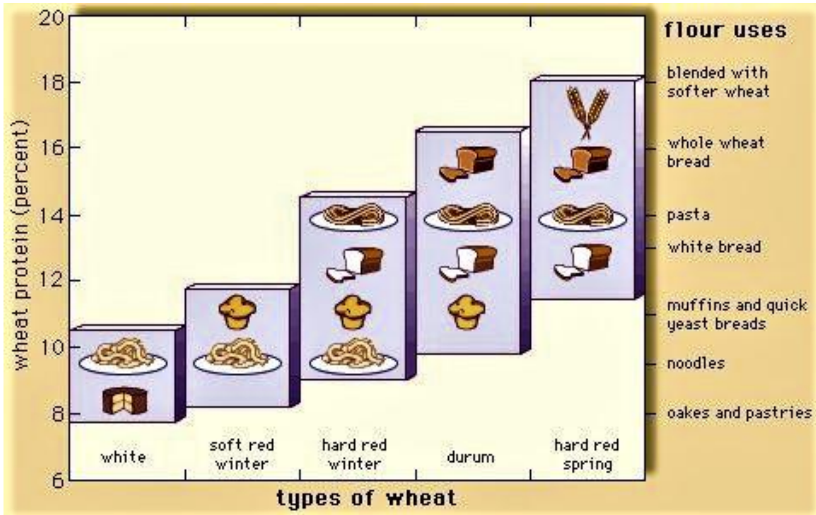
The Variety Registration System: Testing, Approvals, Classes of Wheat, and Quality Types

To be approved for cultivation in W. Canada any new CWRS wheat variety has to meet the protein and a large number of detailed flour quality, dough property, breadmaking and other processing functionality standards set and regulated by grain quality and end-use experts, with that evaluation overseen by the Canadian Grain Commission in collaboration with the Canadian Food Inspection Agency Variety Registration Office (CFIA VRO). The determination for adaptation and response to diseases is done under authority of the Canada Seeds Act administered by CFIA VRO. They are assisted in the conduct of trials that evaluate variety merits, trials that are organized by the Government approved Prairie Recommending Committee for Wheat, Rye and Triticale (PRCWRT), itself consisting of three subcommittees of agronomy, quality and pathology (diseases). Determination of market classification is done under authority of the Canada Grain Act administered by the Canadian Grain Commission. The Government, University and private experts throughout this system then recommend denial or approval for registration of any new variety. Lots of government, lots of meetings, lots of evaluation, and complete Government control over release of any new variety…hence the 'Government crop' tag by some people. Over the years there have been many changes to increase transparency and predictability. The system in place now in 2022 is completely different from that in place in 1965. In 1965, no other country had a system with so much control over what kind of wheat a farmer was allowed to grow, but it was extremely effective at maintaining the consistency of quality of all CWRS varieties released, the primary objective. The quality package, especially in CWRS, has never been allowed to fall below that of the best current varieties in any Class, and this guarantee is reflected in the premium prices paid for this Class internationally, and its consistency of quality type in the market.

A major advantage of the Canadian system of simultaneously determining the value of a new variety for cultivation and its market class designation is to inform the seed company which obtains the marketing rights to a new variety as to its potential size in the seed marketplace. Consequently, the risk associated with seed multiplication is greatly reduced and the rate of adoption of a new variety is accelerated. By contrast, European countries and Australia, for example, have two separate steps and jurisdictions to determine the eligibility to grow a variety and its subsequent market classification.

This Candian system and process, looking very cumbersome on paper, actually worked extremely well, and over the years Canadian spring wheat breeders were able to make use of the many collaborative networks that were in place, to better evaluate the market potential of their potential new varieties. The Canadian Wheat Board had a market development team to evaluate the potential of new wheat quality types, and introduced several new market classes between 1985 and 2000. Breeders continuously made advances in variety improvements in the areas of plant characteristics, disease resistance, straw strength and earlier maturity, for example, that would improve their suitability for production. A major genetic limitation for the breeders, however, was that in most cereals, including wheat, there is a negative relationship between the protein level in the grain and the grain yield potential. If you find a higher yielding line it will usually have a reduced protein content. Since the protein content was not allowed to be lowered in CWRS wheats, nor could the other quality traits be changed, this did not allow for much widening of the genetic base to seek higher yield potential. This relationship was one of the issues that was a potential candidate for Briggs' PhD studies, since the tight quality requirements were not allowing Canadian growers the ability to substantially increase their per acre yields in a way competitive with what was happening in other countries. Wheat classes with higher protein content command a higher price per ton, and CWRS was a market for which Canada wished to continue its' dominance. Wheat types of different protein content are available in world markets, but are used for different purposes, as shown in a very simplified manner in Figure 1. McCallum and DePauw (2008) describe the history of the Canadian wheat Classes and variety changes over time in much greater detail than in this account, which is focused primarily on developments in the CWES Class.

Figure 1 A simplified illustration of the general relationships between wheat protein %, flour use and wheat types (Retrieved 3/3/22 https://www.britannica.com/technology/cereal-processing/Wheat-varieties-and-characteristics)



Not shown in Figure 1 is the general relationship that wheat types towards the right side of the Figure have higher levels of strong gluten levels in the protein, which gives structural strength to products made from flours that have this, such as a loaf of bread or, for durum wheats (which have a different type of gluten) a length of spaghetti or a fancy pasta product shape. The wheat types in Figure 1 towards the left have lower to very low levels of gluten as well as a lower gluten strength, which makes them more suitable for making cakes and pastries . Also, consistent with the negative protein % vs yield potential relationship described earlier, wheat types to the left generally have the highest yield potential of wheat types worldwide, as do winter wheats. In Figure 1 terms, the only 'equivalent' types of wheat produced at all since the 1800's in W. Canada (and specifically in 1965 when Briggs started his wheat research in Winnipeg) were only four, as follows:

Hard red spring type: CWRS ('Breadwheat', major acreage)
Hard red winter type: CWRW ('Multi-purpose', minor acreage)
Durum type: CWAD ('Pasta' wheat, major acreage)
White type: CWSWS ('Cakes/pastry', minor acreage)

Winter wheat (CWRW) has the potential for very high yields in regions of the world where it can be grown, but acreage expansion in W. Canada has always been restricted because of its major limitations in surviving W. Canadian winters. In recent years newer varieties and management system have helped the acreage increase but it still is a minor acreage in relation to CWRS wheat. In W. Canada Soft White Spring Wheats (CWSWS) have demonstrated their ability to produce very high yields with low protein content on a very limited acreage of irrigated land available, particularly in S. Alberta. The CWSWS varieties are all very late maturing, requiring a long frost-free season, which also limits the potential acreage. Because of the high starch content in the seed the CWSWS type has in recent decades also become of some industrial interest for use in ethanol production (although always in a yield/price competition with numerous other grain choices available for that market). The Durum (CWAD) production acreage and market has always remained strong, but it is a wheat type best adapted to and therefore limited to acreage in rainfed Saskatchewan and S. Alberta, where it also requires a long frost-free season length. Durum from those areas, but not normally beyond them, is considered to be the best quality durum grain for pasta wheat anywhere in the world (McCallum and DePauw, 2008). Further durum acreage expansion in W. Canada may be possible in the future with new varieties that have a greater range of adaptation, and use of some new crop management systems (Beres, pers. com. 2022). The McCallum and DePauw 2008 review offers a far more detailed analysis of many aspects as they affected W. Canadian wheat variety choices and production by growers. It covers factors that affected wheat production, marketing and demand, all the many changes in the Market Classes and Grades established under authority of the Canada Grains Act over time, and genetic and pedigree information about which wheat varieties were grown in different years, and is a highly recommended read (Briggs, pers. comm.).

<u>1960's and 1970's Challenges for Breeders in Releasing Higher Yielding Wheat Varieties</u>

Returning to the choice of wheat types and varieties specifically available to wheat growers in 1965, none of the approved Classes were at that time able to provide really high yield improvements over the most widely grown CWRS varieties of the day for most of the potential W. Canadian spring wheat acreage. In the majority of the W. Canadian wheatlands, growers still clamored for substantially higher yields as a way to increase their returns, as they perceived that the growers in competing countries were indeed enjoying much larger gains in yield, perhaps by up to 30-40%, they often claimed. They were asking if perhaps some new kinds of spring wheat varieties for W. Canada could be developed to compete with those higher yielding wheats that their competitors enjoyed. This was a good question, and a challenge that Canadian breeders had actually been working hard at in addition to continually, although slowly, improving the yields within the existing four wheat Classes. Nevertheless, growers did recognize that the breeders had already been very successful in improving the CWRS yields well beyond the level of the original 1939 'Marquis quality standard'. Unconfirmed estimates about that rate of yield increase between 1939 and 1965, suggested a rate of varietal yield increase just by breeding alone of up to perhaps 0.2% per year. Thomas and Graf (2014) later estimated that the rate of CWRS varietal yield increase prior to the 1990's was still only 0.33% per year, probably limited by the over-riding need to maintain the very special CWRS Class quality package, but which denied introduction of much new genetic variability into the breeding of that Class. For the period of the 1990's to 2013 they estimated that the yearly CWRS varietal yield increase rate had improved to as high as 0.7% per year, comparable to similar varietal yield gains in higher protein wheat types in other major wheat producing countries. This doubling of the rate of genetic yield gain resulted from a massive infusion of incremental wheat breeding resources, in particular from the farmer levy on wheat production collected from the final CWB payment to producers and administered by the Western Grains Research Foundation. The breeding programs doubled in size to handle much larger populations and benefited immensely from the incorporation of new technologies and equipment.

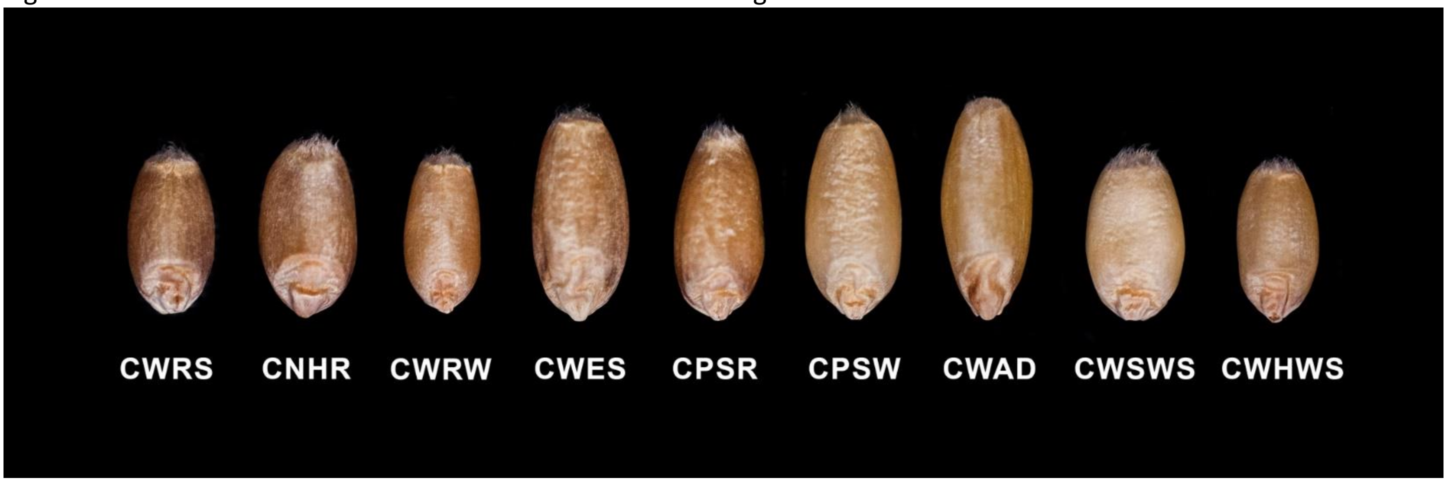
In 1965, in addition to the biological / genetic breeding obstacles to improving yield in spring wheat, Canadian breeders also faced another breeding obstacle that no other wheat producing countries experienced. This one was brought about by the Kernel Visual Distinguishability (KVD) system used by the Canadian Grading System, that ensured that wheat deliveries of any variety that were of different quality type each entered the correct bins at the time of delivery.

Gord Gilmour (Country Guide, March 21, 2016) succinctly described this KVD system limitation for breeders, and his comments about it are directly quoted here, as follows. *'For decades, it was "What you see is what you get" when buying Canadian wheat. Not only did new varieties have to perform well in the field and in the bakery, they (i.e. the grain, KGB note) had to look similar to all the other varieties in their class. That helped the consistency…a strong selling feature for Canadian wheat, but there was a downside. New varieties could perform well but could not be registered if they could not be visually distinguished from other Classes'*. In 1965 the breeding difficulties for delivering this KVD requirement were still frustrating the ability of Canadian breeders to register new wheats with potentially 20-30% higher yields, as their highest yielding new lines usually failed the very strict KVD requirement. Briggs (1991) later on demonstrated that single spikes of three high yielding wheat cultivars (Glenlea, HY320 and Pitic 62) all produced at least a few smaller kernels that could not be distinguished from CWRS kernels, even though the remainder of the seeds on the same spike were easily distinguished. The KVD requirement was very real, but was itself a biologically unreal barrier to releasing higher yielding varieties, most of the time. There had to be a better way to keep different quality types segregated, to improve yield!

Briggs spent considerable time during his 1978 sabbatical in Australia learning how they operated their wheat type segregation system which was based on a farmer declaration of the variety they were delivering, backed up by random sampling for verification, and strict fines and loss of delivery permits for mis-declaration. In 1979, after the sabbatical, Briggs ran an informational workshop at the University of Alberta with a focus on that non-KVD system, at a Northern Wheat Development Group meeting, a group of wheat breeders and agronomists put together to share research ideas and progress for the Parkland region of W. Canada. The holding of a meeting on this topic was of great interest to wheat breeders but was criticized by practitioners who manage the Canadian grading system, who asked for it to be cancelled, which was not done. This inappropriate request was directly aimed at the University of Alberta and was an extraordinary example confirming what Dean Shebeski had told Briggs a dozen years earlier about the 'politics of wheat'.

In the early 2000's the Canadian Wheat Board did occasionally experiment with an Identity Preserved (IP) program which took delivery of specific varieties by name under a declared contract process, but this never became widely used. It took until 2008 before the Canadian KVD system was officially abandoned and replaced with a system where growers make a declaration as to the variety they are delivering, backed up with grain sampling tests, similar to the system that had already been in use in Australia for many years. KVD cancellation certainly helped breeders to subsequently expand their wheat breeding successes and the creation of several new and desirable wheat Classes by 2002, including several that displayed a very high yield potential (Table 1). To illustrate the nature of the KVD variability between Classes, a photo of typical seed samples from nine 2022 W. Canadian wheat Classes is shown in Figure 2, below.

Figure 2 Grain Characteristics of Western Nine Canadian Milling Wheat Classes in 2022



(Source retrieved 4/3/2022 https://grainscanada.gc.ca/en/grain-quality/grain-grading/wheat-classes.html

"Wheat is 85% Politics"......... and that got in the way of higher yielding wheats how, exactly?

The title of this very lengthy Part (A) backgrounder about 1960-1970's wheat breeding has the by-line "The 'Government Crop' – "14.5% Protein and 85.5% Politics" and the reader may be wondering why that is used here. It is actually a quote from Briggs' PhD program supervisor, Professor Len Shebeski (Dean of the Faculty of Agriculture at the University of Manitoba) who soon after Briggs' arrival in Winnipeg from the UK in 1965 called him into his office to describe the many Government controlled complexities of getting a new wheat variety registered in W. Canada, some already described above. These were mostly things that had nothing very much directly to do with the genetics, methods or technologies of the breeding process itself, but could still get in the way at that time, he said. At the end of his tutorial Shebeski said "…and there you have it, Canadian spring wheat, 14.5% Protein and 85.5% Politics". A comment remembered well by Briggs, it was very true then, but is now much less the case since (a) all KVD requirements were removed in 2008 and (b) the Canadian Wheat Board was closed down as the grower agent for all sales of wheat in 2012, discontinuing that past role as the mandated single desk purchaser and marketer of wheat in Western Canada.

In 2011 Professor Brian Fowler, a hard red winter wheat breeder at the University of Saskatchewan, presented a very forceful critique of all the reasons why the KVD system had not even been doing a good job of separating wheat quality classes (Fowler 2011). He described in much detail how it had been an unreliable method for segregating wheat quality types, and that it had completely hindered the release of significantly improved potential new varieties of Canadian Western Red Winter (CWRW) wheat varieties for W. Canada.

For more supporting evidence about how the power of the 'Politics of wheat' actually worked, at least until the 1990's, this author draws attention to Chapter 26 of the book 'Harvest of Gold: The History of Field Crop Breeding in Canada' edited by A. E. Slinkard and D. R. Knott (1995). Chapter 26, entitled 'The Western Registration Recommending

Committees and their Role in Cultivar Development' was written by Dr. Bryan Harvey, an eminent barley breeder and now Professor Emeritus of the University of Saskatchewan, who chaired many of the involved committees over many years. His experience-based anecdotes and revelations in there will make a very interesting read for those who wish to learn more about the earlier politics of field crop variety registration! At the end of that read however, Harvey did include a simple statement with which today's plant breeders would all agree, in support of the system…Quote…"These are committees that work".

Despite all the challenges in the 1960's and into the 1970's, Canadian wheat breeders were in that period still able to release two new spring wheat varieties for W. Canada that did finally move the potential yield bar significantly past the best CWRS varieties of the day. The first of these was Pitic 62, an introduced spring wheat variety bred at the international wheat breeding program of INIA and CIMMYT in Mexico, registered for Canadian use in 1969 (INIA and CIMMYT, 1972). Pitic 62 was a semidwarf, high yielding variety but it was not actually very well adapted to much of the W. Canadian Prairies mainly because of its very late maturity (up to 9 days later than the most popular CWRS variety Neepawa in some Central Alberta trials (Briggs 1975). Although some very high yields were possible (eg. 30% higher than the CWRS variety Manitou under irrigated conditions, and 10% higher in dryland conditions: McCallum and DePauw 2008) it unfortunately had a low bushel weight and poor milling characteristics, 2% lower grain protein, and was usually deemed suitable only for delivery as feed grade, a pricing outcome not very attractive to growers. Nevertheless, the Canadian Grain Commission created a new wheat Class in 1972 to accommodate it, as they accepted that the KVD characteristics of Pitic 62 were sufficiently different for it to avoid any contamination with CWRS grades. This completely new Class was called Canadian Utility (CU) wheat (Table 1). The germplasm/pedigree base in Pitic 62 was completely different from that of any existing varieties in the CWRS Class, thus allowing the high yield to be achieved, albeit with lower corresponding protein content. Pitic 62 remained a member of the CU Class until 1993, when it was delicensed and that Class was then renamed CWES, to accommodate specific and focused marketing of the very strong gluten variety Glenlea registered in 1972, and described later in this script.

Although Pitic 62 never gained much traction it did provide a test variety that allowed the Canadian grains system to evolve protocols suitable for managing novel types of high yielding varieties. This was an important learning curve for the entire wheat value chain, from breeder to grower, to grain marketer, processor and consumer. It set the scene for a different kind of high yielding semi-dwarf variety that was registered by the University of Manitoba two years later in 1974, this one named Norquay (Evans et al 1974), a white-seeded, semi-dwarf wheat with very strong straw. It was early maturing with good drought tolerance and suited to most of the Prairie regions but was subject to sprouting when in the swath and was more subject to shattering losses compared to CWRS varieties. It was of completely different quality type than Pitic 62. It was very quickly deregistered in 1976 because delivered seed samples of Norquay were sometimes reddish in color, not white, and could be confused with CWRS, to which its' completely different quality posed a major threat.

Dr. Ron DePauw (Briggs note: himself definitively an internationally recognized wheat breeder) did write a brief article about the origins of the CWES Class. It included information about the origin of the Class, and the names of key personnel involved in all sectors who worked on its creation. (Chapter 3 p36-37 in Harvest of Gold: ed Slinkard and Knott, 1995). The most important part of that process, however, was the registration for W. Canada of the new spring wheat variety Glenlea, the specific subject of Part (B) of this article, a story not previously told in any detail. Glenlea was named after the University of Manitoba Crop Research Station just south of Winnipeg.

PART (B) The University of Manitoba red spring wheat research that resulted in the establishment of the Canada Western Extra Strong Wheat Class (CWES), and the development of Glenlea, the CWES variety standard for 32 years

Background: The University of Manitoba / Briggs spring wheat breeding methods project

In 1965 the University of Manitoba already had a very strong research base in exploring the genetics of wheat and other cereal crops, particularly triticale. It had also embarked on a quest to find ways to improve cereal grain yield by selecting for it directly, particularly in the early generations after a new cross was made, which was a new concept in breeding methods at that time. This concept was promoted by Dean Leonard Shebeski in particular, but there was little prior published literature on the topic. At that time yield testing in a conventional wheat breeding program did not usually start until selection for all other traits had been completed, in later generations up to seven or eight years after making the cross by which time the selected lines were already essentially true breeding. Because of this the number of different advanced lines that would be yield tested from any single cross was low, and the yield testing nurseries were usually quite small. The basis of the new concept was that because grain yield potential was controlled by a very large number of different genes acting in concert, there was a need to test large numbers of lines from each cross to have a better chance of producing a novel line with a significant gain in yield potential. If large numbers of genes affected grain yield, then this made its' improvement a numbers game, implying the need to establish the testing of much larger numbers of lines for yield, as well as testing yield more accurately in early generations. Would research on this concept of Shebeski's show that these ideas were correct?

The Faculty of Agriculture had obtained a series of grants from the Manitoba Department of Agriculture, Manitoba Pool Elevators, the North-West Line Elevator Elevators Association, and the National Research Council of Canada, to support investigations on this topic. A Plant Science Department graduate studentship was also allocated to support it. This author was very pleased to be recruited from the UK to carry out some of those studies and was later also fortunate to receive a National Research Council Assistantship which enabled completion of a four-year PhD program. The program was intended to answer research questions for which breeders needed some answers, to the extent possible from one single breeding methods project. The project did produce a number of findings of interest to wheat breeders and they were published in peer reviewed journals (Euphytica, Crop Science and the Canadian Journal of Plant Science). Findings were on a diversity of topics, some well beyond the scope of work that was originally envisaged. The following is a brief listing of some of those topic areas.

- Use of check variety control plots in wheat yield nurseries, to improve the accuracy of yield assessments
- Effectiveness of testing in early generations for yield, to predict the yield performance of lines in later generations
- Ability to visually evaluate the yield potential of lines in yield trials, to save the cost of harvesting poor lines
- The effect of protein content on the multiplicity of other wheat quality parameters, within a single variety
- Evaluation of genetic and environmental effects on spring wheat grain and flour quality
- The study of protein quantity and quality as factors in the evaluation of bread wheats

This author gained immeasurable wheat research experience from the Professors who served on his advisory committee, from the technicians who were assigned to assist in this very large field and laboratory project over four years, and from numerous other associates. They included Leonard Shebeski (Supervisor), Bob McGinnis and Laurie Evans (Supervisory Committee Members), Walter Bushuk (Professor of cereal chemistry and utilization, where the quality tests were run for this project), Bob Baker (at Agriculture Canada, and quantitative genetics expert), Farouk Chebib (fellow graduate student but expert on computer programming and data analysis, a new thing at that time), and from Didzus Zuzens (wheat program technician). These research colleagues of many years ago have all, very sadly, passed on, but their valuable inputs were all essential to all that happened then, and for what followed.

The reader will have noticed that there is no reference above to any objective of creating a new variety from this work, nor was there any expectation of that outcome at any time during the project. That possibility only appeared in 1969, at which time one selection in its 7th generation stood out as having outstanding agronomics, especially for yield.

What happens genetically in a new wheat cross? A simplified genetics explanation, with terminology

An explanation of some genetics terminology is required before the breeding of Glenlea can be properly understood.

When a cross in wheat is made between two parents (P1 and P2) the seed first produced is called F1 seed (1st Filial generation) and all those seeds are genetically identical, each carrying one set of genes from each parent, one set on the chromosomes they got from P1, plus one set from those they got from P2. No other source of genes can come in from anywhere else, since wheat is a self-pollinating crop. When an F1 plant is grown and the seed from it is harvested it is called F2 seed, and so on through the following generations as they are each in turn grown out (F3, F4, F5, F6, F7, F8, F9, F10 etc). The F2 seed is unique in this process, because each F2 seed is genetically different from every other F2 seed, because each has been newly created by the genetic recombination (mixing up) of all the genes that were different in the two parents. Thus, if one looks at a collection of F2 plants growing spaced apart, the viewer will see the maximum amount of differences in appearance that will ever be seen from that cross, which is also a reflection of how much the parents P1 and P2 differed from each other genetically.

Differences in most of the many genes that influence yield potential of a plant are not 'visible', as many are to do with the physiology and biochemistry of the plant yield itself, but the same principle applies to them. If a breeder wanted to see or create more variation between the F2 plants, and potentially also capture more variation for the yield potential genes amongst them, there are only two ways to do that: (1) Grow out a bigger population of the F2 plants so that a bigger range of recombinants is created and/or (2) ensure that the parents P1 and P2 are more different from each other in more genes, with more widely different genetic backgrounds. (The 1970 Shebeski 'Modified Pedigree' breeding method extends that concept to where the breeder would then carry out yield tests on bulk F3 seed harvested individually from each of many F2 plants, the most that can be managed in the budget the better, which was the method used in this project).

With each generation grown out (F3 to F10 and onwards) the self-pollination system of wheat causes a theoretical 50% more of the remaining genes to become genetically pure-breeding, those genes that have not already become 'fixed', so that by F9 or F10 all of the lines derived from those F2 plants would be very close to being completely pure-breeding. The breeder's final job along the way is to identify which of those advanced generation lines will perform well enough to be a new variety. In the 1960's, seed of any potential new variety would typically have been in the F7 to F9 generation before it was further genetically purified for entering into Registration performance trials. It might have reached the F11 or F12 generation before growers received seed for production, when it would then be essentially pure-breeding and all the plants within the variety would also be uniformly similar in appearance, with any remaining 'off-types' manually removed.

The Nuts and Bolts of how Glenlea (CWES) Wheat Variety was Bred, and then Registered in 1972

Personnel and Resources

There are numerous authors of the published Glenlea variety description (Evans et al. 1972). Evans was the breeder who determined the parents of all fourteen of the wheat crosses used in the Briggs project, and Evans, McGinnis and Shebeski were the grant holders of the program from which it was derived. Shebeski was also Briggs' graduate studies supervisor. Zuzens was the technical assistant who actually made the crosses and later on established the breeder seed, and Briggs was the PhD project director/coordinator/decision maker for the entire research project. The latter included the selection of individual plants and progenies from F2 onwards, and the conduct of all related yield trials until 1969, when the seed from the most advanced lines was already in the F7 generation. As previously noted, Professor Walter Bushuk, although not named on the variety release, made his laboratory staff and equipment available for all related grain and breadmaking quality tests. Briggs (personal observation) also gratefully recalls small armies of summer students made available for weeding the very large yield nurseries of this project. All weeding was done by hand as herbicide spraying in breeding nurseries was not yet a normal practice in 1965. Alternate generations (F2, F4 and F6) were grown in winter season nurseries of the CIMMYT international program at Ciudad Obregon, Sonora State, Mexico, in a collaborative arrangement negotiated by Shebeski and McGinnis, which was a vital component of the project. (NB Briggs personally managed the harvesting of materials in the winter nurseries, and spent three weeks there every April of 1966, 1967, 1968 and 1969 for that purpose, greatly envied by his fellow graduate students who were trapped in their university classrooms for the duration!)

This very large field project, and the associated extensive quality data from the breadmaking quality laboratory obtained with Professor Bushuk's collaboration, created a total database far beyond the capacity of manual calculable scope. Briggs became a close colleague of fellow Plant Science graduate student Farouk Chebib, who was already an expert on statistics and computer programming, and he provided computer programming advice on how to analyze all the data. Briggs learned Fortran programming to meet his computing needs and the new main-frame IBM card punch computer in the Engineering Faculty was also made available to Briggs for night-time use. That happened as a result of a network formed at TGIF events with some engineers, fellow graduate students and Post-Doctoral Fellows in the Faculty of Engineering, regularly held at the local but then infamous Montcalm Hotel on Pembina Highway. Computer use in the Plant Sc iences was novel then and made for a lot of very time consuming data-card punching, but saved the day!

As a matter of record, when Briggs left Winnipeg in 1969 for his new Assistant Professor position at the University of Alberta, he had already advised Dean Shebeski that if the University of Manitoba would not request registration for the line that later became Glenlea, that he would like to do so from the University of Alberta, so that the merits of that potential variety could be moved onto W. Canadian farms. He also knew at that time that Professor Bushuk was a fan of registration for Glenlea, because of its strong gluten properties that were only later better understood (Bushuk 1979). It was therefore no surprise when this variety was subsequently successfully registered by the University of Manitoba in 1972.

The origin, grain yield, agronomic and quality performance of the Glenlea 'Extra Strong' variety:

In preparation for the Briggs research project widely spaced F2 plants from up to fourteen different hard red spring wheat crosses made at the University of Manitoba were already growing in the 1964/65 winter nursery in Mexico. Each of the spaced plants would produce enough seeds (up to 4000 on a single plant) to grow a standard size un-replicated yield plot in the subsequent yield testing nursery in Winnipeg in the following summer. The cross from which Glenlea emerged (Evans et al 1972) was made in 1965 and had F2 plants growing in Mexico in the winter of 1965/1966, with harvested seed from the separate plants then used for an F3 single plot yield test, following the 'Modified Pedigree' breeding method suggested by Shebeski (1970). The cross which produced Glenlea had the parentage (Pembina^2 x Bage) x CB100, where CB100 was a Mexican strain having the cultivars Sonora 64, Tezanos Pintos Precoz, and Nainari 60 in its parentage.

When harvesting the individual F2 plants in the spring of 1966 in the Mexico winter nursery Briggs noted that one of them really stood out in appearance from all the others in that cross, being extremely vigorous in form with a very large number of synchronously maturing tillers with long spikes each with a large seed number, and also leaves clean from any of the prevailing rust and other diseases in the nursery. (A photo was taken of this strikingly different-looking robust single plant that later proved to be the progenitor of Glenlea wheat, but unfortunately it has been lost in the intervening 58 years). Seed from this plant was used to plant an un-replicated F3 bulked-seed yield plot at the University of Manitoba Research Station (at 'The Point') in the spring of 1966, one of 827 F3 lines yield tested in that nursery (Figure 3).

Figure 3

The Point, University of Manitoba

Briggs and Bob Sarges plant the 1966 F3 yield nursery

F3 Yield Nursery, 1966

Harvest time in the 1966 F3 yield nursery

The F3 plot derived from that specially noted F2 plant in Mexico proved to be the fourth highest yielding plot of the 1966 nursery, with plot number designation 203B, which became the designated name for this selection. At harvest random plants from it were grown in the Mexico winter nursery, then F5 bulks from them separately tested for yield in Winnipeg in 1967, as well as the F4 bulk. In subsequent generations beyond that F3 test the progenies selected from this line were always amongst the highest yielding of all the many other lines also retested, confirming its high yield potential suggested in the single F3 plot. The results that suggested confirmation of a high level of yield potential for 203B and its derived generations are presented here.

(A) Results from the PhD Thesis Project Study:

1966 F3 (Un-replicated plot)	130% of adjacent Manitou control plot yield	(No estimate of significant differences)
1967 F4 (Replicated yield trial)	135% of adjacent Manitou control plot yield	(Statistically significantly higher yield)
1967 F5 (Replicated yield trial)	125% of adjacent Manitou control plot yield	(Statistically significantly higher yield)

(B) Average of 50 Station-years of E. and W. Canada trials (1969-1971) from Registration Description (Evans et al. 1972)

Glenlea variety (previously 203B): 124% of Neepawa (CWRS control), and 114% of Pitic 62 (CU control)

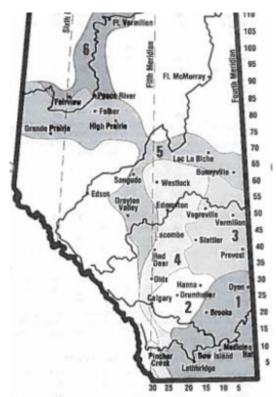
Glenlea was registered in 1972 but had to be placed in the Canada Utility Class for marketing, where it could still easily be kept separate from CWRS wheat because it had very large kernels easy to identify in the KVD based grading system (Figure 2). It was a very different quality type from the only other CU variety, Pitic 62, which was mostly used for feed, but most of the Pitic 62 harvest probably ended up in on-farm feed use, or in feed grades anyway. The CU Class by this time was perceived as a place to register high yielding wheats that could encourage a feed-wheat market, but that market never really developed. A high yielding semidwarf CU wheat named Norquay was registered by the University of Manitoba in 1973, but was deregistered two years later because of difficulties in distinguishing it from CWRS varieties using the KVD system. The significant typical yield gain of Glenlea over the most widely grown CWRS variety Neepawa was confirmed in subsequent W. Canadian Provincial Testing programs. Typical agronomic performance results are shown from the 1999 'Varieties of Cereals and Oilseed Crops for Alberta' regional performance description (Table 2).

Table 2 1999 CWES Spring Wheat performance (From: 1999 Varieties of Cereals and Oilseed Crops for Alberta)

		By Alberta Zone: Yield % of CWRS Neepawa							Days to maturity, difference from CWRS Neepawa	
		Irr 1	1	2	3	4	5	6		Lodging
Glenlea	(UofM)	105	112	115	106	112	118	116	+5[1]	Good
Laser[2]	(UofA)	121	104	114	95	115	110	99	-1	Excellent
Bluesky[3]	(AAFC)	101	104	103	103	112	113	106	0	Fair
Wildcat[3]	(AAFC)	97	100	112	96	111	105	90	0	Fair

Notes: 1 Glenlea is poorly adapted to much of Alberta because of its' late maturity
2 University of Alberta CWES variety, still new to growers in 1999
3 Agriculture and AgriFood Canada, Beaverlodge, Alberta varieties

Figure 4



Alberta Crop Zones

University of Alberta Cereal Breeding: Seeding, and Yield Plots

Although Glenlea was rated as having good straw strength, it would still often lodge under high yielding conditions (See lodging scores in Table 2). It was also a tall variety, especially under wetter conditions that promote high yield, and was much later maturing than most CWRS varieties, and suited only to Zones 1, 2 and 3 in Alberta, and also to longer season areas in Saskatchewan and Manitoba. It also proved to be a popular variety in Saskatchewan and E. Manitoba partly because of its good resistance to common root rot, smuts and rusts that could be a problem there. McCallum and DePauw (2008) indicate that it possessed the leaf rust genes *Lr1, Lr13* and *Lr34*, and was the first major Canadian variety to possess the latter important gene. It also carried the stem rust genes *Sr5, Sr6, Sr9b* and one other. In comparison to CWRS wheat varieties, which have 'strong gluten flour strength', Glenlea was soon discovered to have 'extra strong flour gluten strength', flour very different in quality from the CWRS type.

Sidebar info: What exactly is wheat flour gluten strength?........A brief but necessary technical explanation

Every Canadian wheat market class has a designated variety that is used to set the target quality requirements of the grain, its flour, dough mixing properties and other processing parameters. Glenlea eventually became the reference variety standard for the CWES spring wheat class. Any proposed new variety in any wheat Class had to be equal to or better in quality than the reference variety for its Class, in order to be registered. About mid-2000, assignment of a designated variety was changed to have several varieties to represent the boundaries for the Market Class. The quality requirements in the flour are very different for different Classes of wheat and completely influence the products for which they are best suited, as shown earlier in Figure 1. Wheat flour 'strength' is an assessment of the gluten capabilities of the protein of a variety to support the structures that are created during baking, for example that allow for a loaf of bread to rise and not collapse, and also to have a suitable crumb structure for bread loaf to be sliced and have no holes in it. As other examples, a 'very weak' flour could not make an acceptable loaf of bread, and a 'very strong flour' would not make a very good flatbread, which requires a weak strength. Soft grained wheats are generally weak, hard grained wheats are generally strong (Figure 1).

A specially designed laboratory machine, the Brabender Farinograph (Figure 5), is used to estimate the relative strength of flour samples. In this machine water is added to a sample of flour which is mixed in a bowl by a reciprocating paddle that rotates back and forth. The resistance to mixing is continuously measured and recorded on a drum chart over time, until the test is stopped. As the mixing continues the original water/flour slurry offers low resistance to mixing, but this increases as it becomes a dough, and then it becomes harder to mix, reaches a maximum resistance, and finally the dough breaks down with further mixing. Values from the changing resistance pattern are recorded and used to assess many useful properties about the dough mixing properties (Figure 5). Figure 5 shows the range of differences for some of these between a 'weak gluten' flour and a 'strong gluten' flour.

A few of the key Farinograph strength measures are noted here:

- Arrival time = Time for the mixing to reach maximum dough consistency. Doughs from stronger gluten flours take longer and need more power to reach the Peak, weaker gluten flours a shorter time and less power
- Stability = Period of time before the mixing starts to break down the dough structure. Doughs from weak gluten flours break down more quickly, strong gluten flours take much longer
- Departure time = Time from Arrival to a defined mixing resistance level (See examples in Figure 5). This is short for weak gluten flours and much longer for strong gluten flours

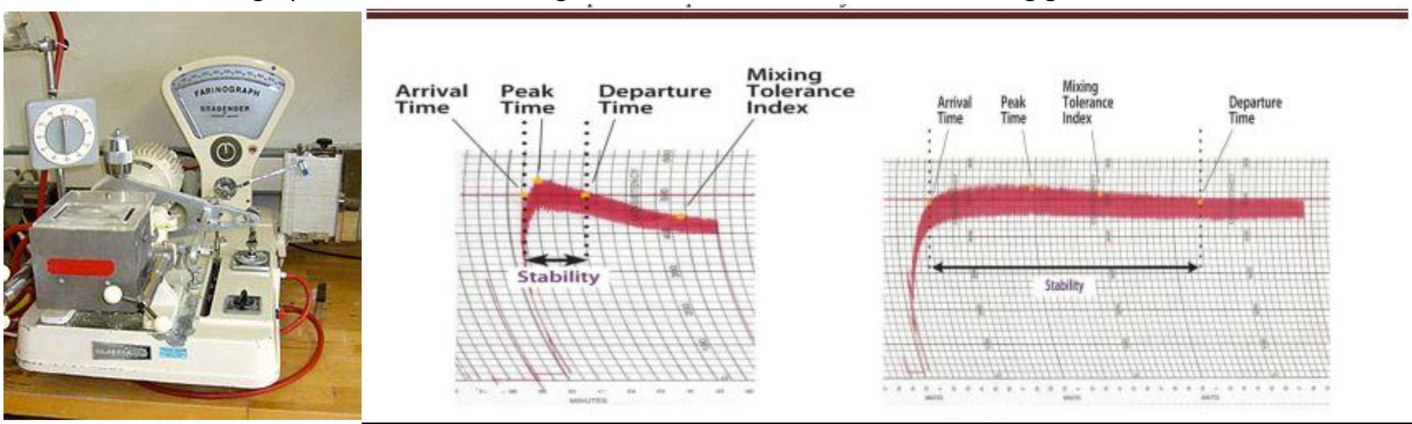
One other major quality measure that is important for any wheat flour that will be used for making bread, alone or in blends, is a measure called the 'Gluten water absorption'. The percentage of water by weight in a typical loaf of bread can range from 35% (artisan breads) to over 75% (white sandwich breads) and bakers usually prefer flours which can absorb higher levels of added water. The farinograph is also used to determine the optimum 'gluten water absorption' for a flour, a method too complex to describe in detail here, but another very important test. (Author 'trivia' note: The consumer may not be very impressed to learn that the loaf they just bought for $4.50 might consist of up to 75% water, perhaps the most expensive water they ever bought…but that 'high cost of water in food' applies to many foodstuffs we regularly consume. Even the average male human body is about 60% water (females 5% less) but can lose about 10% with ageing).

Please scroll down ! Thank you.

Figure 5

Typical farinograph charts from:

Brabender Farinograph Weak gluten flour Strong gluten flour



(Source: Brabender) (Source: Madhawi and Pandey, Lucknow University 2015)

Enough about wheat flour gluten quality, and back to the Glenlea story!

Glenlea was denied entry to the CWRS class for at least three main reasons, and most likely many more. The first was that it did not have a CWRS KVD seed type. The second was that, although it was a hard grain wheat that milled very well, its' large seed size was beyond what millers were used to in their mills, and that would cause them milling problems particularly if it became mixed with other seed of a different size or hardness. The grain protein content was also lower than that of CWRS varieties. Of greatest importance, however, was that the flour from Glenlea when used alone in the methods used for evaluating CWRS wheats did not produce bread of equal quality to that from CWRS varieties. The cause of this was only discovered later (Bushuk 1980) who determined from baking and farinograph studies that Glenlea flour had an extra strong gluten characteristic that greatly changed how it reacted in different dough mixing, baking and other processing characteristics, compared to a CWRS wheat. Apparently Glenlea flour had 'overly strong' or 'extra strong' gluten strength due to the over expression of the glutenin genetic DNA subunit *Glu-B1al,* which enabled it to 'carry' weaker gluten wheats in flour blends to make acceptable bread (Bushuk 1980). This 'quality deficiency' as defined by CWRS standards, became the very feature that later made it such a success as an 'Extra Strong Gluten' CWES variety.

In the first half of its a 32-year long (1974 – 2006) acreage success as a preferred CWES wheat Glenlea was used mainly as a blending wheat to prop up lower gluten strengths in flour mixtures containing weak gluten strength flour sources. It was also used to add extra structural strength to specialty bread loaves that included all kinds of additional ingredients, such as multi-grain breads, raisin breads and breads with special 'nutrient rich' natural ingredient additives. This specialty bread market increased very rapidly during that period. In the second half of its 'reign' as a variety it was additionally found to be a good choice for frozen dough products, where some of the gluten strength is lost during the freeze-thaw cycles of those products prior to baking. To promote Glenlea use for these kinds of products Pitic 62 was deregistered in 1993 and the CU Class was cancelled and re-named to the CWES Class with Glenlea as the only variety in it. At that time the Canadian CWES Class was the only internationally available source of that quality type, domestically or internationally, and occupied a unique new place in the world of wheat grain markets. In Canada the CWES Class was never a major one in acreage compared to the CWRS or Durum Classes but did offer a new market and pricing option for growers in the longer season areas where Glenlea was well adapted. Demand for CWES type quality fell away dramatically in the early 2000's as breeders in other countries developed their own 'Extra Strong' wheat varieties, and processors found new ways to make specialty breads and frozen dough products without need for extra high gluten levels in the flour. Some significant improvements in the available Canadian CWES varieties also occurred, described in a subsequent section. Additionally, the yields of newer CWRS varieties had increased very significantly during this period, so that CWES varieties completely lost their earlier 'higher yield but lesser price' competitiveness with the CWRS class.

More about that specific 1966 F3 plot '203B' and its striking appearance:

As the genetic material from which Glenlea was selected worked its' way through the selection nurseries and the years, PhD student Briggs was concentrating mostly on his selection methodology studies, of which that particular genetic material was also a part. His visual and yield based identification of the F3 plot 203B in the 1966 yield trial described earlier was made amongst 827 other un-replicated F3 lines in that yield testing nursery. This nursery was the site of a special study that Briggs conducted where he asked 14 different selectors (professional cereal breeders, graduate students and others) to visually identify what they thought would be the highest yielding lines in the nursery, and to pick what they thought would be the top ten and then the following ten best yielders (Briggs and Shebeski 1970). The purpose of this study was to see if a program could save the very high costs of harvesting an entire nursery (all done by hand in those days) if all the best yielders could be identified visually, so the rest need not be harvested. The yield nursery had a very high level of genetic variability in it, from a large number of different crosses from very genetically different parents included in it, so it was a good place to test this idea. What were the results?

1. All of the selectors visually selected higher yielding lines, significantly higher in yield than random selections
2. Each of the selectors missed a significant number of the highest yielding lines in the nursery
3. 12 of 14 selectors identified 203B in their first or second highest yielding group (= nearly all selectors!)

Findings 1 and 2 confirmed that a breeder had to harvest all the plots to avoid missing some high yielders of value, an outcome of interest to breeders in those days. In 1966 early generation yield nurseries with large numbers of entries were rare and very costly to run. The harvesting of large numbers of yield plots is nowadays commonplace and more affordable, with the advent of new harvesters and technology to manage it, so finding 1 and 2 became of lower importance over time.

Finding 3 was very interesting, especially in hindsight, because it was certainly a unique occasion where so many breeders nearly all independently succeeded in 'visually selecting' an F3 wheat line which actually later became a variety! A feature of this line '203B' was that the plants in it were all very uniform in appearance, which is rare in an F3 line if there are many visual differences between the parents. It also remained similarly uniform throughout all the subsequent generations until it was registered. The plants in '203B' were also very vigorous, with tillers very synchronous in growth, with much larger spikes than typical of most CWRS wheats, and high numbers of seeds per head, all of which could be visually evaluated. This line also had very large seeds which partly contributed to the high yield performance. Briggs had even taken a photo of this '203B' plot because it was so strikingly different, but that photo has also unfortunately been lost over time.

With the renaming of the Canada Utility Wheat Class to the Canada Western Extra Strong Wheat Class in 1993 Glenlea became the very first variety registered for the CWES Class, a notable achievement for the University of Manitoba wheat research program, and an unexpected thesis project spinoff for Briggs that could not have been foreseen, but the sort of thing that sometimes happens in plant breeding and other research.

Part (C) The University of Alberta Releases Laser CWES Wheat Variety, an Agronomic Improvement over Glenlea

In 1969, on arrival at the University of Alberta, Briggs initiated a modestly sized spring wheat breeding program for Central and Northern Alberta, which required the acquisition from scratch of all the required budget, equipment, support personnel and infrastructure for that project. The main objective for the program was to create spring wheat varieties which were earlier maturing and high yielding, suitable in particular for the short season high rainfall areas of Alberta, and especially Zones 4 to 6 of the Parkland Region (Figure 4). For a number of years the only available CWES variety was Glenlea, but it was only suitable for the long season Zones 1 to 3 because of its very late maturity. This small breeding program was able to register a CWES variety in 1997, named Laser, which was a high yielder in most zones in comparison to other available spring wheat varieties, and was also the earliest in maturity (Table 2). Laser had several different sources in its genetic background, which included Norquay (for strong, shorter straw and earliness), Glenlea (for its yield and quality package), and a University of Alberta early maturing, short straw selection derived from the international CIMMYT breeding program, 70M009). It was slightly earlier maturing than Bluesky and Wildcat (registered earlier by breeder Dr. Phil Clarke, Agriculture and Agri-Food Canada, Beaverlodge) but Laser had excellent straw strength, at a level not yet exceeded even by 2022 by the newest CWES wheats (Table 2). This combination of earlier maturity, high yield and excellent straw strength also made Laser very suitable for straight combining in many parts of the Alberta production. Laser was made available to Canterra Seeds for marketing, and royalties from seed sales were re-invested in the University of Alberta wheat program. During the five-year plateau of its highest annual production Laser occupied over 20% of the W. Canadian CWES acreage. Laser was particularly well adapted to conditions of high yield potential, including the conditions in the Parkland Zone of W. Canada

Part (D) W. Canadian production of the CWES spring wheat class, and its eventual demise

In this section the author relies mostly on the variety acreage estimates drawn from McCallum and DePauw (2008) in their review of the historical pattern of CWES varieties in W. Canada, plus Statistics Canada data. Glenlea itself was the major variety in the CWES type of wheat from 1974 until its rapid disappearance from the W. Canadian seeded acreage in 2007 (a run of 32 years). It was marketed in the Canada Utility (CU) Wheat Class for the first 20 years of that run, after which it was marketed in the CWES Class. Variety surveys were not conducted in W. Canada between 1994 and 1997, but McCallum and DePauw (2008) suggest that Glenlea would also have been the leading CWES variety during that period Table 3 presents estimates of the yearly total acreages of CWES production, and % area by variety, from their study.

Table 3
Average yearly CWES acreage for the period 1974 to 2021 for W. Canada, and estimated % of area by variety

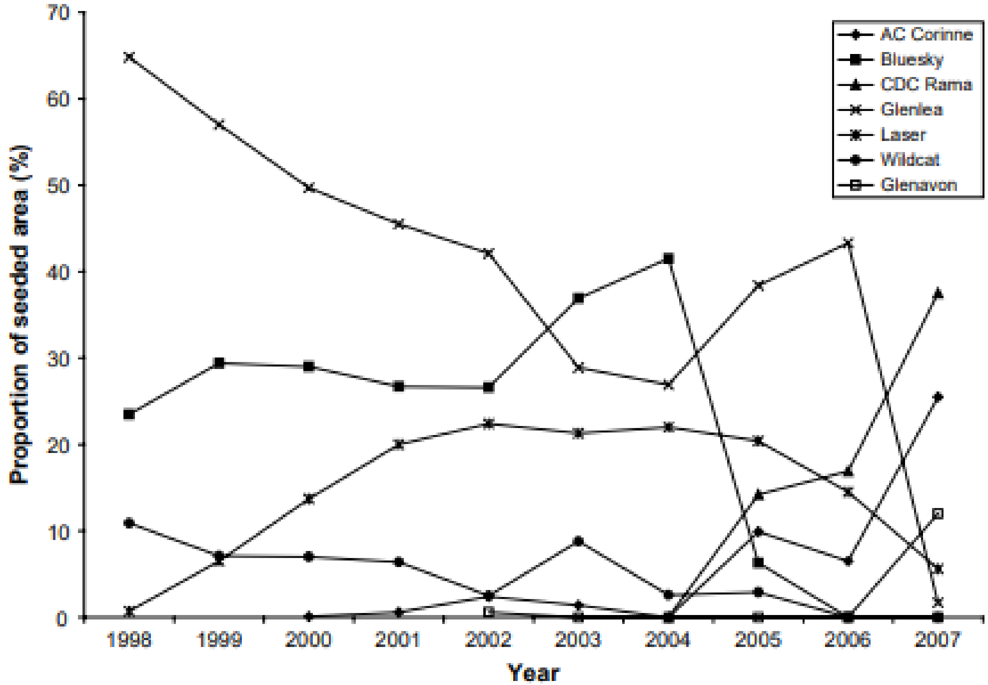
	# Yrs.	Total CWES Acres[4]	% Acres by Variety Glenlea	Bluesky	Wildcat	Laser	Others[3]
1974 - 1987	(14)	682,192	Near 100	0	0	-	-
1988 - 2000	(13)	625,569	68 in 1993	31 in 1993	1 ? in 1993	-	-
2001 – 2007	(6)	239,548	38[2]	23[2]	0[2]	21[2]	18[2,3]
By 2020	Declined to 865[1]		0	0	0	7	93[3]

Notes: 1. Only in Manitoba 2. Values for 2007 from McCallum and DePauw, 2008
3. New varieties 4. Totals also include all CU varieties up to 1992

Much of the detail about the acreage penetration of individual varieties is lost in the long-term averages shown in Table 3. Those details for 1998 to 2007 are shown in Figure 5 (Sourced from McCallum and DePauw 2008). After its domination of the Class from 1974 until the late 1990’s Glenlea acreage declined steadily until its rapid disappearance in 2007. The short resurgence of production in 2003 and 2006 might have been related to the market discovery that Glenlea level extra gluten strength was particularly of value for making frozen dough products which were increasing in popularity at that time, although this explanation is purely speculative. Some of the Glenlea acreage had earlier been replaced by Bluesky and Wildcat, both released in 1987, which both gained popularity in the short season Parkland region of the Prairies because of their early maturity. Bluesky became the preferred variety of these two, and Wildcat acreage never exceeded 10 –15% of the total CWES acreage in this period, with zero acreage by 2004.

The University of Alberta CWES variety Laser first entered the acreage picture in 1999 (coincidentally the same year Briggs retired from there after a 30-year long University career). After five years occupying around 20% of the CWES acreage the Laser % of acreage then declined, as did that for Bluesky and Glenlea, as market demand for the extra strong wheat type declined sharply, with the exception of a very small production area left in Manitoba by 2020.

Figure 5 CWES Variety % of Total Acreage, 1998 - 2007 (Source: McCallum and DePauw 2008)



Very notable in Figure 5 is the appearance in 2005 of three new Glenlea quality varieties, CDC Rama, AC Corinne and Glenavon, that replaced almost all of the acreage of all previous CWES varieties by 2007. These were each significant yield, maturity, agronomics or disease resistance improvements over Glenlea and were intended mainly for the longer season areas of the Prairies, particularly in E. Saskatchewan and Manitoba. Unfortunately, these improved varieties were launched at a time when the total CWES acreage was diminishing rapidly, with only a small acreage of production left by 2020, in Manitoba (Table 3). Other significantly improved CWES varieties were also registered from 1999 onwards until 2019, and they are also listed in Table 3. All are approved CWES Class varieties still approved by the Canadian Grain Commission for production in W. Canada, as of the 2021 - 2023 Statute. Of special note amongst these is the variety Glencross which demonstrates earlier maturity than Glenlea and is also the first Canadian CWES variety with resistance to the orange blossom wheat midge.

For a CWES variety to generate similar gross returns per acre compared to CWRS at 13.5% protein, the CWES variety had to yield about 10% more than the CWRS variety. Some of the new CWRS varieties such as AC Barrie (McCaig et al. 1996) and AC Intrepid (DePauw et al. 1999) yielded considerably more than Katepwa and were early maturing and strong strawed, rendering CWES production unprofitable in comparison. The CWRS variety AAC Brandon (Cuthbert et al. 2017) yielded 12% more than Katepwa with similar protein content and significantly shorter straw, which made all CWES varieties a non-competitive choice for growers.

Table 4 Designated CWES Varieties 2021-2023 (Source: Canadian Grain Commission 2021/ 2023 Canada Grains Act)

University bred CWES Varieties/Year registered/Institution		AAFC bred CWES Varieties	
Glenlea	1972 (MB) Univ. of Manitoba	Bluesky	1987 (AB)
Laser	1997 (AB) Univ. of Alberta	Wildcat	1987 (AB)
CDC Rama	2002 (SK) Univ. of Saskatchewan	Amazon	1998 (MB)
CDC Walrus	2004 (SK) Univ. of Saskatchewan	AC Corinne	1999 (MB)
		Glenavon	1999 (MB)
		Burnside	2004 (MB)
		Glencross	2019 (MB)
(AB = Alberta; SK = Saskatchewan; MB = Manitoba)		CDN Bison	2019 (MB)

During the peak production years of the CWES wheat Class some processors indicated that they sometimes experienced inconsistent levels of extra gluten strength in the commercial grain samples that they received, not always as strong as the original Glenlea to which they had become accustomed. This raised the question as to whether there was too much variability in the extra strength levels offered by the different CWES varieties available, which were also grown in different regions, or were these just differences induced by different growing conditions? In 2009 Christian Lukie completed an MSc study under the direction of Professor Harry Sapirstein at the University of Manitoba to find out if there might be significant differences in strength between them, even though all the CWES varieties were known to have extra strong gluten. His conclusion was that Bluesky had the same desirable level of extra gluten strength as Glenlea, but that Wildcat and Laser did not, with both of the latter having a lower level of gluten strength expression than Glenlea. A recommendation was made to the consulting group that engaged the study, to remove Wildcat and Laser from the CWES Class, and to ensure that future varieties would all be equal in gluten strength quality to Glenlea set as the flour gluten strength standard. No action was taken on that suggestion, so Wildcat and Laser are both still approved members of the CWES Class (<u>Table4)</u>.

Part (E) <u>Additional Observations and Commentary about 'The Glenlea Effect'</u>

The breeding details and the successful 32-year production run of Glenlea CWRS spring wheat was unique to that variety, but it was also a variety that played a significant role in the development of breeding methodology and the expansion of new spring wheat Class options for growers in the Canadian Prairies (Briggs, 2022 personal observation). Some of these different 'effects' are highlighted here. These observations and conclusions are generally supported by many subsequent research publications by many authors about how to best breed high yielding spring wheat varieties.

<u>Findings of Interest to Spring Wheat Breeders:</u>

- The <u>breeding methods studies</u> from which Glenlea emerged confirmed that early generation yield testing of large numbers of spring wheat lines from a cross could identify high yielding lines of improved yield potential of value to growers. Such yield testing was very costly then, however, and is nowadays better done by using replicated yield trials of much larger numbers of lines than was typical in the 1960's. The latter has now become the norm in modern breeding programs that use mechanized field equipment and more efficient field-testing technologies, both in early and later generations. Use of novel experimental designs for yield testing has also reduced the need for repeated control plots, which also reduced yield testing costs and allowed more lines to be tested for the same cost. Also, the use of the 'doubled haploid breeding' technique that accelerates 'fast-track' creation of pure-breeding lines in wheat, has now become commonplace, which also reduces many of the findings about early generation yield selection to now being of mainly historical interest. In 2021 it was estimated that as many of 50% of the recommended hard spring wheat varieties available to growers in W. Canada have been bred using the much faster doubled haploidy method. However, the findings from the Briggs early generation selection studies were still important in the 1960's. (NB Briggs did obtain a small grant in the 1990's to get the very efficient doubled haploidy method working in his own small breeding program, before it had become a routinely used method. However, results were not sufficiently reliable to apply in the breeding program, so that approach unfortunately had to be abandoned, also due to budget constraints).

- Although <u>visual selection of yield potential in yield plots</u> proved very effective at identifying many of the high yielding plots / lines in a yield nursery, the harvesting of all plots ensures that the highest yielding lines will definitely be identified. In 2022 Briggs is unaware of any Canadian or other breeding programs that use visual selection amongst plots for assessing grain yield potential in spring wheat.

- The 'Modified Pedigree Breeding Method' of Shebeski (1970) used in the Briggs studies requires every other generation to be grown as single plants that were selected for their agronomic appearance, but not for individual plant yield, which was not measured. There is now an abundance of literature that indicates that <u>selection on the basis of single plant yields, especially by visual assessment, is not effective</u> in increasing yield potential in spring wheat crosses, and that was never attempted in the Briggs project. There is still some irony that the single F2 plant whose progeny became the variety Glenlea some eight generations later was actually visually identified as a single plant that was noted as very clearly being the highest yielding plant in that irrigated F2 nursery in Mexico, under growing conditions that would never be experienced in Canada. Was this the exception that proves the rule? Briggs (2022, personal observation) notes that it was this particular plant that had the largest number of seeds of any single plant harvested in four of his consecutive Mexican winter nurseries (nearly 4,000 seeds, a veritable bush of very productive tillers, with long spikes each with a high number of seed-bearing spikelets on that very productive plant). Was that just one of those serendipity, once in a lifetime events, from which both Briggs and the wheat farmers of W. Canada directly benefited? Or was it just the Shebeski breeding methodology theories proving out favorably? As for methods of assessing yield, Briggs does not disagree with the literature that shows that measuring yield on single plants is ineffective, but does agree that replicated plot yields are the best way to assess grain yield potential of large numbers of breeding lines, nowadays a normal breeding program practice. Modification to the Shebeski method by the wheat program at Swift Current AAFC has practiced early generation selection for grain yield, protein content and a whole suite of other traits (Pers. com. DePauw. 2022). DePauw's modification of the Shebeski method has successfully resulted in varieties from this program occupying 40% to 60% of all wheat acreage in Canada, for example AC Brandon (Cuthbert et al. 2017).

- The use of frequent control plots to improve the accuracy of grain yield assessment in early generations is not a protocol that survived into modern breeding methods, but was replaced in DePauw's modified Shebeski method by a special statistical method that uses moving means to correct for the inherent background variation in potential yield that occurs throughout any field used for yield trials. Use of this method has also been validated under W. Canadian Prairie conditions by a number of studies conducted by other Canadian wheat researchers. It has proven to be very effective and is a much more efficient approach that allows much larger numbers of breeding lines to be evaluated with the same testing budget.

- One single research project could never answer all the questions that were posed in 1965! The bigger questions for wheat breeders in the 21st Century now revolve around the newer breeding methods available, such as how to optimize the use of doubled haploidy in concert with sundry other new molecular genetics selection techniques, especially for individual gene deployment and the use of DNA markers, a whole new world of plant breeding methodology. The genetic theories that Professor Shebeski proposed over 50 years ago, and that the Briggs cohort of fellow plant breeding graduate students learned from him at the University of Manitoba, have nevertheless stood up well to the passage of time. The valuable variety Glenlea was itself a very tangible outcome from the very first time that 'the Shebeski method' was actually applied in a breeding program.

Effects of Glenlea on the Creation of New Spring Wheat Classes in W. Canada:

- Glenlea was first registered as a Canada Utility (CU) class wheat, which was initially viewed as a Class for handling high yielding wheats that might have a place in a potential 'low priced grain' feed-wheat market. Prior to the CU Class no new Canadian spring wheat classes had been created since the 1930's. Glenlea was easy to keep separate from the premium CWRS bread-wheat Class because its large seed size was a good marker to satisfy the necessary KVD requirements of the day. It was the only successful CU wheat variety that achieved significant acreage penetration and accounted for nearly all of the CU grain deliveries until 1993.

- The 'Extra Strong Gluten' quality characteristics of Glenlea were very quickly identified by the time Glenlea was registered. Its newly discovered demand as a blending wheat to support the flour quality limitations of weaker wheats led to specific marketing of this new kind of wheat quality in domestic and international markets. This was more easily achieved by the creation of the new CWES spring wheat Class in 1993, specifically developed for marketing Glenlea, a unique quality type then made available to international markets and a major new event in the generally conservative Canadian wheat system. During its 32-year production run the additional market for

Glenlea in frozen dough products also emerged. It disappeared as new processing technologies were found that diminished the need for the extra strong gluten flour. These advantages of Glenlea also disappeared as some other countries developed their own extra strong wheat varieties, and because very large yield gains in newer Canadian CWRS varieties made CWES non-competitive in per acre returns for Canadian farmers.

- As Glenlea in its new CU and later CWES Class appeared as an alternative spring wheat choice for growers they still remained interested in having access to even higher yielding varieties that could be sold into the biggest world wheat markets, including those that required wheat with a medium protein content, medium gluten strength and medium kernel hardness ('3M'). A variety of that new quality type for Canada was registered by Agriculture and Agri-Food Canada in 1985 to accommodate this new demand, named HY320. A new Class had to be created for it, Canadian Prairie Spring - Red (CPS-R) spring wheat (DePauw 1995). However, breeders of all the newest classes (CU, CWES and then others) argued that the KVD system still limited their ability to release even better varieties, and even more diverse quality types for diverse markets. The pressure for changes away from the KVD system first started with the breeding issues in the CU and CWES Classes and then in the CPS-R Class, eventually leading to the need for KVD being abandoned in 2008 as a breeding requirement. This immediately resulted in very significant increases in yield potential and improved agronomic features in many different spring wheat quality types, the creation of many more Market Classes (Table 1), and in an increased rate of release and proliferation of spring wheat variety choices for growers, even within Classes. For example, even in the CWRS bread-wheat Class, the number of recommended varieties available to choose from in Alberta rose from 28 in 2008 to 50 by 2022. This was at least partly because the KVD restriction was removed, allowing for more varieties to qualify for registration. Also created was a better chance of a successful outcome from an increasing level of investment by the private sector in wheat breeding, whose activity also increased with the advent of Plant Breeder's Rights. Although it was a CWES wheat, Glenlea was a significant variety that helped draw attention early on to the need to create more market choices for W. Canadian growers, and to reduce the risk of depending on only a single quality type, the traditional Canada Western Red Spring (CWRS) bread-wheat type.

- The details for the transitions that had to occur to allow new Classes of wheat to come into play in W. Canada are very complex, but the concept was caught in various proposals of the kind shown in Figure 6, an example prepared by the Canadian Grain Commission in 2015. It illustrates the thinking, the objectives and one hypothetical model for Canada spring wheat to compete with its major wheat sales competitor, the USA Hard Red Spring Wheats (U.S.HRS). With KVD gone, consideration of concepts such as this (but not necessarily this one itself) generated a more liberating planning model for plant breeders, and did lead towards many more successes in gaining genetic improvement in spring wheat yield potential.

In Figure 6, for example, three existing Canadian spring wheat classes are shown, each offering a quite broad range of both gluten strength and protein level within their production range, and all in competition with the U.S. HRS, but overlapping and to some extent competing with each other in quality type for international markets. A novel example proposal on the right in Figure 6 used the concept of tightening up the quality requirements for each individual Class so that each offers a more narrowly defined and more targeted quality type. Thus, the three different flour qualities of each are more distinct from one other in the market, and therefore do not compete so much with each other. Many benefits might occur from this plan:

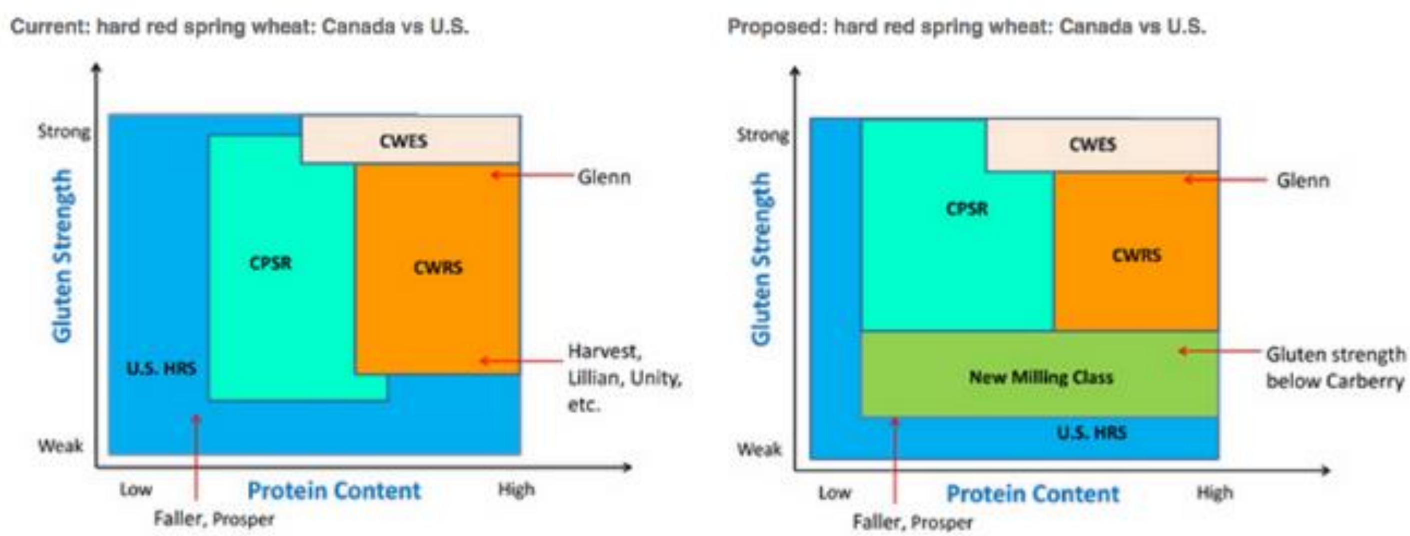
1. With more clearly defined, narrower quality goals breeders can more easily find a Class fit for a new line that has higher yields and improved agronomic traits.

2. Potential new varieties are bred that have qualities targeting the more narrowly defined quality needs of different processed products, where the consequent quality superiority to wheat from non-Canadian competitors then commands a better price.

3. More specialty Classes means more Specialty wheats for different specialty markets, rather than having more broadly defined wheat Classes trying to fit wherever they can.

4. Creation of a new Class to target a very large international milling class market, where none of the three existing classes previously fitted very well (the new 'green box'). These kinds of concepts have been acted on by the Canadian Grain Commission and are reflected in the much larger range of spring wheat Classes that Canadian growers can produce today, as reflected in Table 1 presented at the very beginning of this script. More choices for farmers, more markets to produce for, and most importantly, more probability of breeders releasing more choices of varieties for different production conditions! However, one also must expect that not all new Classes might succeed, and that market demands will continually change. What is it they say……."the only constant is change itself"! The 32-year long successful CWES niche market for Glenlea was a good example of that, when it quickly and almost completely collapsed because of novel wheat processing changes that emerged. This took away the need for genetically delivered extra strong gluten, an outcome which could not have been easily predicted.

Figure 6 Visualizing Future Needs for New Canadian Spring Wheat Classes to Compete with US Wheat _A Model for Discussion (Source retrieved 14/3/2022 Canadian Grain Commission, 2015)



The Value of Glenlea CWES Spring Wheat in W. Canada:

- It is very unusual for a single variety to have a 32-year run as the most widely grown variety in any wheat Class grown in W. Canada, as did Glenlea. This probably reflects not only the market satisfaction with the variety but also the fact that the breeding of CWES quality spring wheats did not have a perceived high priority as a major objective of any of the larger breeding programs until the latter half of the Glenlea era. Consequently, there were few new CWES varieties available to replace it until the 2000's, and those then gained very little acreage as the demand for the Class was already tailing off.

- Another factor that reduced the competitive value of CWES varieties on producer fields was the steady march of per acre yield improvement as a result of intensified breeding of very successful CWRS varieties, so that the earlier yield advantage of CWES varieties was lost, combined with the fact that the per bushel value of CWRS was also higher. (NB from Briggs: Many of the varieties that provided the yield increases in CWRS varieties during this period were products from the breeding program of the second author of this script. DePauw has published separately about how those yield increases were achieved.)

- The value of most new varieties is substantially related to how many acres of production they occupy over their production run in their targeted area of production, and their agronomic value. No officially accepted estimates of CWES Class farm-gate value have been reported, nor are they easily made, and nor are they substantively attempted here. However, with an average insured production of 0.65 million acres per year from 1974 to 2000, plus an additional average production of 0.24 million acres per year from 2001 to 2007, and a likely average yield greater than 40 bushels per acre, the total farm-gate value might conservatively have exceeded $63 million per year (based on only $3/bushel), with a 32-year total of over $2 billion. The University of Manitoba can certainly continue to celebrate that major outcome from its investment in the research which produced Glenlea. This first author is pleased to share this story about the research and circumstances that produced the 'bonus' outcome from that long ago graduate student project, the variety Glenlea CWES red spring wheat.

Canada Western Extra Strong (CWES) Red Spring Wheat: The Best Choice for Flour Blends and Frozen Dough Products
(Photo sources: unsplash.com)

Bon Appetit !

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