A study on

The Growth Potential of Triticale in Western Canada

A report that outlines the characteristics and potential
of triticale as a crop in W. Canada,
and identifies the barriers to reaching this potential

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Executive summary

A review of the current status and future potential of triticale in W. Canada was conducted by GrainTek as a consulting project for the Government of Alberta (Alberta Agriculture, Food & Rural Development). This study reviewed past triticale production patterns worldwide, the genetic breeding basis that supports current variety release in Canada, and the extent of varietal adaptation to W. Canadian conditions, in comparison to other adapted W. Canadian grains. The review included assessment of triticale use for feed, forage, silage, human food, nutraceutical and industrial applications, not all of which have developed into Canadian markets at this time.

The study used a number of approaches to access information, including literature reviews, government, industry and other publications, proceedings of international conferences, discussions with cereal breeders (including triticale breeders), crop specialists and seed growers, and surveys directed to designated groups to obtain special information. Other approaches included very extensive searches on the web, and numerous phone calls. Opportunities were also taken for discussions with attendees at the CSGA (Alberta Branch) meeting in Edmonton (January 2001), at the Cereal and Oilseed Advisory meeting in Lacombe (December 2000), and at the Prairie Registration Recommending Committee for Grain in Saskatoon (February 2001). Other travel initially anticipated to Saskatchewan and Manitoba was not undertaken, as parties there preferred to provide information by phone or email. Visits were made to API Grain Processors, Red Deer, Alberta, to discuss aspects of ethanol production using grain, and to Progressive Seeds Ltd. to discuss their interests in seed sales of varieties from the Alberta Government breeding program. All discussions were focused on identifying views on the prospects for increasing triticale acreage in W. Canada, and in identifying crop characteristics, or informational and research deficiencies that would hinder further adoption of the crop.

The report is presented in four main sections.

Section A describes the scope of the study, and the international and national crop area of triticale. W. Canada grows only approximately 73,000 hectares of the world crop of around 3.9m hectares, although the Canadian area is likely considerably underestimated due to unreported forage production and farmer-run seed use. A major expansion of Canadian use occurred in 1998 and 1999, probably associated with an increasing crop use for forage and silage.

Section B reviews the two Canadian breeding programs, and recommends breeding priorities for the future. It strongly recommends continuation of both breeding programs, especially for silage and other forage applications, and for swine feed use.

Section C, entitled 'Experience-based, end-user, evaluations of triticale' has 10 sub-sections. The first three report findings from a seed-grower survey, from discussions with Alberta and other crop specialists, and from a mini-review about Canadian triticale use, conducted by a visiting student working at AAFC, Swift Current in 1999. The remaining

sub-sections individually review use for feed, for forage (including a survey of several triticale silage users), for flour-based food products, for fractionation to identify value-added grain components, and for ethanol fuel production. Following discussion and evaluation in each of these categories, specific recommendations are made for each, that could help in alleviating obstacles to adoption for that particular use.

Section D considers all other issues seen as important for trticale, and presents discussion of the marketing difficulties related to non-approved 'brown-bagged' seed use (which seriously compromises *bona fide* seed sales), and a novel approach for assessing higher revenues from check-offs on cleaned seed, proposed by a seed company. A substantial number of recommendations are made about methods that can be used to improve producer knowledge about this crop, which, as with the animal feed industry, is generally at a low level. An optimistic view about the ability to increase triticale acreage is made in this report, based on the extensive review of all related factors. A target to double the acreage within three years is seen as achievable, given action on many of the recommendations.

Over 60 individual recommendations are made in this report. Of these, four are dominant, and 'over-arching':

1. Producers, processors and feeders all lack access to a fully informative, reliable source of Canadian information about this crop and its potential for forage, feed and other uses, which provides localized data relevant to their needs. Information about triticale is hard to find, or is outdated or limited in scope. A major 2-year effort to establish a central information site for the crop is needed, including website technology, combined with an expansion of prairie-wide meetings to describe the value of this crop as a forage and as a feed for monogastric animals. The value of triticale use in the context of highly manured cropping systems, as a disease cycle breaker in intensive cereal cropping systems, and as a reliable forage or grain supplier in times of drought stress has not been fully brought to the attention of the potential users. Also, in this time of increasing demand for forage and feed to meet the needs of rapidly increasing livestock numbers, the potential benefit from the higher grain and forage yields of triticale compared to other crops has not been fully exploited. A renewed and expanded extension program that describes the potential benefits of triticale must do this in the context of its potential to contribute to sustainable cropping, animal feeding and agricultural management systems, not just on the merits of the yield potential, or as a low cost feed.

2. Some basic research using the improved new varieties for W. Canada is needed to build a more valid feed data base for use in feed formulations. Much of the earlier Canadian data is based on old varieties which had deficiencies in test weight and other factors that are generally no longer a problem. Extensive use of research conducted at production scale commercial facilities is recommended, to answer some of the outstanding questions about triticale use for silage, and for swine and poultry feedgrain. A specific market demand for trticale grain for cattle feed is not expected to develop, nor is it expected to contribute significantly to triticale acreage expansion.

3. The scope for expanded acreage for silage use is seen as the greatest opportunity, although to support this, there needs to be some applied-use studies completed that investigate the optimum time of cutting, the optimum cut size for triticale silage, and studies of feed acceptance. Agronomic studies to look at region specific use of spring or winter types in mixtures (spring/winter mixtures, mixtures with other cereals, or mixtures with legumes e.g. peas) need to be completed, as well as feed acceptability studies of those mixtures.

4. Internationally, triticale is used as a preferred feed for swine because of its excellent energy and protein quality profile, which allows for less use of high priced protein supplementation. This use has not yet been extensively adopted in W.Canada, but is now starting. Extension and production unit research and demonstration is needed in Canada to expand this use of triticale grain for swine, to catch up with the technology adoption on this front that has already happened elsewhere. Impact of this approach would probably be greatest in the grain grower – processor – feeder enterprises, which are abundant throughout W. Canada, offering large potential for acreage expansion. Benefits of triticale production on highly manured lands can also be captured in this grain production scenario.

A summary report of the complete set of recommendations is presented in a separate report entitled 'Summary recommendations from a study on the growth potential of triticale in W. Canada'. Each of the individual recommendations is discussed at length in this main report. In addition, an extensive bibliography relating to each of the discussed topics is also included in this main report.

Acknowledgements and disclaimer

The information and opinions expressed in this report were compiled from the literature and from interviews and meetings with many persons in W. Canada and elsewhere involved with Triticale production, processing or consumption. The author accepts responsibility for any errors or omissions in the representation of these sources. GrainTek also acknowledges with thanks the many inputs from the following persons, without whose in-depth knowledge the report would be much less informative. Many others also contributed, but their names are not listed, at their request:

Daryl Dimitrik (Man. Agric. and Food); Jill DeMulder (AAFRD); Murray McLelland (AAFRD); Trevor Schoff (AAFRD); Ron Hockridge (AAFRD); Curtis Weeks (AAFRD); Graham Ogilvie (Progressive Seeds Ltd); Dr. Jim Helm (AAFRD); Dr. Don Salmon (AAFRD); Dr. Grant McLeod (AAFC, Swift Current); Tracy Knowles (API, Red Deer); Rick Corbett (AAFRD); Dr. Doug Korver (AFNS, University of Alberta); Dr. Willem Sauer (AFNS, University of Alberta); Dr. Zenon Kondra (Miracom, Carstairs); Dr. Mirza Baig; Dr. Linda Hall (AAFRD); Dr. Gary Mathison (AFNS, University of Alberta); Dr. John Kennelly (AFNS, University of Alberta); Emily Samoil (AARI); Peter Dzikowski (AARI); Dr. Don Milligan (Beef specialist, AAFRD); Dave Struthers (Winter Cereals Canada); Many respondents to the feed industry and silage use questionnaires, and respondents to other letters and emails (not all listed here).

I wish to thank the many triticale seed growers and marketers who shared their extensive experience with this crop by completing a questionnaire, and in conversations with myself. These included Len Solick, Greg Herle, Rex Cunningham, Edwin Kiffiak, Leo Meyer, Mel Stickland, Glen Goertzen, Allan Hardy, Leonard Haney, Patrick Fabian, Sulo Luoma, Marvin Nakonechny, Bryan Corns, Dan Michener, and Richard Nordstrom. Other contributing seed growers are also thanked, who chose not to be specifically acknowledged here.

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SECTION D

SECTION A

1. Scope and purpose of the study, and organization of the review and report

The scope of this report is described in the agreement between GrainTek and the Alberta government, where GrainTek agreed to conduct a review to be completed no later than March 31, 2001. The Appendix of that agreement describes the scope as follows

'The growth potential of triticale in western Canada'

'Triticale, after nearly 30 years of research, is beginning to find a place in western Canada cropping practices. This crop has potential as forage, feed grain, alcohol production and food uses. Alberta Agriculture, Food and Rural Development, Field Crop Development Center in Lacombe has been a leader in the development of both winter and spring types of triticale and have partnered with Progressive Seeds Ltd. to market their varieties and to develop market opportunities for triticale. Over the last three years they have concentrated upon the forage potential of the crop. The acreage of triticale sown for all uses has gone from a few thousand acres to an estimated 100,000 acres in the last 3 to 4 years. In order for this growth to continue we must identify the potential for this crop and the existing barriers to reaching this potential. Some of these barriers will be educational in nature but many will be due to the lack of quantifiable research information on the production and utilization of the crop.

……(Therefore)….a comprehensive report will be prepared that will outline the potential for triticale as a crop in western Canada, and that will identify the barriers to reaching this potential. …..(It is expected that) …..a set of recommendations will be developed that will guide the department's and it's partners in the realization of this crop's potential'.

Although the focus of this review is on the potential in western Canada, the scope accepted is wider than that, and also includes the international situation for triticale development. Many countries have larger acreage and more diversified market uses than found in Canada (Table 1), and the experience in these markets and in the international breeding and use of triticale is also briefly reviewed in the context of the project objectives. Statistics for Canadian triticale production are presented after Table 1, but are likely underestimated because of unreported use as forage acreage (sourced from Statistics Canada). Many contacted during this review felt that the Canadian acreage estimates were not very reliable, and several felt it was underestimated by as much as 50%.

This report, although much involved with review of triticale performance and its potential, does not attempt to provide an exhaustive compilation of literature about the crop. This is available, in many cases, from other existing sources. The general structure of the review and report is based on the following general format:

1. A detailed description of the genetic basis (past, current and future) from which improved triticale varieties of the future will be derived. This section also emphasizes

the strengths and weaknesses of existing Canadian varieties for various end-uses, and breeding priorities and advances that would be desirable.

2. Canadian experience with triticale is described, drawing on inputs from seed-growers, researchers, scientific literature, feed formulators, producers and end-users. Special meetings, phone interviews and surveys were also conducted for this purpose.

3. For selected applications / end-uses additional review was conducted of Canadian-based research (and other related sources), for feed use, forage use, food use and industrial use. In most cases this also served to highlight the limited local adaptation / end-use work conducted in W. Canada with the new, improved Canadian varieties.

4. Each section of the report concludes with a summary assessment of where the limitations to triticale use in that use sector occur, and sets forth recommendations that could assist with the expansion of triticale crop adoption and use in W. Canada.

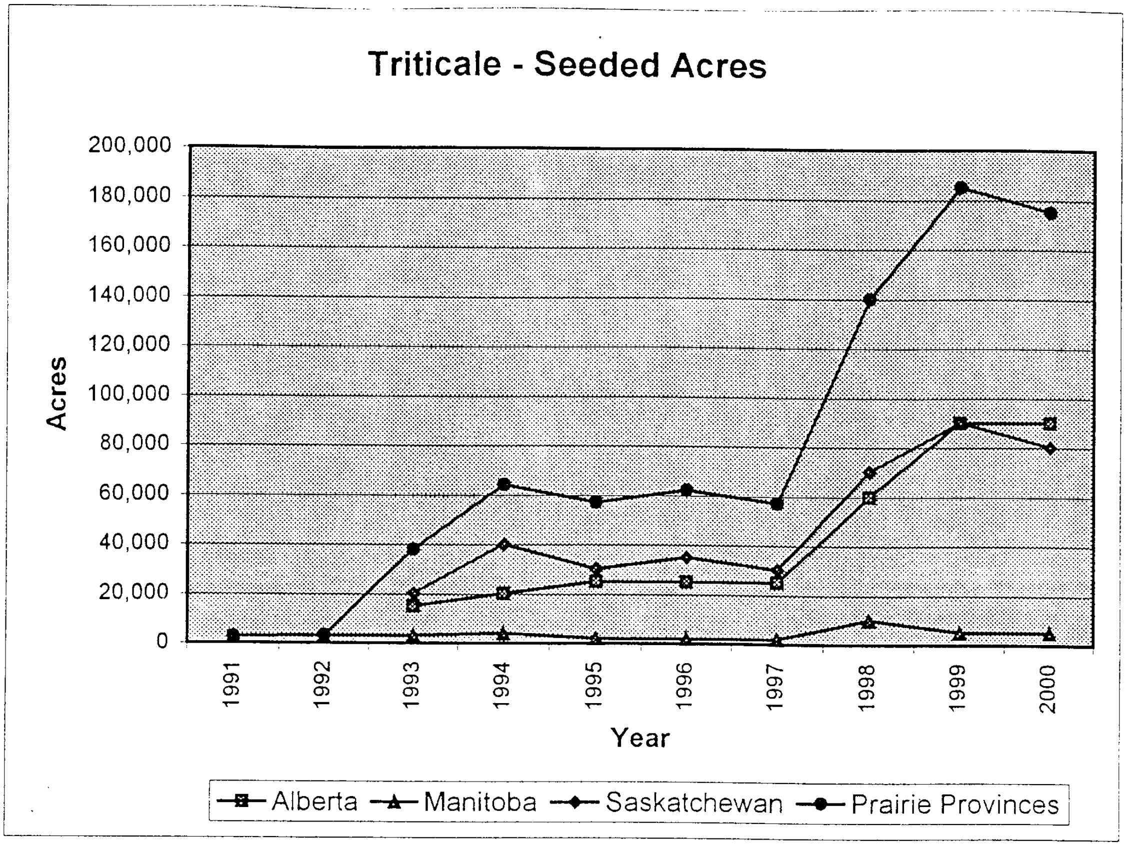
Table 1 Triticale production (area in hectares) in 1986, 1991-1992, 1995,1997-1998 and 2000
(Sources: Guedes-Pinto, H., Darvey, N., and Carnide, V. P. Eds., 1996 Triticale: Today and Tomorrow. P17, from W. H. Pfeiffer, CIMMYT, Dev. in Plant Breeding, Kluwer, 1996; and Juskiw, P., Ed., 1998. Proc. 4th Int. Triticale Symposium, July 26-31, 1998, Red Deer, Alberta, Canada p.xiii); FAO data for 1995 and 2000 from www.fao.org; Canada 2000 data from Statistics Canada

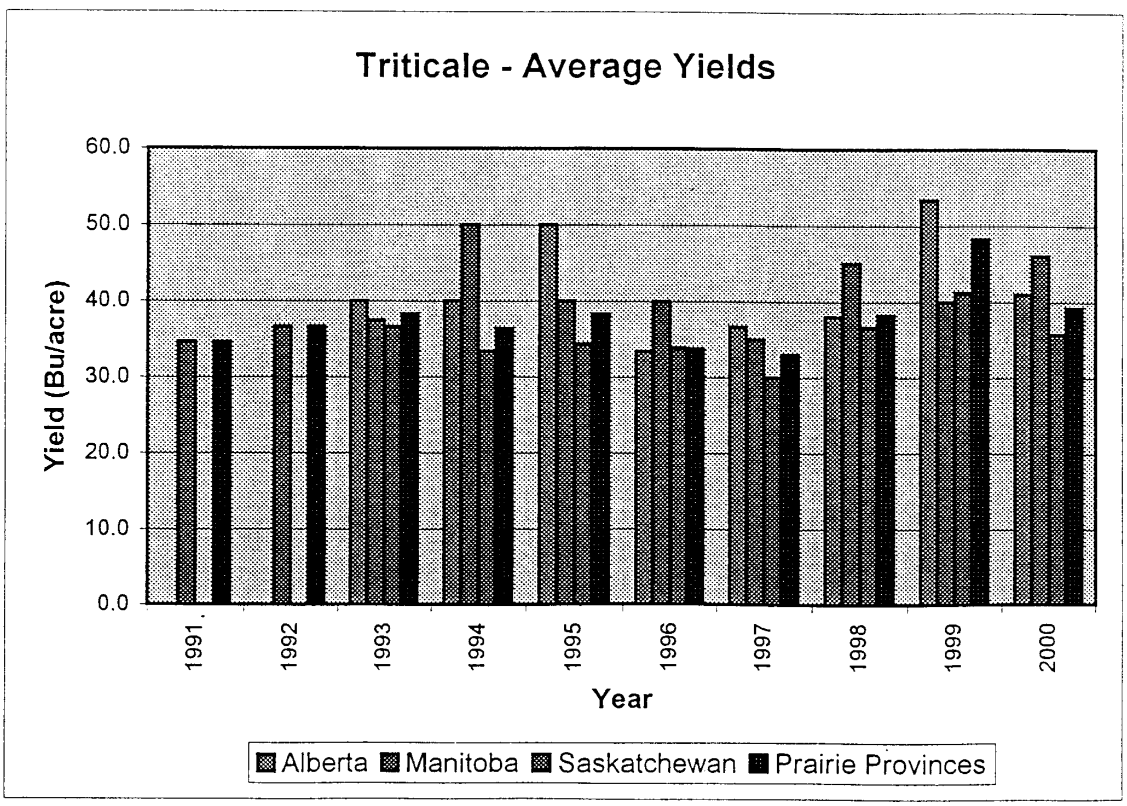
Country	1986	1991-1992	1995	1997-1998	1997/98 Type		2000
Algeria	-	10,000	-	10,000	1,2	S	-
Argentina	10,000	16,000	-	-	1	S	-
Australia	160,000	100,000	221,097	245,000	1,2	S	286,000
Austria	1,000	2,000	19,279	-	1	W	27,500
Belarus	-	-	38,000	73,200	2,3	W	65,000
Belgium (+ Luxembourg 1995,2000)	5,000	10,000	12,300	9,000	1,2	S	11,600
Brazil	5,000	90,000	-	100,000	1	S	-
Bulgaria	10,000	100,000	-	5,000	2	W	-
Canada	**6,500**	**2,000**	**-**	**34,000**	**2,1**	**S,W**	**63,842**
Chile	5,000	10,000	-	-	1	S	-
China, NE/Heilongjiang (*All China)	25,000	1,500	690,000*	41,000	1,2	S,W	700,000
Fed. Republic of Czechoslovakia	-	25,000	16,219	-	1	-	37,168
France	300,000	162,000	183,500	165,000	1,2	S,W	233,000
Germany	30,000	207,000	288,600	436,000	1,2	W	499,499
Hungary	5,000	5,000	64,000	-	-	W	91,000
India	500	-	-	-	-	S	-
Italy	15,000	30,000	-	-	-	S	-
Kenya	-	8,000	-	-	-	S	-
Latvia	-	-	2,700	2,000	2,3,4	W	6,400
Lithuania	-	-	22,500	-	-	-	32,000
Luxembourg	400	2,000	-	-	-	W	-
Mexico	8,000	3,000	-	6,000	1,2	S	144(?)
Morocco	-	10,000	-	17,000	3,1		-
Netherlands	1,000	4,000	2,600	-	-	W	6,600
New Zealand	-	2,000	-	-	-	S,W	-
Poland	100,000	659,300	616,443	736,000	1,2	W	600,000
Portugal	7,000	90,000	44,126	48,000	3,4	S	26,000
Romania	-	20,000	-	25,000	2	-	-
Slovakia	-	-	7,683	-	-	-	8,700
South Africa	15,000	95,000	-	60,000	1,2	S,W	-
Former USSR	250,000	500,000	-	500,000	1,2	W	-
Spain	30,000	80,000	-	34,000	3	S	-
Sweden	-	1,000	-	-	-	-	-
Switzerland	5,000	11,000	5,350	-	-	W	9,000
Tanzania	400	-	-	-	-	S	-
Tunisia	5,000	16,000	-	-	-	S	-
UK	16,000	16,000	7,000	6,000	1,2	W	9,000
Uruguay	-	-	-	4,000	1,2	-	-
USA	60,000	180,000	-	350,000	2,1	S,W	-
Total	1,075,800	2,467,800	N/A	2,906,200			N/A

- = No data; 1= Feed; 2=Fodder; 3=Food; 4=Industrial; S =Spring type; W = Winter

Total world hectarage 3,902,353 ha (Calculated from sum of most recent estimate for each country)

1991 –2000 Triticale acreage and yields (Source: Statistics Canada, February 2001)





SECTION B

GENETIC BASIS, BREEDING AND VARIETAL PEFORMANCE OF TRITICALE

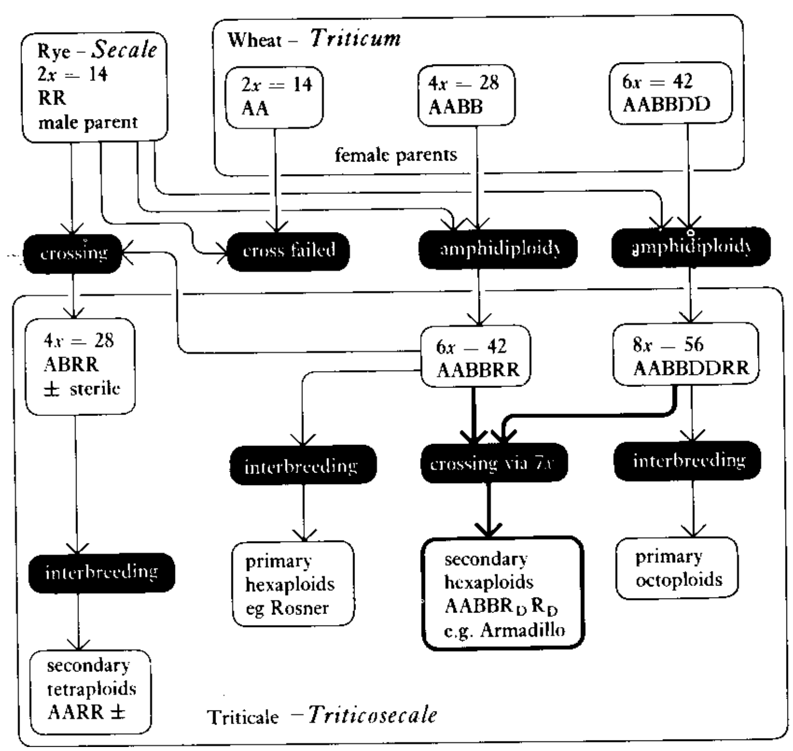
2.1 Genetic sources and potential of 21st century triticale germplasm: Past, current and future breeding goals, achievements and limitations

2.1.1 The synthesis and genetic structure of triticales – there are many kinds

Since the very first hybridized triticale was made from crossing rye and wheat in 1876, many more triticales have been synthesised. This has resulted in this novel species (non-existent in the wild state) becoming suitable for cultivation as a crop for many different purposes. Some of the earliest work that actually resulted in varieties of commercial value was conducted at the University of Manitoba from the mid 1950's to the early 1960's, with the variety Rosner being the first triticale released in N. America. Since that time Canadian breeding research has endured varied levels of support, including termination of the Manitoba program, but longer term commitment evolving at Lacombe, Alberta (funded by the Alberta Government) and at Swift Current funded by Agriculture and AgriFood Canada (AAFC).

Triticales are synthesised by crossing rye either with tetraploid (durum) wheat or with hexaploid (bread) wheats, to create triticales that are hexaploid or octaploid, respectively. The summary chart from Simmonds (1976) in Figure 1 concisely compares the many different kinds of triticale which exist, and describes their varied chromosomal constitution.

Figure 1 The evolution and origins of triticale (Simmonds, 1976)



Hexaploid triticale has proven to be the most successful commercially, to date, and most breeding and research continues with this type because of its superior vigor and reproductive stability compared to the octaploid type. Primary hexaploid triticales therefore have 28 chromosomes from the durum wheat (genome AABB), plus 14 chromosomes from the rye parent (genome RR), for a total 42 chromosomes, but they lack the DD chromosomes from a different species, which donated the bread quality genes to breadwheat. By contrast, the octaploids have 56 chromosomes, 42 from wheat (AABBDD), plus 14 from rye (RR). The octaploids therefore often have better breadmaking quality, but often prove to be unstable in field performance, as well as suffering from genetic instability that leads to floret sterility.

The products that arise from the initial combining of the genomes of rye and wheat, unmodified by further hybridization, are described as Primary triticales. The production of these primary triticales is a rather difficult and slow breeding procedure, and almost no new primary triticales have been produced in Canada since the termination of the Manitoba program. However, a wider array of primary triticales has been produced in other programs internationally since then, and these are almost all represented in the international breeding centered at CIMMYT, Mexico as part of the CGIAR research network. (CGIAR = Consultative Group on International Agricultural Research). CIMMYT also continues to create new primaries, but none are now made in Canada. Both Eastern and Western Europe has been active in primary production, as well as Australia. Primary triticales, however, always require substantial breeding work to remove the problems which they express. These problems generally include partial floret sterility, shriveled seed, low yield potential, poor adaptation to local production conditions, and poor agronomic characteristics. These problems in primaries continue to occur despite recent efforts to pre-breed the rye and wheat parents to seek complementary genes in the two planned parents. In many cases desirable genes from both parents are known to be present in the new primary triticale (as assessed by use of DNA probe technology), but the genes do not express at a suitable level, or may not express at all.

Because of these problems with primaries, breeders started to intercross different primaries, and also cross them with wheat, to seek improved expression of desired traits. The products from this approach are called Secondary triticales, and have new combinations of rye and wheat chromosomes. These types are the most common commercial triticales worldwide, including all Canadian varieties so far released. The only significant production of octaploid primary triticale is believed to be limited to China.

According to the complement of rye chromosomes present, a particular triticale might also be ‘Complete’ or ‘Incomplete’. ‘Completes’ are those where the triticale retains unchanged all of the chromosomes from the rye parent. Generally these types retain much of the robust adaptation characteristics desired from the rye parent, and thrive under conditions where rye is well adapted, such as sandy soils, at high elevations, under high rainfall, or in droughty or soil acidic conditions. Thus, ‘complete’ triticales tend to be the type of choice for superior plant growth in marginal agricultural areas, where other crops including wheat may not perform well.

Two of CIMMYT's complete triticales, Beagle and Drira, are progenitors of many of the present day commercial varieties grown in Australia, Spain and various third world countries, and appear in the background of many breeding populations distributed worldwide. Another important 'complete' triticale that features in many pedigrees is the winter variety Lasko, bred and released in Poland.

'Substituted' triticales are those in which the rye chromosome 2R has been replaced with the wheat chromosome 2D from breadwheat. This important change allows for an improvement in bread-making quality in triticale, and was also associated with a solution to the problem of seed shriveling and floret sterility of early triticale varieties. The source for this change was through the variety Armadillo, the product of a naturally occurring outcross from wheat into triticale at CIMMYT.

Under non-stressed conditions the 2D/2R substituted types generally perform better than other triticales. They tend to mature earlier and may be better for bread-making, and offer better prospects for improvement in dough strength from the flour. Unfortunately, the chromosome also contributes a sticky dough characteristic that can be very detrimental for products made in high throughput mechanized processing facilities. Other substituted chromosome types also exist, including the 6A/6D wheat chromosome substitution, which introduces improved bread-making quality, but with all the rye chromosomes still present. This type is found in some CIMMYT materials, as well as in some European winter types.

In many cases where triticale has been backcrossed extensively to wheat, this may result in elimination of some or all of the rye chromosomes, or in retention of only parts of the rye chromosomes which may have translocated (attached) themselves to the wheat chromosomes. These types are sometimes described as 'Partial' triticales. Without cytological analysis it is not possible to know the chromosomal composition of a particular triticale line in a breeding program, as it could be 'complete', 'incomplete', 'substituted', or 'partial'. When a cross is made between triticale lines, it could be between parents that individually might carry a complete rye genome, or only a small part of it. As might be expected, the more that triticale is backcrossed to a wheat parent, usually to recover an improved grain quality type, the more the progeny performance resembles that of the original wheat type, as more rye genes and alleles are eliminated. As far as the author of this report is aware, the specific chromosomal constitution of all current Canadian triticales has not been characterized, although most are believed to be complete hexaploids.

2.1.2. The quality characteristics of older and modern varieties are different

Triticale was originally envisaged as a way to combine the excellent field adaptability of rye to marginal conditions with the yield potential and high grain quality of wheat. In most parts of the world full expression of both parts of this ambition has not been achieved, despite major progress on both fronts. Also, since the initial concept was determined, a large number of the earlier breeding programs have now been discontinued, especially after the 1970's and 1980's. Programs were discontinued usually because of slow progress in improving the floret sterility problem (which reduced yield potential), and the seed shriveling problem (which reduced value in feed and milling, and the food quality potential). Much of the earlier literature on grain quality was based on research using varieties that had problematic grain characteristics (shriveling, sprouting, low test weight, high α-amylase content etc.), problems that are not now as important in modern varieties as the result of genetic improvements from breeding.

For the reasons outlined above there is now a need to repeat much of the earlier grain quality and use research using modern varieties, to establish the extent to which earlier negative attitudes towards market adoption of triticale are no longer valid. New triticales have grain quality characteristics that are suitable for many grain markets. Lack of production acreage in Canada has been a disincentive for renewed research on this. Basic research on quality specifications for new or potential triticale grain markets is beyond the scope and capacity of the two remaining Canadian breeding programs, but both are limited in breeding scope in the absence of this information. Specific gaps in market quality information are considered later in this report.

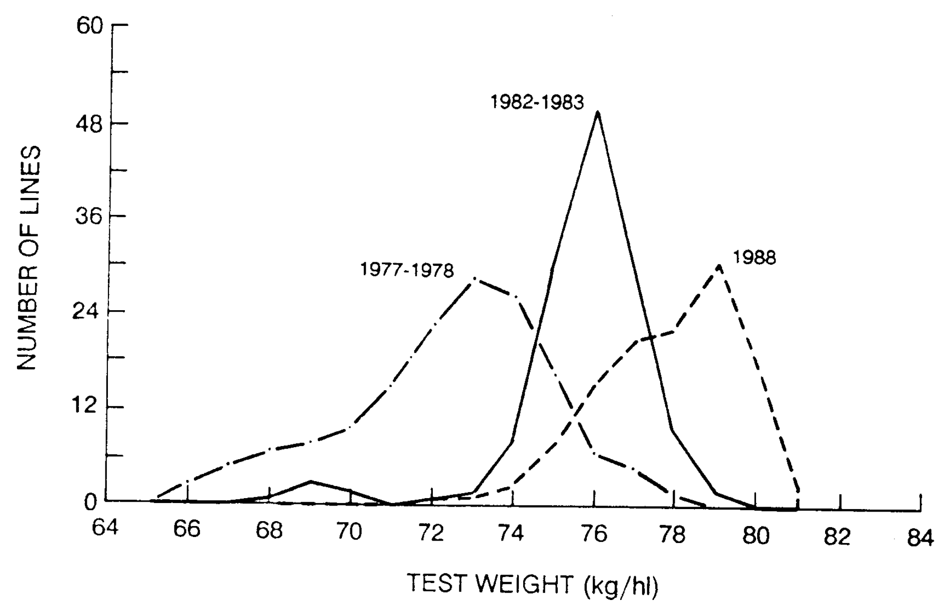
2.1.3 Solving the initial problems in triticale – internationally and nationally

The initial Canadian cultivars from the University of Manitoba program (Rosner, Welsh) had many agronomic and grain quality deficiencies, and proved inadequate to meet a grain market in Canada for either feed or food. They were not initially evaluated for potential as forage. On the production side they failed because yields were not competitive with other feeds (e.g. barley, feed wheat) or for food (e.g. wheat). They were late maturing, tall and lodging prone, with a high degree of floret sterility (and subsequent ergot occurrence), and had shriveled grain, low test weight, and prone-ness to post-harvest sprouting, that all detracted from milling quality. On the plus side, grain had high lysine availability, and food products from triticale had a novel, desirable, nutty flavor that appealed to taste panel members. These first triticales also appeared to have (except for ergot susceptibility) a good level of resistance to prevalent cereal diseases and races in W. Canada, which is still the case in 2001.

The original gene pool for the University of Manitoba primary triticales was relatively narrow, and did not involve a wide range either of rye parents or wheat parents. Also, there was no reported pre-breeding of potential parents, to seek specific complementary traits from the wheat and rye for creating the primaries. As a result, the range of genetic variation in the total program was limited, and subsequent breeding potential by selection was consequently limited.

By the time the new fertile, high test weight, non-shrunken seed, semi-dwarf types emanated from CIMMYT, which was creating a far broader range of primaries than in Manitoba, the latter program had virtually closed down, both for basic and breeding research. Continuing Canadian programs then relied almost completely on accessing triticales from CIMMYT, or other non-Canadian programs, selecting from them lines that were best adapted to northern conditions. Germplasm and parent exchange with CIMMYT has been extensive, and still continues. Also, breeding moved extensively to the production of secondary triticales, including backcrosses to wheat, still continuing at AAFRD (Lacombe) and AAFC (Swift Current). The massive improvement in triticale grain quality that occurred in the 1980's is evidenced in the improvement of test weight that occurred in entries in CIMMYT's outreach nurseries in this period (Figure 2 from Anon, 1989).

Figure 2 Test weight improvement in CIMMYT triticales – 1970's to 1980's



In this same period, improvement in potential baking quality was also achieved (Pena and Balance, 1989) to where loaf volume nearly equivalent to those of the best Mexican wheat cultivars was achieved with many triticale lines. However, triticales worldwide would still be rated as having weak gluten, compared to international breadwheat quality standards, and suffer from 'sticky gluten', that requires blending with wheat flour up to a maximum 30% to avoid problems in continuous process breadmaking plants. The 'sticky gluten' problem remains to be solved. The weak gluten is a negative in the breadmaking market, but is a plus in other flour product markets (see later section on triticale flour quality).

Because of the major improvements in triticale achieved by breeding in the 1980's, and subsequent improvements both in feed and food potential, much of the earlier published data about triticale grain quality is irrelevant for modern varieties, as their grain properties are much improved. Thus much of the earlier processing quality and feed research work needs to be repeated using the improved, modern varieties. In most cases very little of this revisiting of the research with new varieties has happened, especially in Canada. To re-establish the specific advantages of triticale grain for Canadian processing and feed opportunities it is imperative that this work be initiated and completed as soon as possible, to determine the real potential for modern Canadian triticale varieties in the modern marketing situation. Results from this will indicate where the priorities for grain quality improvement by further breeding should then be placed.

The improvements in grain quality of triticale have occurred worldwide, and it is useful background information to compare the international breeding priorities of the mid 1980's with those of today, as is done in the following sections of this report. Many of the issues of that era are still limiting more extensive adoption of triticale in competition with other cereal crops, worldwide and in Canada.

2.1.4 International triticale breeding, issues and adoption – the mid 1980's situation

In 1986 Varughese (CIMMYT Research Highlights, 1985, CIMMYT, Mexico) presented a review highlighting the advantages of triticale as a crop for marginal environments. International recognition of this wide adaptability resulted in active European breeding programs at that time in Bulgaria, former Czechoslovakia, E. Germany, France, Greece, Hungary, Italy, the Netherlands, Poland, Portugal, Romania, former Soviet Union, Spain, Sweden, UK, and Yugoslavia. Most of these programs are still active, plus others in Asia, S. America, the USA, Canada and Australia.

Some of the special features of triticale that were attractive enough to merit active programs were as follows, and are still valid. Many of these advantages can be expressed under Canadian conditions. In Poland adaptability to acid soils, to replace rye, was noted, including winter types with especially good resistance to mildew and rusts. Also, the special amino acid composition suited for monogastric feed (for pigs and chickens) was a proven advantage. Research to solve quality problems to gain entry to the bread market was a high priority. In the Soviet Union yields >20% more than wheat were obtained, with 1-2% higher protein content, and special adaptability to arid conditions, with salt tolerance and high forage potential was noted. In Portugal CIMMYT lines performed well on acid soils and in arid conditions. In Africa triticale yields were superior to wheat under marginal conditions, up to 100% higher than wheat in some conditions (a result confirmed by the author of this report when in Kenya, 1981-1983, especially on acid soils). Brazil was a major adopter of triticale, which was fully integrated into the bread flour stream for marketing. Their varieties were all based on selection from CIMMYT introductions. The Brazilian advantage was seen in adaptation to acid soils, and in disease resistance to scab, Septoria and Helminthosporium. Australia reported a high adoption level for the improved varieties, for use in feed for sheep, cattle, poultry and pigs, and for forage. Triticale outperformed wheat on marginal and arid conditions and on acid soils, and a limited food market was developing slowly.

Thus by 1986 the special agronomic characteristics of triticale were being recognized worldwide, and the crop was seen as one worthy of further research investment, especially to improve market quality traits. This optimism resulted in more than a doubling of world triticale acreage between 1986 and 1991/92 (Table 1). Specific breeding needs of international concern, that needed improving, were seen in 1986 as follows:

1. Broaden genetic base, both from rye and wheat
2. Improve disease resistance of all kinds (regionally specific needs)
3. Further improve adaptation to acid soils (need rye level) and other stresses
4. Seek earlier maturity (shorten post-flowering period) especially for grain types
5. Repartition assimilates from vegetative parts to grain (higher harvest index)
6. Further eliminate grain shriveling, and achieve test weight equal to wheat
7. Improve lodging resistance, including semi-dwarf development
8. Reduce post-harvest sprouting in wet regions, and reduce grain bleaching
9. Identify anti-nutritional components, that limit feed intake
10. Do extensive feeding trials on specific classes of livestock and animals
11. Eliminate 'sticky dough' problem, so triticale can be used in baked products

Most of the above list are still on the priority lists of today's breeders (see later section of report), although many of the traits have already been greatly improved. Some of the topics have received almost no research attention since the mid-1980's (e.g. anti-nutritional components). Also, the limited reference to forage potential prior to the 1986 reports highlight the newness of this area of end-use research.

The Varughese review also highlighted issues that affected adoption of the crop, some positive and some negative, that are still valid in 2001. In the food market triticale was seen as a replacement for wheat (and therefore at a disadvantage due to lack of supply and familiarity). Low price could promote use, but not production. On the plus side special flavor characteristics could be exploited, for cookies, bread, baked goods and crackers, particularly for small operations where 'sticky gluten' problems could be avoided. The limited published nutritional data confirmed that triticale had a high nutritional value, particularly high in amino acids and vitamin content, compared to wheat. P and K content were also usually higher than wheat, as well as Na, Mn, Fe, and Zn. In addition, digestible energy of triticale was reported as similar to wheat (14.1 and 14.4 MK per kg, respectively), lysine availability was higher than wheat and other cereals, and biological value was 15-20% higher than wheat when evaluated in living animal tests.

Some typical nutrient characteristics of triticale vs other cereals are presented in the following tables. The superiority of triticale lysine content over wheat has been repeatedly reconfirmed worldwide, including data (Table 4) reported by the National Research Council of Canada (NRC, 1989). This trait alone makes triticale of nutrient interest for monogastric animal diets.

Table 3 Amino acid content in triticale, wheat and rye (CIMMYT Laboratories, 1982)

Amino acid	Triticale (Yoreme)	Wheat (INIA)	Rye (Snoopy)
	g per 100g protein		
Lysine	3.44	2.83	4.02
Threonine	3.55	2.98	4.06
Methionine*	1.28	1.42	1.35
Isoleucine	3.45	2.68	3.70
Leucine	7.20	7.22	7.75
Phenylalanine	4.94	3.77	4.74
Valine	4.48	3.73	5.10
Tryptophan	1.20	1.10	N/A

* Partial destruction during hydrolysis

Table 4 Amino acid content of triticale and some other cereal grains (NRC, 1989)

	Lysine	Threonine	Methionine	Leucine
Triticale	3.4	3.6	1.3	7.2
Wheat	2.8	3.0	1.4	7.2
Rye	4.0	4.1	1.4	7.8
Barley	3.6	3.5	1.5	-
Corn	3.0	3.5	1.5	-

Data in g/100g crude protein

Table 5 Vitamin content (dry basis) of triticale, wheat and rye (From Michela and Lorenz, 1976)

	Triticale (Winter type)	Triticale (Spring type)	Wheat	Rye
	TR383	6TA204	Chris	Prolific
	$\mu g\ g^{-1}$	$\mu g\ g^{-1}$	$\mu g\ g^{-1}$	$\mu g\ g^{-1}$
Thiamine	9.8	9.0	9.9	7.7
Riboflavin	2.5	2.5	3.1	2.9
Niacin	17.9	16.0	48.3	15.3
Biotin	0.06	0.07	0.06	0.05
Folacin	0.56	0.77	0.56	0.49
Pantothenic acid	9.1	8.3	9.1	3.4

Table 6 % of true protein digestibility, biological value, and net protein utilization of some varieties of triticale compared with a wheat variety, using male white rats (Hulse and Laing, 1974)

	Triticale			Wheat
	Mapache	Beagle	PC-297	Hermosillo-77
True protein digestibility	92.7	91.0	91.5	92.0
Biological value	66.1	69.9	59.3	57.6
Net protein utilization	61.3	63.7	54.2	52.9

A number of potential anti-nutritional compounds were also known in the mid-1980's to occur in triticale, but at much lower levels than found in rye, although quantified relevant data is not readily obtainable. Although extensive data are reported on protein and nutritive values of triticale, in the IDRC Report of 1974 (Hulse and Laing, 1974), such data are based on the earlier triticales that, as described earlier, suffered from shrunken kernels and had many other properties different from improved, modern varieties. New data are needed on these characteristics, from the modern varieties grown under Canadian conditions. Candidate problem compounds that may block full use of nutrients include water-soluble pentosans, enzyme inhibitors, alkyl-resorcinols, tannins, acid-detergent fiber, pectins, and protein-polysaccharide complexes. To this author's knowledge the levels of some of these compounds in Canadian triticale varieties are still not known, in comparison to content in other Canadian feed grains.

In the 1986 reports, a minimum yield improvement of +15% over wheat was seen as necessary to compete with wheat as a feed, especially for monogastrics, even though the high lysine content would mean a lowered level of protein supplementation was needed in the ration. On-farm, successful use of triticale as a complete substitute for either wheat or corn was reported for monogastrics, including swine, quail, chickens, broiler turkeys and tom turkeys, and in the latter case improved meat tenderness was recorded.

In the mid 1980's new applications of triticale use appeared including forage use in many forms in springs and winters, as cover crop for erosion control, as an awnless annual forage, and as a break crop in sustainable cropping systems. Thus, even internationally, these forage use applications are very new, and AAFRD, Lacombe was a main leader in the forage work, and in the addition of forage potential as a breeding objective. These aspects are reviewed later. However, because of limited subsequent basic research on triticale as a forage, few useful guidelines are available even to today's breeders that could help them improve forage quality in new varieties, or that could be applied in the selection programs. There is very little progress on the topic of specific forage quality breeding objectives internationally in the last 20 years.

Since 1986, relatively few research trials have been conducted that lead to clear breeding objectives for triticale quality improvement. This topic is further reviewed in the market use sections of this report.

Summary reports describing international breeding objectives and progress since 1986 have been regularly presented at the International Triticale Symposia, including those held in Sydney, Australia (1986), Passo Fundo, Brazil (1990), Lisbon, Portugal (1994), and Red Deer, Canada (1998).

2.1.5 International triticale breeding – the situation in 1998 (4th Int. Triticale Symposium reports)

The most recent systematic review of world-wide applied triticale breeding programs occurred in 1998, at the 4th International Triticale Symposium, Red Deer, Alberta. A summary table (Oettler, 1998) indicated the possible genetic sources for future breeding improvements, for short-term, middle-term, and long-term goals. In comparison to this table, it should be noted that both Canadian breeding programs have already focused for some time on the methods that were judged by Oettler's classification as 'highly beneficial', with little or no emphasis on other approaches. This is a sound strategic approach for applied programs with limited budgets.

Table 7 Introduction of genetic variability and its benefit for applied triticale breeding (From Oettler, 1998)

	Expected benefit		
Route of introduction	Short-term	Middle-term	Long-term
Primary triticale			
8x	-	+	+
6x	-	+	+
Secondary triticale			
8x	-	-	+
6x	++	++	++
4x	-	-	+
Primary x secondary triticale	+	++	++
(Triticale x wheat) x triticale	+	++	++
(Triticale x rye) x triticale	-	+	+
Triticale with alien cytoplasm	-	+	+
Alien species, introgression	-	+	+
Mutagenesis			
Chemical and physical agents	-	+	+
In vitro culture	-	+	+

++ Highly beneficial, + Beneficial, - No benefit

Several interesting breeding goals in countries other than Canada were evident. In Australia, Darvey (1998) indicated a long list of potential goals related to product end-use improvement, for feed grain, forage use, human food (mostly targeting wheat replacement), and industrial uses. This extensive list is presented here, for reference. Darvey suggested that the key to greater global adoption of triticale would lie in achieving suitable bread quality improvement. (This is not true for the N. American production situation, where replacement of wheat in mainstream applications is not a sensible goal. Author). Darvey's list (modified) is as follows:

1. Animal feed and forage factors:
   Protein content/quality; Nutritional and anti-nutritional properties; Vegetative and grain biomass/yield and quality; Test weight; Grazing recovery;
2. Human food (e.g. as wheat replacement):
   Grain color, flour color, and bread color; Bread crumb structure; Palatability; Starch content and composition; Fiber content; Gluten quantity/quality; Extensibility; Stickiness; Grain hardness/softness; Non-starch polysaccharides, etc.; Specific variety uses for specific processed products, replacing wheat;

3. Industrial applications:
   Bio-ethanol production from triticale carbohydrates; High amylose types for plastic production; Pentosans for glues; Straw strength for thatching, building materials, packaging materials, and straw board;
4. Environmental conservation applications:
   Weed control and soil stabilization; Re-vegetation; Reduced herbicide and pesticide use; Improved water use efficiency; Break crop, including extension of rotations;

Darvey (1998) drew particular attention to long-term research potential for three grain quality characteristics, that would likely require dedicated pre-breeding in rye or wheat for the production of new primary triticales:

a) High starch yield, for starch extraction, and high amylose types (of importance for replacing maize, in the Australian situation)
b) Waxy and low amylose products, for their stickiness and flavor enhancement properties
c) High amylopectin (and low pentosan levels for monogastrics), to increase feed conversion

Several other reports at the 1998 symposium (including reports from Australia, and CIMMYT) also reconfirmed effective on-farm use of triticale grain as an un-supplemented grain for swine feeding, confirming achievement of satisfactory nutrient balance for some monogastric animals in current varieties.

Successful production of hybrid triticales targeting higher yields was reported by several authors (including those from Poland, Australia and CIMMYT) with grain yield hybrid vigor of more than 20% over the best parent (Pfeiffer, 1998) in experimental plots using hand crossing or CHA's (chemical hybridizing agents) to produce the F1 seed. Canadian programs may need to consider this approach in the longer term, for achieving higher yield potential (both for forage and grain) in the future, especially if the lower cost CHA approach to making F1 seed can be used. One disadvantage to use of the CHA system is that it is a patented application, so that products from its use may not be free from license charges. Other systems to make hybrids are available, such as the CMS (cytoplasmic male sterility) system in the public domain, but they result in more costly hybrid seed, and it is doubtful that this will be a feasible economic breeding approach until triticale acreages and annual seed sales would be very much larger. Also, there is evidence (Salmon, 2001, pers.comm.) that the restorer genes for the *Triticum timopheevi* cytoplasmic male sterility may not be very effective under C.Alberta conditions. On the contrary side of this argument it should be noted that hybrid wheat production in the USA using the CHA system has become minimal since the owner of the technology of the best CHA chemicals (HybriTech) discontinued business (Pers. comm. Dr. Joe Smith, AgriPro, Feb. 2001).

2.2 Current Canadian varieties and breeding programs

Eleven triticale varieties are available for production in W. Canada (Appendix I) three of which are winter type (with Pika and Bobcat released by AAFRD), and eight of spring type (with Wapiti and Pronghorn released by AAFRD). A list of historical triticale varieties released since 1972 in all parts of Canada is presented in Appendix II.

2.2.1 Agriculture and Agri-Food Canada (AAFC) breeding program, Swift Current

This breeding program has been effective at releasing new varieties suited to W. Canadian conditions, including the newest variety AC Ultima, which is a significant improvement in Hagberg falling number, although this still does not approach the desirable levels found in spring wheat. Higher Hagberg falling numbers are associated with reduced post-harvest sprouting and amylase activity, traits very desirable in grain for milling and food use. In the current program only a few crosses are made each year at AAFC, but extensive, multi-location agronomic and disease resistance evaluation of new triticale lines accessed through CIMMYT nurseries is undertaken, from which adapted lines are selected. As is the case for the AAFRD program at Lacombe, no new primary triticales are created by AAFC, but at the request of Canadian breeders some special primary and other crosses are occasionally made at CIMMYT, to seek special breeding populations with adaptation to Canadian conditions. Compared to CPS spring wheat, the best triticale varieties are much higher yielding, but are later maturing, taller, lower in grain protein content and test weight, and somewhat more prone to sprouting. Incremental improvements of all traits compared to those of already released varieties are very likely to be achieved in the future, but major breakthroughs in trait improvement are not likely in new Canadian varieties to be released in the next five years. Evidence for this view can be obtained from examination of the 2000 W. Canadian Triticale breeding report (from AAFC, Swift Current) and from the performance data of entries in the 2000 W. Canadian Coop trial. (Data reproduced here with permission from PRRCG, not for further reproduction). Lines described in these tables are the only potential new Canadian varieties of the next 3 to 5 year period.

Table 8 Performance of new triticale lines in Saskatchewan AAFC trials, 1999 (mean of 4 sites)

		Yield $kg\ ha^{-1}$	Ht. cm	Days to mature	Lodging 1-9	Field scores: Leaf rust	Stem rust	Test wt. $kg\ hL^{-1}$	Hagberg falling number
CPS checks:									
AC Crystal		4863	92	111	1.0	20RMR	tr	78.4	315
AC Vista		5176	96	100	2.7	40MRMS	tr	78.0	362
Triticale checks:									
AC Certa		5967	115	107	1.5	tr	tr	73.8	119
AC Ultima		6355	108	103	1.6	tr	tr	72.2	186
Range for									
triticale	low	4882	97	104	1.2	tr (mostly)	tr	69.7	62
lines (n=60)	high	6367	121	112	5.9	20MRMS		73.6	105

Advanced lines from the AAFC, Swift current program were tested in the Triticale-A-1 test at four locations (Swift Current, Stuart Valley, Regina and Indian Head) in 1999, compared to CPS wheat and triticale checks. Out of 60 lines tested (from CIMMYT and other introductions) 56 yielded as well as or better than AC Vista CPS wheat, the best significantly more by over 25%. The best line in the test out-yielded the best triticale check (AC Ultima) by 8%. Although favorable variation was evident for all traits, the new entries continued to be typically taller and later maturing than the CPS wheat checks, but with excellent straw strength and resistance to leaf and stem rust. Test weights were lower than for the CPS wheats (typically by around 6 kg hL^{-1}). Hagberg falling numbers were also typically much lower than for the CPS wheat checks.

Similar trait values were found in a similar test of more advanced lines in 1999 (AAFC Triticale Trial A-II), except more lines with shorter straw were evident, as well as modest improvements in achieving higher falling number values. In the pre-Coop Triticale B Test in 1999 (at 8 locations in Saskatchewan and Alberta) the check variety AC Ultima was the highest yielding triticale entry, out-yielding the best CPS and SWS check varieties by over 25%, although 3-5 days later in maturity. Two of the triticale entries were close to the wheat checks for test weight, which would be a significant breeding advance for triticale. Similar ranges of the same traits were found in the corresponding 2000 trials (data not reported here).

In the 2000 Triticale Coop trial (at 9 locations in W. Canada) none of the candidate entries significantly out-yielded the highest yielding triticale check (AC Ultima), although several lines appeared to have potential for yield increase beyond the checks. AC Ultima out-yielded the highest yielding CPS wheat check (AC Vista) by 23%, but was 4 days later in maturity (based on 6 reporting sites)

Table 9 Triticale Coop 2000 Summary of agronomic and disease data
(from 2001 PRRCG, Wheat, Rye & Triticale Subcommittee Minutes, pg. 301)

Table 14.

Triticale Co-op 2000 Summary of Agronomic and Disease Data

		Yield	Rank	Heading	Maturity	Height	Lodging	TestWt	Kern.Wt	FaNo	Disease Reaction: Rust		FHB
		(kgha^{-1})		(d)	(d)	(cm)	(1-9)	(kghL^{-1})	(mg)	(s)	Stem	Leaf	Index
T417	AC Crystal	4162	11	61	103	87	2.5	75.2	33.1	244	R	MRMS	38
T413	AC Vista	4610	9	59	102	93	4.2	73.6	36.9	287	MRMS	MRMS	34
T950	AC Reed	4258	10	59	102	85	2.1	73.0	29.4	254	MRMS	S	27
T124	Pronghorn	5867	3	57	107	110	2.0	68.0	38.2	85	MRMS	TR	22
T128	AC Certa	5617	5	58	110	115	2.8	72.8	37.5	78	MRMS	TR	25
T150	AC Ultima	5805	4	58	107	106	2.8	68.6	39.6	137	MRMS	TR	37
T163	9530B-022	5928	1	57	106	104	2.3	68.0	40.0	124	MRMS	TR	30
T167	88L012053	4922	8	59	107	109	2.3	64.0	37.4	86	MRMS	TR	63
T169	T9800D-018	5922	2	57	106	104	2.3	67.8	39.1	106	MRMS	TR	32
T170	88L012114	5176	7	58	108	110	1.9	66.5	37.9	79	MRMS	TR	42
T171	92L012010	5207	6	59	108	111	3.6	68.4	33.4	96	MRMS	MR	23
	Mean	**5225**		**58**	**106**	**103**	**2.6**	**69.6**	**36.6**	**143**			
	LSD	656											
	# Stations	**9**		**4**	**8**	**9**	**6**	**9**	**9**	**9**			

2.2.2 Alberta Agriculture, Food and Rural Development (AAFRD) breeding program, Lacombe, Alberta

In the 2000 AAFRD and AAFC, Lacombe, Research Report, the objectives of the AAFRD breeding program are described: 'The development of high yielding and improved quality spring and winter triticales adapted to production over a range of agro-climatic conditions in Alberta'. Specific breeding objectives are listed as follows:

	Spring	Winter
Higher yield	√	√
Earlier maturity	√	√
High protein content + feed quality	√	√
Higher annual forage yield	√	√ (including spring seeded response)
Maintain forage feed quality	√	√
Awnless types for green feed	√	√
Sprouting resistance	√	√ (seed and chaff related factors)
High test weight	√	√
Improved leaf disease resistance	√	√
Improved drought tolerance	√	√
Germplasm improvement	√	√ (using other triticales + spring wheats)
Snow mould resistance	-	√
Improved winter hardiness	-	√

Specific components of the AAFRD program include:

1. Transfer of earliness genes from spring wheat into spring triticale
2. Transfer of sprouting resistance from spring wheat into spring triticale
3. Screening for further improved seed type and silage yield
4. Developing lines with reduced awn expression, for use in green feed, like Bobcat
5. Alberta evaluation of novel germplasm introductions from Europe, USA, Asia, Mexico and other Canadian programs, and hybridization with novel adapted wheats that provide a wider germplasm base for desired traits (e.g. Pronghorn introgressed with CPS and CWES sources of wheat quality).
6. Development of strong-strawed semi-dwarf winter triticale with earlier maturity, improved seed type and sprouting resistance
7. Evaluation of winter triticale for grazing potential, and other uses as forage, spring or fall seeded.
8. Introgress a high level of winter-hardiness from rye
9. Field screening of spring triticale for root-rot resistance
10. Field evaluation of spring and winter triticales for tanspot and Fusarium resistance

Research partners for these various breeding projects, and for the development of primary triticales for Alberta, include AAFC (Brandon and Swift Current), CDC (University of Saskatchewan), CIMMYT (Mexico), Progressive Seeds Ltd., and the University of Sydney (Australia).

<u>2.2.3 Characteristics of current available triticale varieties and their productivity compared to Canada Prairie Spring wheat</u>

Triticale and wheat varieties are not often included in the same yield trials so that scientifically exact yield comparisons are rarely available although same site, different trial, data are readily available. Also, when triticales (all tall varieties) are included in the same trial with CPS wheat varieties (all semi-dwarfs), the CPS varieties suffer competitive disadvantage in the small plot trial system, and their yield is likely underestimated compared to the triticale yields. The most extensive (averaged) data on varietal performance is found in provincial variety testing systems, and those data for 2001 are reported here, as well as other comparative data derived from Coop Registration trials.

Table 10 describes relative triticale variety yield performance, compared to Pronghorn in Alberta, Banjo in Manitoba, and AC Certa in Saskatchewan (2001).

<u>Yield of spring triticales:</u>

As indicated, yield data compared to other cereals are scarce, and may not always be completely valid. Nevertheless, in Alberta Pronghorn is described as ‘yielding about 30% greater than Katepwa, or about 26% higher yielding than AC Barrie. CPS wheats average from 5-21% higher yielding than AC Barrie. Banjo triticale was described as 18% higher yielding than AC Barrie in Manitoba. No specific comparisons of triticale to other cereals are reported for Saskatchewan.

These sources of information generally indicate that triticale outyields CWRS wheats consistently, but can yield worse than or better than CPS wheat in various conditions. The reported values are generally consistent with a high triticale grain yield potential reported from a W. Canadian seed-grower survey conducted as part of this project (see later), that indicated yields on-farm from 5-25% higher than CPS varieties.

<u>Maturity of spring triticales</u>

The lateness of triticale varieties is a major hindrance to its wider adoption, especially in the spring type, and this lateness is well described in the variety description pamphlets, and in agronomic advice to seed triticale as early as possible. In Alberta (2001 pamphlet), the mean maturity requirement of AC Barrie wheat was described as 109 days, with Wapiti triticale requiring 116 days. The earliest triticale variety is Pronghorn, requiring 112 days to mature. In Alberta the CPS wheat AC Taber (3 days later than AC Barrie) required 112 days, but all other CPS varieties are earlier by 1 to 10 days. In Manitoba (2001 pamphlet), AC Barrie was reported as requiring 99 days, and AC Taber 103 days. Spring triticales there are described as needing 100 days, later than CWRS but earlier than most CPS. Saskatchewan (2001) describes triticale as ‘2 to 3 days later than AC Taber’, which translates to 6-7 days later than AC Barrie.

Clearly, even the earliest triticales suffer from too late maturity, although this appears to be less of a problem in Manitoba, with its high heat unit accumulation and shorter seasonal requirements. This lateness, magnified in the wetter areas that also have the higher yield potential, leads to higher harvest risk and potential downgrading and sprouting damage, and grade and quality loss. AC Ultima is a good step forward in improving sprouting resistance, but its level is still far short of wheat. Earlier maturity will be essential in new spring triticale varieties if the crop is to better compete with other grains such as CPS wheat, or hulled or hull-less barley especially in feed markets, despite its apparent yield advantage for grain over those cereals.

Other characteristics of modern spring triticale varieties

Except for lateness, triticales possess many favorable characteristics for W. Canadian production. Triticale varieties are susceptible to ergot, but not as badly as rye, nor under good growing conditions where floret sterility is uncommon and yields are high. In farmer surveys of modern triticale varieties, risk of ergot occurrence is usually rated as insignificant to zero, but it does occur occasionally. Producers continue to be concerned about ergot potential in triticale, whilst this is not generally a problem in the competing feed grains wheat or barley. It is hypothesized by breeders that the reason for less ergot problems in today's triticale varieties, compared to the past, is the elimination of floret sterility as a significant problem in the new varieties. Unfortunately, the earlier experiences of ergoty triticale remain in the public perception of this crop, and still contribute to a negative (although often invalid) assessment of this crop for feed use. The ergot problem has not yet been fully overcome, but is not as frequent or severe as in the past.

In the early days of the 1990's Fusarium outbreak in Manitoba, it was believed that triticale might have a high resistance level. It is now known that Fusarium susceptibility (head symptoms, or DON content) of triticale varieties is no better nor worse than the best wheat varieties (AC Barrie, Katepwa, AC Cadillac, AC Majestic, and McKenzie), which all rate 'Fair in resistance to FHB'. In contrast to this, all CPS varieties are rated 'Poor to Very Poor'. Thus triticales, although not resistant, may still have a small short-term advantage compared to wheat as a high quality feed grain source in Manitoba, until FHB resistant CPS or feed wheat varieties are released. Field research is needed in Manitoba to determine if the reported lower levels of symptoms of FHB on the heads of winter triticale (and winter wheat), likely a result of escape because of the earlier flowering date compared to spring cereals, does translate into sufficiently low DON levels in the grain. This would give the crop a real advantage as a feed source in Manitoba. DON levels lower than 1.0 ppm are required for swine, dairy cattle and horses, and levels of 5.0 ppm or lower for beef cattle, sheep and poultry. It is known that when cereal heads are artificially inoculated the order of susceptibility for producing high DON levels is triticale > wheat > barley > oat (Source: Dr. J. Gilbert, FHB mini-workshop, ECGB meetings, Saskatoon, Feb. 2001, non-minuted). Demand for feed is very high in Manitoba, especially for the 6 million hogs in the Fusarium affected area (planned to double in number). Currently some 600,000 to 840,000 tonnes of feed grain is being shipped into Manitoba annually to meet its feed requirements. It would be prudent to completely research the potential for producing low DON triticale in Manitoba, most likely achievable in the winter type.

Winter triticale varieties for grain

This is a relatively new crop for grain, and few field trials have been conducted in W. Canada to specifically compare winter triticale yields with that of spring cereals. Provincial variety pamphlets do not list data, only comments, such as:

- Bobcat, Pika and Wintri are the only available varieties, and 'have winter hardiness similar to the most winter hardy winter wheats, with 10-15% higher yield' – Alberta 2000 pamphlet. In Alberta this mathematically converts into a yield advantage over AC Barrie of around 20-25%, with maturity similar to CPS wheat.
- Bobcat is a new cultivar of winter wheat which is awnletted, with shorter, stronger straw. This trait is also desirable in the spring type. The awnlet trait may have advantage in feed situations, to improve the acceptability of feed to animals (similar to smooth awn preference in feed barley).

Table 10 Spring triticale grain yield potential, as described in 2001 Prairie Region Variety Publications of Alberta, Manitoba and Saskatchewan

Alberta –

spring triticale

Variety	Irr. 1&2	Area (see map) 1	2	3	4	5&6	Comp Mat.	Te. Wt.	Kn. Wt.	Ht. cm	Resistance to: Ldg.	Shat.	Loose Smut	Bunt	Com. Rt. Rot	Toler. FHB
		yield as % of Pronghorn														
AC Alta	107	99	101	100	92	NS	2	54	48	95	G	G	R	R	S	XX
AC Certa	97	97	93	95	92	NS	1	58	42	108	G	G	R	R	I	F
AC Ultima	105*	97*	98*	119*	107*	NS	0	56	44	105	G	G	R	R	I	F
AC Copia	102	100	98	96	85	NS	1	57	45	104	G	G	R	R	I	XX
Pronghorn	**100**	**100**	**100**	**100**	**100**	**NS**	**112**	**55**	**42**	**105**	**G**	**G**	**R**	**R**	**I**	**F**
Sandro	103*	96*	96*	102*	99*	NS	1	58	40	101	G	G	R	R	I	XX

Remarks – All varieties are late maturing compared to CWRS wheats (approximately 10 days) and should not be grown for grain production in Areas 5 and 6. PRONGHORN and AC ULTIMA are earlier maturing than other spring triticale varieties. AC ULTIMA – seed supply limited in 2001. PRONGHORN – yields about 30% greater than KATEPWA in areas of adaptation. Large seeded varieties should have an increased seeding rate.

Manitoba –

Comments:

Triticale is used in Canada both as a food and livestock feed. Seed yield is generally higher than Glenlea wheat but protein content is slightly lower.

The newer available varieties, although susceptible, have reduced incidence of ergot compared to nonregistered varieties and rye.

Forage yields of some varieties are listed in the Forage Crops section.

Variety Descriptions[1]

Variety	Long Term Average Yield % of Banjo[2]		Days to Maturity[3]	Height[4]	Resistance to:[5] Lodging	Stem Rust	Leaf Rust	Bunt	Fusarium‡
AC Alta	102	(22)†	-1	-7	G	G	G	G	n/a
AC Certa	101	(22)	-3	-2	G	G	G	G	F
AC Copia	92	(18)	-2	-3	G	G	G	G	n/a
AC Ultima	104	(5)	-4	-4	G	G	G	G	F
Banjo	100		0	0	G	G	G	G	n/a
Pronghorn	97	(17)	-4	-2	G	G	G	G	F
SANDRO	105	(20)	-3	-6	G	G	G	G	n/a

[1] Except for the Long Term Average Yield data, the information was obtained from the Cooperative Registration Trials. This information should be used as a general guide only.

[2] Banjo average yield 62 bu/ac (4176 kg/ha) over 32 site-years.

[3] Maturity data provided to compare relative differences among varieties - actual maturity will vary depending on seasonal growing conditions. Banjo maturity is about 100 days.

[4] Height is relative to Banjo at 42 inches.

[5] G Good; F = fair; n/a = not available.

† Number in brackets is actual number of site years in direct comparison to Banjo (in Manitoba trials 1989-2000). The more site-years the more dependable the data.

‡ Fusarium head blight (FHB) infection is highly influenced by environment and heading date. Data on varietal reaction to FHB is limited and should be used with caution. Under high levels of the disease all varieties will sustain damage.

Saskatchewan -

Triticale

Main characteristics of varieties

Variety	Years tested	Yield as % of AC Certa Area 1	Area 2	Area 3	Area 4	Irr*	Test wt. (kg/hl)	Maturity	Resistance to Lodging	Stem rust	Leaf rust	Bunt	Root rot
AC Certa	9	100	100	100	---	100	74	M	G	VG	VG	VG	G
AC Alta	9	103	103	98	---	109	68	L	G	VG	VG	VG	F
AC Copia	11	99	98	94	---	99	72	M	G	VG	VG	VG	F
Pronghorn	9	99	101	102	---	107	69	E	G	VG	VG	VG	F
Sandro	6	103	101	94	---	---	73	E	G	VG	VG	VG	G
AC Ultima	5	105	106	103	---	---	70	E	G	VG	VG	VG	F

• Relative yield under irrigation is based on limited data.

Additional Information

Triticale matures 2-3 days later than **AC Taber** CPS wheat, therefore it should be planted as early as possible. Some cultivars of triticale will mature very late in Area 4. The seeding rate for triticale should be at least 30 percent more than that of CWRS wheat to obtain the same number of plants per square foot. Susceptiblity to Fusarium head blight is at least as great in triticale as in wheat. **AC Ultima** is a new cultivar of spring triticale. It has improved Hagberg Falling Number. Seed supplies of **AC Ultima** will not be available in 2001.

Winter triticale has winter hardiness equal to that of winter wheat. **Pika** is the only cultivar of winter triticale with seed available. **Bobcat** Is a new cultivar of winter triticale. It is awnletted with shorter and stronger straw than **Pika**. Seed of **Bobcat** will not be available in 2001.

An additional source of comparative yield information on spring triticale was presented by McLeod et al (1998), summarizing Western Spring Triticale Cooperative test data from 1995-1997 by soil zone (Table 11). Average yield of all triticales exceeded that of the CPS wheat AC Taber by 8-10% in all zones, with one individual variety (AC Alta) on irrigation exceeding the yield of AC Taber by 17%.

Table 11 Coop trial yields of triticales and CPS wheat check, W. Canada, 1995-1997

	Yield ('00 kg ha^{-1})				
	Zone 1	Zone 2	Zone 3	Zone 4	Mean
AC Taber (CPS)	**43.4**	**44.8**	**78.4**	**71.3**	**50.2**
Frank	46.5	51.6	82.6	71.8	54.5
AC Copia	45.7	48.8	80.7	83.7	54.3
AC Alta	47.4	45.4	87.0	83.5	54.4
AC Certa	46.6	49.5	81.8	77.9	54.4
Pronghorn	48.3	48.9	90.3	77.7	55.7
Sandro	46.4	48.8	83.5	76.0	54.1
Triticale mean	**46.8**	**48.8**	**84.3**	**78.4**	**54.6**
(No. of stations)	13	12	3	3	31

Zone 1 = Black soils of MN and SK; Zone 2 = Brown and dark brown soils of SK and AB; Zone 3 = Black soils of AB; Zone 4 = irrigated brown soils of AB.

2.2.4. Recommendations for Canadian breeding programs

The approaches of both breeding programs are very sound, and they are both focused on relevant objectives that are likely to be achieved in incremental steps, over time. In both programs it will be useful to maintain the strong connection with CIMMYT and other international programs, especially for purposes of creating new primary triticales, from preselected or pre-bred rye and wheat parents. It is not recommended that either Canadian program start making its own primaries, although the introduction of faster, more efficient breeding methods is appropriate, as planned (ie. use of doubled haploidy techniques at AAFRD). Neither program will be large enough, or the potential triticale acreage large enough, to justify the basic work and facility development and increased costs necessary for primary creation.

In general, the genetic deficiencies identified in the various surveys are all being addressed by the current breeding work, although the resource base for assessing improvements in forage breeding aspects is very limited, and could be increased, given the primary impact for that use of triticale, winter types in particular. Local Canadian adaptation breeding work to improve the forage types is essential, since forage potential is not generally a selection criterion in the CIMMYT program, from which most adapted Canadian materials is ultimately derived.

The following recommendations for additional breeding attention are suggested:

1. In triticales for feed grain, especially spring types, seek lower phytate content, to raise the 'environmentally friendly' attributes of the consequent manure, in reducing phosphorus loading in the soil.
2. Both for forage types and grain, investigate the feasibility of hybrid types, based on successes elsewhere. The program should use the CHA approach, rather than the CMS approach, to avoid the difficulties and time delays which are found in pre-breeding parental lines and obtaining efficient restoration and cross-pollination in the CMS system. In the case that proprietary rights limit access to the CHA approach, owners of that technology should be sought as partners in the development of hybrids, rather than shying away because of perceived cost. Lessons learned with hybrid wheat in this regard in the USA should be noted, as they will also apply to triticale hybrid technology. Seed costs of hybrids developed using CHA will always be significantly less than costs from the CMS system, which should assist hybrid seed sales.
3. The large seed of triticale leads to high seed costs, especially when high seed rates are used to promote forage growth in springs and winters. Some basic research should be done to see if grain and forage yields can be maintained if varieties with a small seed are developed, which would lead to lowered seed costs. It is possible that this objective might prove to be biologically unachievable, if large seed size is correlated with early seedling vigor and high yield, but the research question is worth investigating.
4. Internal program review should be done at AAFRD to see if breeding the spring type for forage is worth maintaining, or whether forage work should be confined to the winter type only. The author merely raises this question, being unaware of the relative importance of each type in the entire forage use scenario. Statistics on this are unavailable. Focusing on one or the other type might allow better progress on the one type, given limited breeding research resources. If market share of the spring types is high, and expected to remain so, this recommendation should be ignored.
5. Although stronger gluten triticale can likely be achieved, it is unclear what the extent of the demand for this food quality type will be, domestically or for export. The AAFRD program should indicate the target market for this type, to justify the effort to be spent on it. High gluten in feed wheat, for example, is considered an anti-nutritional character, as it can affect feed acceptability. A high gluten triticale type may make problems in a monogastric feed stream worse if it gets mixed in with varieties bred for improved feed value. Are there plans to market these types separately, and how will it be done?
6. Following results from studies to determine any anti-nutritional compounds in the grain (ie. for poultry) sub-projects to reduce anti-nutritional compounds for the grain feed stream should be initiated. If these prove unimportant, the emphasis should continue to be on the highest possible yields of high energy grain, but in earlier maturing varieties, especially for the spring type.
7. Producers would like to have a semi-dwarf spring type with the same yield potential as existing spring types. Can extra effort be devoted to this objective, even if the objective is hard to achieve?

8. Of interest to breeders (not likely producers) the chromosome constitution of all existing Canadian cultivars should be determined, a project very suitable for an advanced undergraduate research project course at the University of Alberta. The purpose would be to determine the extent and range of rye introgression at the chromosome level in current cultivars, and the genomic level differences amongst cultivars. This analysis would help in determining parental values in future secondary triticale breeding.
9. Although triticale acreage is still relatively small, it is imperative that Canadian breeding programs be continued. They are justified on two bases, because of the fit of triticale as an annual forage (grazed or silage) in farming systems using widespread manure spreading, and because of the 'now being discovered but long known' value as a high energy, protein efficient feed for monogastrics, especially swine. The high per acre yields and feed efficiency of triticale, compared to other locally available feed grains, offers a partial solution to W. Canadian feed shortages for livestock that are anticipated in the future. Further improvements in varieties released will make these advantages of the crop even more obvious. Also, evidence to date suggests that triticale could be a suitable grain source for ethanol (biofuel) in the future, especially in areas where corn is unavailable, but this hypothesis still requires R and D confirmation. No special grain quality selection for biofuel or other alcohol production potential is recommended at this time.

SECTION C

EXPERIENCE-BASED, END-USER EVALUATIONS OF TRITICALE

3. Triticale seed grower view-points: Evaluation of triticale varieties, breeding needs and potential markets – results of a survey by mail-out, of W. Canadian triticale seed growers in Alberta, Manitoba and Saskatchewan

A questionnaire (Appendix III) was sent out to all seed growers of triticale listed in the 1999 W. Provinces Seed Guide. 19 responses (just less than 50%) were received, representing seed production in all three provinces, and dry and wetter areas. Questions were about experience growing triticale, and sought opinion on the strengths and weaknesses of the crop, and priorities for future improvement and expansion of acreage.

Responding growers had each grown from 1 to 15 different varieties (average 3), with 2 to 30 years of experience (average 9) with the crop. 15 of 18 indicated that triticale yield was 'somewhat' or 'much' better in stability than yields of other cereals, and that it was 'somewhat' or 'much' better in competition with weeds than other cereals. Triticale is usually described as being better adapted to stress conditions than other cereals. All respondents felt this was true for droughty conditions, but were equally divided in rating triticale 'equal to' or 'better than' other cereals under wet conditions. Two thirds rated triticale as 'better' adapted than other cereals on low fertility or problem soils, and none indicated it was worse. Most comparisons were made to CWRS or CPS wheat, or to barley. These ratings confirm prior international experience with triticale.

Respondents reported their average, highest and lowest on-farm yields, compared to CWRS or CPS wheat. For the 16 responses received, the average triticale yield ranged from 40-80 bu/acre, compared to 38-90 bu/acre for CPS wheat, and 30-60 bu/acre for CWRS wheat. As a % of CPS yield, triticale yields ranged from 80-125%, with a mean of 115 %. (CWRS yields were in all cases lower than CPS yields, as expected). The highest individual cereal yields reported were all for triticale (at 90, 96, 98 and 115 bu/acre). These seed growers all endorsed the high grain yield potential of triticale compared to wheat. Inadequate sample size did not allow comparison of winter vs spring triticale yields of these growers.

The high enthusiasm for yield potential was reversed when maturity requirement was considered, with lateness of maturity (spring and winter types) seen as a major problem compared to other cereals, especially in the spring type. Compared to CWRS wheats, triticale averaged 10 days later (range 5-25 days), and from –1 to +15 days later (average 7 days later) for the comparison to CPS wheat, when both spring and winter types were considered.

Respondents were asked to rate severity and frequency (0-5 scale) of disease occurrence in their production fields or those of seed customers. Most indicated little to no disease problem. Individual disease occurrences included one report each of Fusarium (severity/frequency 3/3), take-all (2/1), leafspot (1/1), root-rot (3/3), and glume blotch

(2/2). Ergot occurred for 7 of 18 respondents with severity/frequency ratings of 4/4, 5/2, 4/3, 2/2, 1/1, 1/1, and 1/1. Ergot was described as a continuing potential concern by most growers, even if they had not personally experienced it.

3.1 Priorities for breeding improvement

Priorities for improvement of the spring triticale crop were requested, in written form. The following table indicates the frequency (out of 16 responses) for different priorities that were named.

Table 12a Frequency of response for crop breeding improvement priorities of spring triticale mentioned by seed growers

Earlier maturity	17	Larger kernel (?)	2
Less ergot	6	Improved feed quality	2
Faster grain drydown	5	Improved protein content	2
Shorter straw	5	More sprouting tolerance	2
Less tough straw in silage	4	Fusarium resistance	1
Awnless types for green-feed	3	Uniform kernel size	2
Better yield stability	3	Higher silage yield	1
Easier threshing, less head break	3	More allelopathy	1

Breeding improvements desirable in winter triticale were also reported (Table 12b), but only 10 respondents had specific experience with the winter type. Earliness of maturity appeared to be much less of a problem in the winter type, despite being as late as the CPS wheats.

Table 12b Frequency of response for crop breeding improvement priorities of winter triticale mentioned by seed growers

Improved winter hardiness	5	Earlier maturity	1
Improved grain yield	3	Better lodging resistance	1
Improved grain quality	3	Less volunteer problem	1
More leafiness, less fibre	3	Shorter straw	1
More ergot resistance	1	Better fall growth	1

Respondents were also asked to rate and list the importance of different favorable production characteristics of the winter type. The following were all rated as important or very important by all respondents (except two who felt earliness was unimportant):

Rank	Characteristic
1	Earliness for grain
2	Redistributing seeding and harvest time, to spread cropping work
3	Adds extra choices in the crop rotation, including forage, green manure, dual purpose or silage use
4	Control of soil erosion
5	Higher yield potential than spring cereals

The inherent lateness of maturity was still noted as a problem for the winter type, compared to CWRS spring wheat. Winter triticale averaged 12 days later than CWRS wheat varieties grown (range 5-30 days), and 16 days later than CPS wheats. (An apparent inconsistency in these two figures is caused by respondents using different wheat varieties and classes for comparison in different locations).

Seed growers were also asked to tabulate their views on the specific advantages and limitations of winter triticales, with responses listed in Table 13. One consistent viewpoint was the advantage of the spring seeded winter type which, from a single planting operation, could provide spring graze (pasture), early silage, fall pasture, and spring pasture in the next year, perhaps with a second year silage crop as well.

Table 13 Seed grower assessments of advantages and limitations of winter triticale

Advantages	Limitations
Spread harvest time	Difficult threshing and harvesting
Early crop, high yield	Seeding/harvesting at the same time
Erosion control	Volunteer problem
Direct seeding possible	Poor winter survival
Good weed competition, uses fewer chemicals	Big 'brown bag' seed problem
Cover for wildlife	Too tall, poor lodging – for irrigation
Healthy feed and food	V. high power use when combining
Repeat seed sale for forage	High seeding rates required
Excellent graze (up to 3 crops)	Must seed early
Winter forage available	
Seed sales year round	
Potentially much expanding market	
Break crop from barley diseases (silage)	
Lots of straw for cattle bedding	

3.2 Availability of localized information

Respondents were asked to score their estimate of the level of localized information available on (I) Production agronomy, and (II) Product quality for 22 known, specified end-uses, to determine marketing informational needs. Average response scores are reported in Table 14 (1 = very lacking; 2 = somewhat lacking; 3 = adequate; 4 = fairly good; 5 = excellent). All of the average response scores, in all categories, were less than 3.0, indicating that the localized information base for all subject areas was viewed as from 'very lacking' (1.0) to 'somewhat lacking' (2.0), with no category rated as 'adequate', 'fairly good' or 'excellent'. Some variability in response was evident, as indicated by the ranges (indicated in brackets). Some of the highest values, indicating knowledge perceived as available, were reported for forage use (greenfeed, silage and under-seeding). The overall range in response values was narrow (1.2 to 2.5 on a 5 point scale) making these responses not useful for determining differential priorities. Most of the very lowest scores were found for human food applications, or for value-added applications, where there has been little research of any kind in Canada about market potential.

Table 14 Average response scores (1-5) for level of localized information available, as assessed by seed growers. Lower values indicate information very lacking (1 = very lacking; 2 = somewhat lacking; 3 = adequate; 4 = fairly good; 5 = excellent)

Potential uses		(I) Production Agronomy Mean (Range)	(II) Product Quality Mean (Range)
Feedgrain	- Beef cattle	1.8 (1-5)	1.9 (1-3)
	- Dairy	1.6 (1-3)	1.8 (1-3)
	- Poultry	1.8 (1-4)	1.9 (1-4)
	- Swine	1.3 (1-5)	1.9 (1-5)
Forage	- Greenfeed	2.2 (1-4)	1.9 (1-3)
	- Sileage – Dairy	2.2 (1.4)	2.2 (1-4)
	- Sileage – Beef	2.5 (1-4)	2.5 (1-5)
	- Relay cropping	1.7 (1-3)	1.9 (1-4)
	- Mixed cropping	1.7 (1-3)	1.5 (1-3
Human food	- Consumer acceptance	1.4 (1-4)	1.2 (1-3)
	- Specialty foods	1.5 (1-4)	1.3 (1-3)
	- Health foods	1.6 (1-4)	1.3 (1-3)
	- Organic production	1.5 (1-3)	1.5 (1-4)
	- Nutritional studies	1.3 (1-3)	1.3 (1-3)
	- Malting/distilling	1.7 (1-3)	1.4 (1-3)
Value - added products / processing:			
	- Ethanol / energy	1.8 (1-4)	1.7 (1-4)
	- Grain components	1.7 (1-4)	1.5 (1-3)
	- Straw processing	1.6 (1-4)	1.9 (1-4)
	- Nutritional extracts ?	1.5 (1-4)	1.2 (1-3)
	- Flavor extracts ?	1.4 (1-4)	1.4 (1-3)
'Exotic novel uses'			
	- Reclamation	2.0 (1-4)	2.0 (1-4)
	- Re-vegetation	1.8 (1-4)	1.8 (1-3)

3.3 Research priorities for triticale as seen by seed-growers

Respondents were also asked to rank their priorities for research needs for triticale for different uses, reported in Table 15. Very wide diversity of opinion was evident for this, for every end-use, but average rankings did range from 6.2 to 18.7, out of a maximum 22 specified uses. These rankings are more of interest when considering where new research needed now should be focused for longer-term benefit on acreage increase (Author comment).

Table 15 Average ranking (of 22 items) for research priorities in triticale as seen by seed-growers, listed in rank order. Lower values indicate a higher research priority.

Potential uses (Ranked by priority)	Research priority (mean ranking)
Value-added products - Ethanol / energy	6.2
Value-added products - Grain components	8.0
Feedgrain - Beef cattle	8.6
Human food - Organic production	8.6
Human food - Consumer acceptance	9.0
Human food - Malting/distilling	9.2
Human food - Nutritional studies	9.3
Human food - Specialty foods	9.3
Forage - Silage – Beef	9.8
Human food - Health foods	11.2
Feedgrain - Poultry	11.5
Forage - Silage – Dairy	11.6
Forage - Greenfeed	12.1
Value-added products - Nutritional extracts	12.9
Feedgrain - Swine	12.9
Feedgrain - Dairy	14.1
Value-added products - Straw processing	14.2
Forage - Mixed cropping	14.4
Value-added products - Flavor extracts?	15.3
Forage - Relay cropping	15.8
Novel uses - Reclamation	17.2
Novel uses - Re-vegetation	18.7

3.4. Marketing issues that affect triticale adoption

Respondents were asked to rate 14 different marketing issues from 1-5 (1 = very much; 5 = unimportant) in relation to how each may limit the future adoption or expansion of the triticale crop in W. Canada. Mean responses (and category frequencies) are reported in Table 16.

Table 16 Mean response (and frequency of category response) for degree to which selected issues will affect future triticale expansion, as assessed by seed growers

Potential marketing issue	Mean	Category 1	2	3	4	5
Potential users un-informed about triticale	1.1	14	2	0	0	0
Lack of promotion / extension about triticale potential	1.3	12	6	0	0	0
Limited current supply chain discourages user commitments to this novel crop	1.4	10	7	0	0	0
Potential grain export markets only partially explored	1.5	11	4	0	0	1
Lack of recognition of triticale as a useful rotational break crop to control diseases, etc.	1.6	8	7	1	0	0
Production economics of triticale not well known vs other crops	1.6	7	8	1	0	0
Current perceptions of triticale inaccurately based on obsolete early varieties	1.6	9	7	0	1	0
Poor scientific local data base describing modern adapted varieties for various end uses	1.7	6	8	0	1	0
Potential growers un-informed about triticale	1.8	7	7	1	1	0
Triticale seed market compromised by ‘brown-bagging’	2.0	9	2	0	3	1
Poor returns for triticale vs other cereal grains	2.2	5	6	4	0	1
Triticale has a special value as a non-board grain	2.3	8	2	1	4	1
Shipping costs to potential markets limit crop adoption	2.7	2	7	3	2	2
Seed supplies limiting	2.9	4	2	3	5	2

In addition to the issues listed for rating, respondents noted other significant marketing issues, including (a) ergot occurrence in triticale, (b) triticale mistaken for lower value rye grain, (c) low test weight negatively affecting triticale sold by the bushel (rather than by the ton), (d) seed is not always pure, nor of consistently good germination or vigor, and (e) extension staff are often not up-to date on the characteristics or potential uses for triticale, or the high potential for grain feed or forage, or its nutritional value. Results from this part of the seed grower survey clearly confirmed the repeatedly stated view that informational shortfalls and unfamiliarity with triticale potential are the major obstacles to the expansion of this crop in the short-term.

4. The general perception of the role and potential for the triticale crop in its current marketing situation. A compilation of views obtained from a conference call with representative cereal crops specialists of AAFRD, and others

4.1 Agronomic and other limitations of triticale for various applications

A conference call was held on December 5, 2000, at AAFRD, Lacombe, and was coordinated by Murray McLelland, chaired by Keith Briggs, with Graham Ogilvie in attendance and Jill DeMulder, Trevor Schoff, and Ron Hockridge on the phone. Curtis Weeks was unable to attend, but sent notes on questions sent out in advance. Observations and summaries from this meeting are presented in point form, in random order. Several relevant comments from others not at the meeting are also integrated in the notes.

A list of positive and negative features of the crop was arrived at by the end of the discussions. These are presented first, followed by comments made during discussions

Favorable features	Negative features
High forage yields	Seed costs too high (large seed)
Good disease break from barley crop	Late maturing – hard to grow seed
Wide adaptation to stress conditions	Silage hard to chop
Winter types available, for flex cropping	Cattle rate of gain not always good
High whole plant yield	Limited herbicide registrations
Late fall / early spring graze	Few sales options for grain
Good energy source	More power needed to chop the forage
Low β glucan content in grain	Rough awns not good for feed grain
Winters give 2 y prodn. from 1 y planting	Poor grain image, because of rye parent
Spring type silage, insurance for hot Aug.	Limited grain markets
Exc. lodging res. under high fertility/rain	Spring types too tall and late maturing
Winter type more hardy than winter wheat	Not as hardy as winter wheat (!)
Winter type competitive with weeds	Triticales not weed competitive (!)
Exc. nutrient sink for removing nutrients as whole plant (eg. manure 'sink') with high yield and standability	Seeding date window for winters too tight
	Difficulty packing silage (why?)
	Hard to cut /swath, tough straw in bottom
Potential for industrial fiber?	W. triticale not usually earlier than CWRS
Non CWB grain – occasional advantage for grain exports to USA ?	KVD* limits ability to release best varieties
	Long dry-down time for grain increases risk

*kernel visual distinguishability

Other observations about this list were as follows:

1. Both corn and triticale are being used as a sink to use up excess nutrients from heavy manure applications in 'feedlot alley' in S. Alberta. Triticale seems adapted for this.
2. The economics of any kind of triticale production in Alberta are not yet really well researched.

3. More work is needed to get herbicide minor use registrations for triticale as soon as possible.
4. Management studies are needed as to how to cut / manage straw under wet vs dry conditions, where limitations are very different. On-farm demo approach?
5. 'Brown-bagging' of seed is killing the triticale seed market, as the crop is trying to get established. This limits market development severely, and willingness of seed companies to invest in seed increase.
6. KVD (kernel visual distinguishability) issues as they affect wheat, make triticale immediately a second class crop. The best triticales cannot be registered, as they are visually indistinguishable from existing wheat classes. Can triticale be exempted from this requirement?
7. Specialty foods available earlier under the 'TritiRich' label (milled by Ellison at Lethbridge, and Rogers Foods, Armstrong, B.C.) are no longer available in stores. This niche market appears to have disappeared. Was this because of lack of consumer demand, or poor economics for the products? Triticale is still used as one of the '7 grains' in Westin Bakeries '7-Grain Harvest Bread'.
8. Seed markets were transiently available in the USA when the US 'set aside' program for wheat, barley and corn was in place, as triticale was not a specified 'set aside' crop. US growers were happy in those circumstances to grow triticale as a feed source, and had to source seed from Canada. Demand is now low, as the 'set aside' is no longer in place, and US producers already have a triticale seed source.
9. Feeders wishing to switch to triticale are not going to change from their current feed unless there is a significant guaranteed, continuing, grain supply in place, to justify change from their normal feed formulations, and there must be a special reason to use it.

General discussion focussed in turn on triticale use for 1. Feed Grain, 2. Forage, and 3. Food and Industrial Use, as follows:

4.2 Use as Feed Grain

Being not yet established as a significant grain crop in its own right, triticale as grain has to fit into feed markets already in place for barley and wheat. Its own unique properties as a grain are rarely recognized in the Canadian grain market, at least not in price structure. Because of problems with the earliest released varieties, it is still perceived to be a poor feed grain because of ergot problems, and associations with rye, the latter being considered a poorer feed grain. In the market for monogastric feed it has to compete with feed wheat (and in some places hulless barley), and elsewhere with feed barley, for price and quality. As a feed grain it is generally unknown, and gets lumped with feed wheat. Potential users do not know if it has the same feed properties as feed wheat – it is generally an unknown quantity for many. For growers, lateness of maturity both in spring and winter types is a major impediment for adoption, and for feeders the limited supply chain is also a major limiting factor. Inconsistency of supply is one of the 'chicken and egg' issues for grain triticale, although sources of spring triticale are in good supply in some local areas. The existence of a few local niche feed markets was noted, such as for organic chicken production (using winter types, near Camrose, Alberta), and for niche food products made from the grain (although no-one at the meeting had seen such products recently in their local stores).

A discussion of needs for improvement by breeding included: shorter straw (for easier use in minimum till); better tillering in spring types to compete with weeds (compared to barley or oat); earlier maturity; reduced and/or smooth awns; better Septoria (leaf spot) resistance; and improved test weight. A lack of localized data for local varieties on use of triticale grain as feed in specific animal feeding situations was seen as a limitation for adoption as a feed. Extension information on this seems limited. Results of research-based grain yield comparisons to currently grown feed grains also appeared to be lacking for producers in W. Canada, although a three year, multi-location study on this has just been completed by AAFRD.

The key elements of this discussion on grain use summarize as follows (and these issues were the same for all persons contacted during the entire review):

1. The grain crop lacks a critical production mass, and its favorable features are not well known. Its' production characteristics are not all favorable. Continual improvements by breeding are still needed.
2. There is a lack of knowledge about market opportunity for this crop – how to market it, and to whom, and for what price.
3. Because of lack of knowledge, delivery price usually reverts to the lowest possible, such as feed wheat or feed barley, or worse, despite the known quality advantages in some specific feed markets.
4. Many felt that triticale was in the same early development phase as peas as a crop 15 to 20 years ago, and felt that barriers to adoption were very similar to those found in the pea crop development experience. Niche uses are small, and sometimes transient.
5. Knowledge dissemination about triticale will be the key to any production expansion. (Comments were heard that this crop was 'over-hyped' for all end uses by early promoters and some seed-growers, such that high expectations were not achieved by some producers, resulting in an acceptability – adoption 'backlash').
6. The biggest problem for triticale grain (and hulless barley) as feed is that the professional feed nutritionists who run feed mills and determine actual ration compositions are unfamiliar with these grains, and are 'not at the table'. Special workshops may be needed with this group in W. Canada, in order to raise their awareness of the potentials for triticale use as a feed grain, especially for monogastric animals.

4.3 Use as Forage

The main advantage for triticale was seen in its extension of early spring and late fall graze, and for silage applications. Use for silage, followed by grazing, and use as a crop for under-seeding to fall triticale or to spring barley were seen as special, but valuable, sustainable cropping applications of this crop. Other cropping system advantages were also seen (as for grain production) as a break crop from intensive barley cropping (disease break crop for some, but not all, cereal diseases), and for use as a nutrient sink on heavily manured lands, where nutrients are removed in the whole plant form. Winter triticale was also seen as a way to control soil loss in areas prone to soil erosion by wind or water. It was noted that the forage use application is the major adoption route so far, and it was agreed that considerable expansion of this was possible in the future, if more questions about it could be answered, along with development of an improved forage quality / nutritional data-base, and better technology transfer to more potential growers and feeders. Use for annual forage leads to repeat seed purchases from seed-growers, compared to the 'brown-bag' problem that more readily occurs when the crop is grown for grain.

Reflecting current relative importance in production, the discussion about forage use was much lengthier than that about grain use. The long dry down time of triticale compared to other annual silage was seen as an advantage, giving more flexibility for silage harvest operations, compared to other annual silages. The high lignin content in the silage was a disadvantage, slowing chopping time, and requiring significantly higher harvest energy costs compared to other silage crops. Could this be improved by breeding, and awns also be removed in spring types? Occasional reports of 'triticale makes poor silage' do occur, and it is not known if this is due to inadequate processing / management protocols, or due to the varieties. In many cases, switches from barley silage to all triticale silage at feedlots caused initial poor response to the triticale silage in some feeding situations, but animals adjusted back to the new silage after a short time. Unfortunately the initial poor response to the new feed seems to be what gets reported in the feed circuit, not the long-term response. There is a larger experience base at feedlots using triticale than is evident from existing extension materials, or in basic research reports, and an effort should be made to systematically gather this anecdotal 'on-farm feedlot use' data together as it affects triticale silage use.

Significantly more research on the forage quality of triticale is still needed, as it does not have the same physical or nutritional characteristics as oat or barley silage. This work should investigate optimum time of cut, length of cut and chop, characteristics of packing, digestibility, animal intake etc., for different kinds of feeding situations. Re-confirmation is needed for local situations and specific varieties that the optimum silage cut time for the winter type is about 10 days after flowering (different to other annual silage species), and at about the same crop stage as for barley, or earlier, for the spring types. Although new winter varieties are now as hardy as winter wheat, the question was asked if hardiness levels could be raised to that of fall rye (a breeding goal), especially if fall grazing is carried out prior to over-wintering.

Considerable potential was seen for triticale to replace a significant acreage of perennial forage, especially in drier and marginal areas, and to provide advantage in late fall rotational grazing, because of the late 'stay-green' characteristic of triticale. These applications could result in a significantly expanded seed market although, again, 'brown-bagging' of seed was seen as being at a very high and unhelpful activity level in this crop.

Triticale was seen as very adapted to conditions of cropping stress (e.g. for drought, extreme wet, or Solonetzic soils, as in the literature) but comment was made that under extreme stress even it would collapse as a forage crop, and not perform as well as rye. Under high rainfall and fertility conditions triticale is very hard to cut, because of tough lower stems with lots of wet leaves, in a crop that can be over 6 ft tall, although yields are impressive under these conditions. In evaluating silage use, the main comparisons should be to barley silage, especially that from semi-dwarf barley on high fertility in wetter regions, or to dryland corn in S. Alberta.

Key items that were seen as needing further triticale forage development work included:

1. Systematic evaluation of local varieties (spring and winter) under local conditions for silage or grazing, including work on optimal crop management, and detailed 'best harvest' protocol studies, with quality of the silage evaluated using forage consumption by animals. On-farm, production level research was seen as an important tool to develop better extension data for this, to supplement basic research studies.
2. Studies of forage quality effect on animal weight gain of (specific) animals of different age and classes, including assessment of productivity and market quality.
3. In cases where triticale has suffered lowered feed intake by animals, that has in turn affected weight gain, the reasons for this limited intake need to be determined. Is the management of the silage the limiting factor, or anti-nutritional factors of the silage, that could be remedied by breeding or by other means?
4. Much more extension / technology transfer of known results from applications and use of triticale forage needs to be undertaken, with regional differences taken into account. Use of on-farm demonstrations would be the best approach to obtaining site-specific recommendations.

Generally, these 'all Alberta' discussants were convinced about the relative yield advantage of triticale forage, in various harvesting formats. High yields are necessary to achieve reduced costs when feeding silage as part of the ration. However, this yield advantage does not show so clearly in the extension (variety description) materials in the 2001 Manitoba variety description publication. In that source, forage yields of triticale varieties are described as generally lower than the best barley forage yields (based on 3 cut yield assessment), and at best equal to barley, or just slightly higher. Barley forage yields are the highest listed, of the annual grain crops tested. In the triticales, Pronghorn (with limited testing data) and AC Certa had the best forage yields in Manitoba.

4.4 Use for Food and Industrial Products

Discussions on these applications were quite short, as these were not expert knowledge areas for the discussion group as a whole. The 'disappearance' of triticale products from local stores was noted, compared to the past. Is the triticale food product market one that came and went, and why? No answers were available for this question.

On triticale for industrial use (e.g. processing for ethanol for use as fuel) it was noted that no such use has yet emerged, despite the perception that the grain would be very suitable for this, and available at yield levels that could readily exceed that of the best available wheats in W. Canada. Some pilot distillation of triticale has been conducted in the past in Saskatchewan and Manitoba, for whisky etc., at PoundMaker in Saskatchewan, and in High River for ethanol (according to a source at Agricore, Manitoba). It is known that triticale can be used to make a very satisfactory beer (including a 'one-off' pilot run in Alberta for the Triticale Symposium). It was believed that these market demands are all limited by lack of significant grain production, and the need to compete with existing grains in supply, price and processing technology. Most of the human food markets were perceived as small, and this also limits market development interest. Research results from locally produced triticale grain in the food technology area are extremely limited.

The main conclusions from this discussion were:

1. Very little is known about potential applications for triticale food products, food extracts or industrial use in W. Canada
2. Absence of technological data or a guaranteed grain supply each limit development of these potential niche markets for triticale
3. Very little is known about potential consumer demand for triticale food or beverage products, or why earlier triticale food products are no longer so widely available.

5. 'Triticale production in the Prairies of Western Canada – an Overview'. Selected findings from a Diploma thesis study of Eva Broicher, 1999, for Universitat Gesamthoschule Kassel, Germany, October, 1999.

This review by Eva Broicher was conducted as part of a student exchange program, under the direction of Dr. J. G. McLeod, at AAFC, Swift Current. As well as general historic agricultural review, and reviews of Canadian triticale characteristics, the project included results from 30-minute telephone interviews with 15 farmers, 10 of whom produced triticale, and 5 who did not. Key findings from these interviews are selectively reported here. These findings are very consistent with those found independently and reported elsewhere in this report.

5.1 Informational shortfalls for potential growers of triticale (Broicher, 1999)

Most growers indicated that they grew triticale because of its high yield, and consequent potential for high returns per acre. They desired more information in the following areas. (Priorities were not indicated).

1. Seeding rate response information
2. Herbicide and pesticide use information
3. More extensive information about performance of individual cultivars
4. More information about quality and yield as a feed grain
5. Trial data comparing nutritional values of triticale and barley as silage/hay, as well as feed grain, and possibilities for replacing wheat with triticale in the pig industry
6. Historical, breeding and trial results, in a more useful and comprehensive extension form
7. Comparison of protein levels, total digestible nutrients, etc., in grain and silage, with those in other cereals
8. Better information for the feed industry (e.g. compounders, feedlots) about feed value of triticale, to avoid its use just as a 'low cost, low value' barley substitute
9. A wide range of detailed publications are needed for farmers, on all topics (cultivation, harvesting, feed quality, marketing alternatives, new developments, new cultivars etc.)

5.2 Advantages of triticale as seen by triticale growers (Broicher, 1999)

All growers surveyed indicated that they would continue to grow triticale , and variously indicated the following advantages

1. High yield, for grain and forage
2. Better profits – cheaper to seed and easier to establish than forage mixtures for pasture
3. Extended grazing season (e.g. spring seeded winters, for high quality, extended, fall grazing
4. Superior disease resistance, compared to wheat or barley (but one grower expressed concern about ergot, Fusarium and sprouting, that increased production risk)

5. Triticale has good palatability and is well accepted by cattle
6. Triticale is a valuable animal feedstock alternative
7. High protein content, compared to barley hay or silage
8. Triticale has more biomass, leading to higher forage yields, and more return of crop residual to the soil
9. Clear yield superiority compared to other cereals in dry years
10. Easy to handle using regular farm equipment and settings
11. Opportunity to achieve diversity in cropping rotations and in marketing
12. As a non-Canadian Wheat Board crop, offers more flexibility in marketing
13. Potential for emerging or novel product use, in value-added applications and processing

5.3 Evaluation by non-growers of triticale (Broicher, 1999)

These farmers were each aware of the potential for triticale as a crop, but had only superficial knowledge of its characteristics, gained mainly from neighbours or popular media. They all indicated lack of information as one contributor to lack of interest. They all had heard that it makes good silage and feed, that it yields well, is adapted to Prairie conditions, and that the grain is nutritious as feed.

Negatives they had heard about the crop included:

1. Very late maturity for grain (a major concern), therefore limiting the crop to forage use
2. Ergot as a possible problem
3. Insufficient information for cattle producers about nutritional value and feed performance of grain or forage, compared to other cereals.
4. Limited market opportunity for seed growers, and hardly any demand for the grain for feed
5. Absence of assured markets (such as a feedlot with constant specific demand for triticale)
6. Despite a potentially good agronomic fit on the farm, they saw neighbors who were unable to sell their triticale production

5.4 On-farm use of triticale (Broicher, 1999)

Broicher (1999) reported that cattle feeders used on-farm most of the triticale that they themselves produced, as pasture (spring seeded, winter types), as hay or silage, or as grain. These triticale uses had replaced feed previously produced from grass pasture, silage (barley, oats, or alfalfa / bromegrass), or wheat and barley grain.

Triticale was used on-farm in animal diets in a number of different ways, in combination with other feeds. This variety of feeding systems underscores the flexibility of use of the triticale crop as a feed source. On-farm reports indicated high levels of palatability and acceptability of triticale grain by animals, and no health problems attributable to its use for cattle, as grain or silage. Five specific on-farm uses were described in the Broicher report:

1. 50-70% grain mix with barley (30-50%), or as 50% triticale + 50% alfalfa;
2. As pasture, up to 10-15% of the dairy cattle diet; During the grazing season, from 70-100% of the beef cattle diet;
3. 80% silage (mix of barley, triticale and alfalfa), with 20% grain (50/50 barley and triticale); For finishing, the grain component is increased;
4. Grain ration (50/50 oat and triticale); For roughage 66% straw and hay (alfalfa plus bromegrass), plus 34% triticale;
5. 80% grain (50/50 barley and triticale), plus 16% silage (rye, rarely triticale), plus 4% feed supplement;

5.5 Other observations (Broicher,1999)

Current triticale growers continue to have a very positive attitude towards the crop, whether they are new to the crop or long-term growers. They have developed appropriate management methods to solve earlier problems perceived for the crop, such as coarse stems in the forage, ergot occurrence (in varieties from the earlier era), or threshing differences from other cereals. Growers of triticale grain continue to be frustrated at the difficulty in establishing a grain market in W. Canada at a fair feed-grain price that recognizes the superior nutritional quality of triticale. Some profitable niche markets of the past in the USA did not seem to have longevity. Feed prices lower than feed wheat or barley were repeatedly described as a disincentive for production. Also, feed-grain buyers were disinterested because of lack of a reliable supply quantity, that does not then justify their making special adjustments to their feed formulations, to accommodate any special nutritive features of triticale.

6. Experience-based use of triticale grain for feed in Canada

Extensive review of what is needed in any feed grain for different classes of animals has been the subject of many meetings over the years. In W. Canada these discussions usually focus on use of barley (hulled and hulless) and wheat. Discussion of triticale potential has been minimal. As a grain feed it would have to compete mainly with barley, wheat or oat in W. Canada. In the context of barley feed it is appropriate to present the highest priorities for feed improvement that were identified at the 1998 Feed Grain Quality Conference: 'Measuring the feeding quality of barley grain' (Edmonton, Nov 8-10, 1998). These research priorities were determined by vote frequency by attendees at a workshop, for ruminants, poultry and hogs, and were as follows:

(a) Research priorities for ruminants	Priority
1. Determine rate of digestion/release for each livestock class	Very high
- Find optimal rates	
- Find genotype vs environment influence on energy content	
- Find ways to measure processing effects on energy content	
2. Effect of feed processing on end-use quality	Medium
3. Discover ways to measure feed quality to use in formulation	Medium
4. 5 other priorities	Low

(b) Research priorities for poultry

1. Optimize barley intake without sacrificing fatty acid profile	Very high
- Increase available energy of barley for poultry	
2. Identify and reduce anti-nutritive factors	Very high
- Feed intake inhibitors	
- Phytic acid	
- Reducing NSP's (non-soluble polysaccharides)	
- Amino acid digestibility and protein quality	
3. Methods to measure variety and environment effect on feed samples	Low

(c) Research priorities for hogs

1. Digestible energy predictions, to estimate DE *in vitro*, or by NIR	Very high
2. Feed intake predictions	High
3. Ileal digestible amino acid predictions	Medium
4. 11 other priorities	Low

Similar priorities would probably exist for triticale, except for items that relate to hull content. In all classes, the highest priority was on energy content, where triticale does very well in comparison to barley.

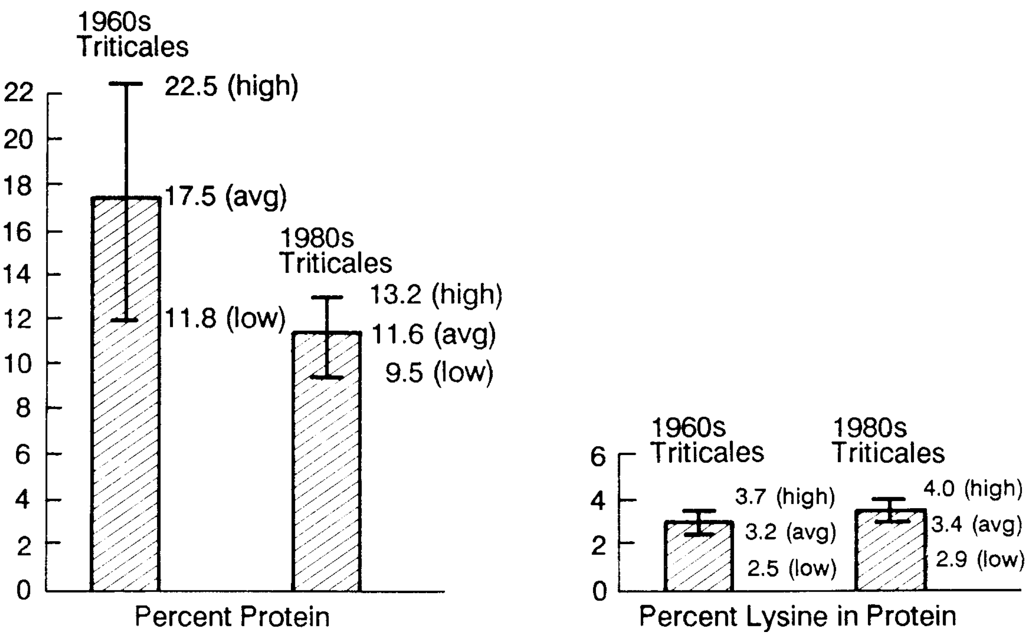
The literature about triticale feed grain use in all classes of animals (monogastrics and ruminants) is limited, and many of the 'classic' papers refer to early work done in the 1970's and 1980's, using cultivars which are no longer representative of the grain properties in varieties grown today. In addition, much of the literature is non-Canadian, and cannot represent conditions or variety grain quality found in the W. Canadian prairies. As a result, few definitive conclusions can be drawn from the literature, except for the very few Canadian studies completed, although some generalities about feed quality can be seen. Also, in cases where multiple triticale varieties were compared, very large differences in individual variety performance have often been found, highlighting the difficulty in interpreting single variety studies that compare triticale performance to that of other species, which is the more common comparison approach in feeds research. Further difficulties in interpreting triticale feed value are found because of (a) the wide range of methods used for feed processing and supplement incorporation in test rations, and (b) the occurrence of ration x animal strain (breed) interactions that are sometimes reported.

These many sources of variability in different studies have often led to contradictory conclusions about the relative value of triticale vs other standard feed grain sources. The lack of experience of how to optimize triticale use in a blended ration is itself a problem in the evaluation process. This is especially the case for poultry feed in Canada, even though other countries have found ways to feed it successfully. Nevertheless, the potential for triticale grain to enter monogastric animal feed streams in Canada is seen as great. It is so far only starting to happen in a small way with swine, often because of lack of confidence or data describing triticale advantages as a feed, or non-appreciation of the extent to which those advantages can be realized in on-farm practice. For example, current feedmills lack special binning space for triticale, and are not likely to invest in it until feed value is proven and appropriate triticale grain supply chains are known to be in place. In the absence of a large commercial grain flow of triticale in general in Canada, the greatest prospects for future use therefore probably lie in the short-term with the integrated grain grower / miller-processor / feeder operations, which do not have to rely completely on external grain sources or prices, and can supply their own source of triticale grain, or readily access it locally.

Nutritional research on triticale – background information

Research on triticale nutritional quality prior to 1969 at the University of Manitoba or at CIMMYT was limited to determination of protein content. The very earliest varieties appeared to have high protein content (up to 17-19%) but as problems with seed shriveling were solved and yield potential was raised by 30 years of breeding, so the protein content in newer varieties dropped (Figure 3). It was also learned very early on that as a percentage of protein content, triticale had a higher lysine content than wheat. This discovery highlighted the potential of triticale as a ‘protein efficient’ cereal, which status it has maintained since, especially for monogastrics. It is surprising that this high lysine content in triticale has not led to a much higher level of adoption in feeds where lysine is limiting, to replace corn or wheat (which are low in lysine), and some or all of the high cost protein meal. This approach was well known many years ago – the author recalls visiting a finishing swine feeder operation in N. Mexico in 1966, that was successfully feeding 100% triticale, without any protein supplementation. By far the majority of the early literature characterizes triticale as nutritionally suitable for humans, pigs, a wide range of poultry and game-birds, sheep and horses, and emphasizes the high quality protein which also allows for protein supplement replacement.

Figure 3 Protein and lysine content in triticale varieties of the 1960's and 1980's (Source: Villegas, CIMMYT)



In the early years of triticale breeding meiotic instability and abnormal endosperm development resulted in a shriveled seed coat, an evacuated crease, an endosperm with floury texture, and low test weight. Today's varieties have solved most of these problems, to where many of the properties, including feed energy potential, approximate those of wheat. As a result, feed grain quality from early publications is not relevant to many of today's varieties. Unfortunately, some negative experiences of the past led to a belief in poor nutritional and feeding value for triticale, and consequent discontinuance of triticale testing for feed value. Early work on use of voles or chicks, for example, to assay protein efficiency or energy level in breeding programs proved ineffective, leaving no alternative but to do this work on the full-size target animal (swine, cattle, dairy, poultry) with prohibitive cost. Willingness to invest in this type of research was limited, given the often conflicting or disappointing results with the early era varieties.

Despite the above assessment, some general findings from the past are still valid. In this review, which is intended to focus on the future, nutritional results from the international symposia are featured, and other key triticale nutrition papers. This is not intended as a complete nutrition review, rather it is intended to indicate where weaknesses and strengths in current knowledge may lie.

Protein quality

The biological quality of protein is determined by its proportions of various essential amino acids, which cannot be synthesized by monogastrics, but must be obtained in the food. In triticale, as in most cereal grains, lysine is the most limiting, although present at higher levels than in wheat (Tables 3,4,6). Comparable data were reported by Larter (1976) in Canadian work, who described triticale lines with 13.3% protein (up to 15.8%), compared to Glenlea wheat at 13.2%, and Neepawa wheat at 14.4%. Lysine levels averaged 3.55 (g/100g protein), range 2.73-4.56, compared to Glenlea at 2.81 and Neepawa at 2.90. In the same meeting Qualset presented results of Ruckman et al (1973) from California reconfirming the higher levels of lysine in triticale, compared to wheat, although these results were obtained with the earlier high protein triticale varieties. One of the varieties produced more protein per acre than wheat, and more lysine per acre than any of the wheats tested in California. Numerous other studies reported at the 1973 meeting supported the conclusion that triticale protein quality is superior to that of wheat, including work of Yang et al (rat studies) and Fox and Kies (studies on humans).

Anti-nutritional factors in triticale grain for feed and food

In the early days of feeding triticale to animals instances were recorded where animals exhibited limited intake or limited feed acceptability in the feeding trial, compared to wheat or other feeds. These effects are still found in some feed situations, and are attributed to 'anti-nutritional' factors. These are still not well characterized, nor have any specific compounds been identified in triticale that consistently explain the reduced feed intake. Further research is desirable on this topic, as it might be possible for breeders to remove problem compounds from new varieties. These compounds should not be confused with 'ergoty' samples, which are much less of a problem with new varieties, but that did reduce intake and productivity in the past.

Anti-nutritional compounds are found in many foods and include water-soluble pentosans (often causing food stickiness), alkyl-resorcinols, enzyme inhibitors, tannins, acid-detergent fiber, pectins, and protein-polysaccharide complexes. All of these occur in small amounts in triticale, but at levels that are much lower than in rye. Several of these may also account for the characteristic flavor of rye and triticale products. Breeding programs have occasionally addressed selection for lower (or higher) levels of some of these compounds in triticale, but the whole area of feed acceptability lacks a focused research effort, especially in Canada. Levels of these compounds in Canadian varieties are not well known.

No compounds unique to or outside the range in food-use cereals similar to triticale grain are known, that do not also occur in wheat or rye, so safety for human consumption meets 'substantial equivalency' requirements as defined in the Canada Food Safety regulations. Triticale has been used for many years around the world as a significant human food source, without food safety problems being reported that are due to the grain characteristics.

6.1 Questionnaire results – Feed formulators perceptions about triticale

Although triticale grain is not yet widely used as a feed grain source in W. Canada, it was felt important to ask feeders and formulators why this was the case. A survey was sent out to over 60 listed feed formulators and users, to determine their relative knowledge level about triticale, and their views as to why triticale might or might not be used by them or by their customers in the future. The individual questions are listed in this section, and the frequencies of response in each category are noted for each question.

Q1 How do you rate your knowledge base about the specific feeding properties of triticale grain

(Circle one)	Very high	High	Medium	Low	Very low
Response frequency:	1	2	5	6	1

Q2 How do you rate your knowledge base about the specific feeding properties of triticale silage

(Circle one)	Very high	High	Medium	Low	Very low
Response frequency:	2	0	1	6	6

Q3 In clients with whom you deal, how would you rate their general knowledge level about the potential for using triticale grain in their feed rations (Circle one)

	Not applicable to me	Don't know	Very high	High	Medium	Low	Very low
Response frequency:	0	0	0	0	3	9	3

Q4 In clients with whom you deal, how would you rate their general knowledge level about the potential for using triticale forage in their feed rations (Circle one)

	Not applicable to me	Don't know	Very high	High	Medium	Low	Very low
Response frequency:	0	1	0	0	1	9	3

Q5 If a workshop about the nutrient values of triticale compared to other feed grains was held in your region, how high would be the interest in it ?

Your interest, or your company (Circle one)	Very high	High	Medium	Low	Very low
Response frequency:	0	1	10	4	0

Regional interest (users) (Circle one)	Very high	High	Medium	Low	Very low
Response frequency:	0	0	7	8	0

Q6 If a workshop about the nutrient values of triticale compared to other grain, forage, greenfeeds, silage was held in your region, how high would be the interest in it ?

Your interest, or your company (Circle one)	Very high	High	Medium	Low	Very low
Response frequency:	0	1	8	5	1

Regional interest (users) (Circle one)	Very high	High	Medium	Low	Very low
Response frequency:	0	2	5	7	1

Q7. What is your main source of information about triticale for feed ? (Circle one)

	Prov.or Fed. Govt.	Non-govt. media	Internet	Own research	Seed-grower	Other
Frequency:	5	2	0	4	1	2

Q8. How much triticale grain do you handle per year, on average, and to what feed markets is it directed ?

None (13) or Total amount per year (specify) 1 x 5,000t, + 1 x 500t (75% to cattle)

Q9. Indicate how important each of the following issues would be (now or in the future) in affecting your decision to use triticale grain in rations. (Circle one on each line)

		Very high	High	Medium	Low	Very low
1. Ability to source sufficient amount	Response frequency:	3	8	3	1	1
2. Nutritional advantage in triticale grain	Response frequency:	2	7	5	0	1
3. Anti-nutritional factors in triticale, if any	Response frequency:	3	8	4	0	1
4. Price per unit weight vs other grains	Response frequency:	2	13	2	0	1
5. Lack of experience as a feed / processing	Response frequency:	0	1	6	4	1
6. Extra cost storing / handling another grain	Response frequency:	3	8	2	0	2
7. Ability to reduce protein supplementation	Response frequency:	0	4	6	4	2
8. Triticale is still an 'unknown' feed here	Response frequency:	0	5	4	5	1
9. It is a high energy, high lysine grain	Response frequency:	0	9	6	0	1
10. Lack of local feed conversion data	Response frequency:	0	6	6	2	1
11. Triticale yields >25% over CPS wheat	Response frequency:	0	6	5	1	3

Q10. If you do not use triticale grain for feed, is lack of a large local supply the main reason you do not use it ? Yes or No (Circle one)

Response frequency: 5 10

Q11. Triticale for grain use has been increasing steadily in W. Canada, and this trend is expected to continue, and for silage also. In each of the feed markets how great would <u>you</u> expect its increased adoption to be in the future ?

		Very high	High	Medium	Low	Very low
For cattle (grain):	(Circle one)	Very high	High	Medium	Low	Very low
	Response frequency:	0	2	4	5	2
For cattle (silage):	(Circle one)	Very high	High	Medium	Low	Very low
	Response frequency:	0	6	5	2	0
For swine (grain):	(Circle one)	Very high	High	Medium	Low	Very low
	Response frequency:	1	5	4	3	0
For poultry (grain):	(Circle one)	Very high	High	Medium	Low	Very low
	Response frequency:	1	3	4	4	1
Other	(Circle one)	Very high	High	Medium	Low	Very low
	Response frequency:	0	1	0	2	0

<u>6.1.1 Interpretation of feed formulator questionnaire responses</u>

This survey did not gain a very high response (< 25%), perhaps itself reflecting the low level of interest in this crop by this potential user group. Three of the respondents were involved in feeds research, and not in the feed formulation industry *per se*. Only two of the respondents actually handled triticale in their operations (500 - 5,000 tonne per year), reflecting low usage by this sector. Of the small sample responding, the largest number obtained their feed information about triticale from government as a primary source, or from their own research. Other sources of information appeared not to be used very much, and none used information from the internet. This result is not surprising to the author, as it reflects the current location of the greatest amount of information, which is not very much at this time. It also underscores the need to establish a single, accessible source of detailed information about triticale for this important feed sourcing sector, and for feeders.

With the exception of three formulators personally involved in feeds research, all respondents rated their knowledge about the feeding properties of triticale grain as from medium to very low. For knowledge on silage feeding properties, 11 out of 13 rated their knowledge as low to very low. Clearly this sector could benefit from a better knowledge base if it is to consider triticale use in its rations recommendations. However, the same respondents also indicated only a medium to low interest in their attending a workshop in their area about triticale feed grain use properties. Interest in a workshop for forage use and qualities was from medium to very low. This lack of interest will continue to be a difficulty for extension efforts that target information transfer to the feed formulator sector in particular, although this remains a worthwhile objective, in the opinion of the author.

When asked the same questions about the knowledge base of their clients, the respondents rated their clients' knowledge base even lower, from medium to low in all cases for grain properties, and for forage feed properties. Interest by clients in local workshops about triticale feed grain properties was again estimated at medium to low, but was somewhat greater for forage quality, but still ranging from high to very low.

Respondents were asked to indicate the importance of eleven different issues that would affect their decision to use triticale in their current or future rations. In the frequency of responses, and from comments appended, the two most important issues were ability to source sufficient quantity of supply, and the extra cost of storing and handling a new and separate grain (primarily of medium to very high importance). 66 % indicated that lack of potential supply was not the main reason for not using triticale at this time, with comments from several suggesting that the storage issue was of much more importance. Other factors of medium to very high importance were the nutritional advantage of triticale grain (high lysine and energy level), possible presence of anti-nutritional factors (not specified by anyone), and price per unit weight. Two issues that were assessed as having median importance (ranging from low to high) were triticale being an 'unknown' feed in the W. prairies, and a lack of local feed conversion data for local supplies.

Two surprises for this author were noticed, the first that as many as five respondents (over 25 %) rated the ability to reduce protein supplementation costs through triticale use as low to very low importance. Three respondents also rated the importance of the high yield advantage of triticale over CPS wheat as of low to very low importance. Perhaps these responses related to feed use for ruminants, where these interpretations would be correct. No respondent rated either of these two issues as of very high importance. This suggests that the well known advantages of high lysine in triticale grain for swine diets, with its ability to allow reduced protein supplementation, is not well recognized in this sector of the industry, and needs a special focus in extension activities.

Respondents were asked to predict where future triticale expansion would most likely occur, in grain or forage use for cattle, or in grain use for swine or poultry. Opinions about this were very varied, from very high to very low expectations of increased adoption in almost all of the categories of use. Most pessimism was expressed (>40 % of responses) for grain use for cattle and for grain use for poultry (low to very low ratings). Silage use for cattle, and grain use for swine were seen as having the greatest potential for increased adoption (rated between high and medium, on average). These views are consistent with views expressed by many other contacts during the course of this review.

General conclusions from the survey:

1. Government and 'own research' are the main sources of information for the feed formulator sector, and none surveyed made use of the internet for this purpose

2. The overall knowledge base of feed formulators and their clients, about feed quality of triticale grain or forage, is not as high as it should be, and in many cases is poor.

3. Interest in attending workshops to learn more about the feed qualities and use of triticale grain or forage is not high in this sector of the feed industry. For their clients, a slightly higher interest level likely exists for workshops about triticale use for forage.

4. It is of considerable importance that formulators and feeders have access to a better data base describing the nutritional properties of triticale samples from the W. Prairie area, so that more extensive, reliable localized data can be used as criteria in determining triticale grain value in rations.

5. In promoting triticale grain use for feed use, the high lysine content of the grain should be especially emphasized, for its special value in feeding swine, where there is added value in being able to reduce the amount of protein supplementation required.

6. Key issues mentioned in comments included 1. Cost problem for extra binning; 2. Lack of a supply stream or a price discovery system; 3. Need for a clear reason to want to use it for feed, compared to other feeds available; and 4. Problems with lateness of the crop, both for grain and silage, because of frost risk and potential loss of feed quality.

7. Although views were varied on this topic, respondents generally indicated that the greatest expectation of increased feed use for triticale would be for silage use for cattle and grain use for swine, with increased usage much less likely for grain use for poultry or for cattle.

6.2 Triticale feed for Swine

As indicated in the historical review section, the superior protein quality and high yield potential of triticale grain has precipitated continuing interest for its use in pig feeding. Unlike the situation with poultry (see next section) uses for pigs are usually reported in the literature as very successful, with 100% replacement of other feed cereals (e.g. wheat, corn, barley, millet) being readily achievable in most cases, without loss of productivity or product quality. Where such substitution is made, less protein supplementation is required because of the high lysine content in the triticale, resulting in a lower cost ration overall. Commercial adoption of triticale for swine rations has already occurred internationally (e.g. in Australia, USA, Brazil, Poland and Germany) but is only now starting to occur in W.Canada, demonstrating a very surprising lag in technology adoption.

Because of the relative absence of reported problems in feeding triticale to swine, this review is kept relatively brief, referring only to significant recent publications. As is the case for other end use applications in Canada, there are few studies of Canadian cultivars fed to swine under Canadian conditions.

In studies in Colorado of replacement use (0-100%) compared to millet, including a sub-study of the low trypsin inhibitor activity of triticale, Erickson and Elliott (1985) evaluated performance of weanling pigs and in swine starter, grower and finishing diets. When least-cost diets for swine were formulated based on the nutrient contents of the triticale, the amount of soybean supplementation was substantially reduced. Triticale use resulted in similar productivity to the other diets. Advantages in costs were attributed to the higher lysine and phosphorus content in the triticale. It was noted that young pigs preferred the triticale ration to the corn-soybean ration. Cost savings from triticale use were estimated at $266 US per 100 pigs marketed.

Myer et al (1990) studied triticale replacement of maize (and soy supplement) in starter pigs and growing-finishing pigs, using three cultivars, in eight trials in Florida. Satisfactory replacement of 100% of the maize and from 30-50 kg of soy-meal per 1000 kg of feed was achieved, and an energy value for the triticale of 95-100% of maize was estimated. Cultivar differences appeared to be small. (In work with growing pigs in Belgium, Leterme et al (1990) evaluated seven triticale cultivars, and concluded that the digestibility and energy value for pigs was essentially linked to the chemical composition of the samples, and were not varietal characters). Myer's earlier results were reconfirmed and expanded in scope (Myer et al, 1996) in studies where use of feed grade synthetic amino acids was incorporated in the diet for growing and finishing pigs. With triticale used as the main cereal (energy) source, the required soybean meal component could be completely replaced with supplemental synthetic lysine and threonine, without affecting productivity or carcass quality. Brendemuehl et al (1996) compared the effects of maize, wheat and triticale on carcass composition and on taste and quality characteristics of pork, in rations balanced to equivalent lysine content using soy-meal supplementation. Grain source did not affect carcass lean meat content, or muscle marbling, texture, firmness or color, nor were juiciness, flavor or tenderness of broiled loin chops affected.

Backfat polyunsaturated fatty acids were slightly lower from the triticale and wheat diets, compared to the maize diet.. These results supported the use of triticale as a complete replacement for maize for growing-finishing pigs.

Balogun et al (1988) compared two samples of OAC Wintri triticale to corn, using cannulated pigs, to assess protein and energy digestibility. They concluded that 'OAC Wintri can be a good alternative to corn as a source of protein and energy in pig diets'. However, examination of the data indicates that the two OAC Wintri samples differed significantly in their dry matter digestibility and gross energy, with one being significantly worse than corn. This result again indicates the influence of environment on feed quality, even with a fixed cultivar, and supports the need for multiple feeding studies of samples from different sources and cultivars, to build a reliable data base from which to predict triticale feed quality.

Myer (1998) also compared diets where triticale was used to replace maize during the pig nursery phase (3-8 weeks of age). Over the 35 day feeding trial, use of triticale resulted in a small, but significant, average increase in the rate of gain, especially in the first two weeks. Feed conversion efficiency was similar in the two diets, supporting the view 'that triticale is an excellent feed grain for pig diets, including diets for early weaned pigs'. In Canadian studies (Robertson et al, 1998; Jaikaran et al, 1998) 100% Pronghorn triticale as the grain source was compared to 100% corn, 100% hulless barley, and a 50:50 mix of hulless barley and Pronghorn triticale. Of 25 production, carcass and meat quality characteristics measured, triticale performed not significantly different from the corn (control) diet in 24 instances, and in all cases not different in comparison to the 50:50 mixture. It was concluded that triticale can be successfully substituted for maize or hulless barley in the diets of growing-finishing (25-110 kg) pigs (Robertson et al, 1998).

The Canadian paper of Jaikaran et al (1998) presents a very thorough review of results from feeding trials of triticale for pigs, including a few (rare?) studies where favorable results were not obtained. Their study of Pronghorn triticale vs other cereal grains fed from 27 kg through 110 kg weight strongly endorsed triticale suitability for swine feed, on the basis of both productivity and carcass and meat quality, and carcass grade.

Edwards (1998) drew attention to the often continuing negative perceptions about triticale which relate back to earlier varieties, and which are no longer valid with new varieties. He suggests that the old anti-nutritional traits of high non-starch polysaccharides (pentosans and β glucans), high trypsin inhibitor levels, high alkyl resorcinols, and high ergot occurrence have all been substantially remedied or are not a problem in the new cultivars of S. Australia, and no longer are an issue there. He indicated that 'the most recent reports of triticale performance in pig and poultry diets confirms triticale to be equal to or better than wheat and maize'. The typical grain composition values for wheat, triticale and rye in S. Australia samples are indicated in Table 17.

Table 17 Typical wheat, triticale and rye composition values (S. Australia, cited from Evans (1998, SARDI), dry matter basis

	Wheat	**Triticale**	Rye
NSP - Soluble arabinoxylans %	1.8	**1.3**	3.4
- Insoluble arabinoxylans %	6.3	**9.5**	5.5
- Beta-glucans %	0.8	**1.7**	2.0
- Cellulose %	2.0	**2.5**	1.5
Total NSP - Soluble %	2.4	**1.7**	4.6
- Insoluble %	9.0	**14.6**	8.6
Starch %	66 (54-74)	**60 (55-63)**	50
Protein %	8-22	**8-22**	NA
Metabolizable energy, Poultry (MJ/kg DM)	9.0-14.8	**14.0-15.2**	(14.2)
Digestible energy, Pigs (MJ/kg DM)	16.0	**16.0**	15.5
Metabolizable energy, Ruminants (MJ/kg DM)	13.5	**13.3**	13.3

Also of interest, from elsewhere, are the average grain compositional values reported in the Ohio State University, TriState Swine Nutrition Guide (1998), and the suggested maximum incorporation rates of feedstuffs for swine (Tables 18 and 19). Some of the maximum incorporation rates cited in this source are lower than those recommended or supported in other published studies.

Table18 Composition of commonly used feed ingredients in swine diets. Selected feedstuffs, values cited from Ohio State University Bulletin 869-98 (1998)

	DE Mcal/lb	C.prot. %	Lys %	Meth %	Meth + Cys %	Thre %	Trypt %	Ether extract %	Crude fiber %
Barley	1383	10.5	0.36	0.17	0.37	0.34	0.13	1.9	18.6
Yellow corn	1600	8.3	0.26	0.17	0.36	0.29	0.06	3.9	9.6
Oats	1256	11.5	0.40	0.22	0.58	0.44	0.14	4.7	27.0
Rye	1484	11.8	0.38	0.17	0.36	0.32	0.12	1.6	12.3
Wheat SRW	1564	11.5	0.38	0.22	0.49	0.39	0.26	1.9	na
Triticale	**1505**	**12.5**	**0.39**	**0.20**	**0.46**	**0.36**	**0.14**	**1.8**	**12.7**

SRW = Soft Red Winter; C.prot = Crude protein; DE = Digestible energy;

Table 19 Suggested maximum incorporation rates (%) of commonly used feed ingredients in swine diets. Selected feedstuffs, values cited from Ohio State University Bulletin 869-98 (1998)

	Starter	Grow-finish	Gestation	Lactation	Limitations
Barley	15	40	40	25	High fiber
Corn	60	80	90	80	Lysine
Oats	5	20	50	0	High fiber
Rye	0	25	25	10	Variability, ergot
Wheat	0	40	30	40	Expensive
Triticale	**10**	**40**	**40**	**40**	**Variable quality/ergot**

6.2.1 Future needs to develop triticale grain as a swine feed in Canada

The clear consensus from all prior work, and a conclusion that seems to have been reached some years ago, is that triticale grain for swine of all ages and types is an excellent feed choice, with few to no feeding problems, and that it is substitutable for other feed grains. When it is substituted, ration costs are lower because of savings from lowered need for soy-meal (or other meal) supplementation.

Adoption of this use of triticale in W. Canada is just now beginning, but is still limited by (a) unfamiliarity with the feed properties for swine, and the nature of optimal formulations to use in combination; (b) lack of a grain supply, and/or storage bins at feeder sites; (c) lack of a locally validated feed compositional data-base established using the newest Canadian varieties; and (d) remaining concerns about whether earlier anti-nutritional characteristics should still be a concern, or whether they will affect feed intake.

Following discussions with Dr. Willem Sauer (University of Alberta, swine feeding specialist) surprise was reiterated that triticale was not already more widely fed to swine in Canada, given the long well-known feed advantages of this grain, and the price competitiveness that should be available from high grain yields in the field. It was concluded that the following approaches would help in promoting increased use for swine feed:

1. Informational workshops about triticale grain for swine, targeted both at swine producers and feed formulators. The technology for triticale use in these situations is already in place, but needs to move out to potential users.

2. Commercial scale, on-site research ('on-farm demos') at selected swine production facilities throughout W. Canada, to compare locally grown triticale, wheat, hulless barley and (imported) corn. The main objective of this is to gain full-scale experience, and to establish a base price for triticale at which diet substitution can occur. This on-site work must follow proper experimental protocol, so that findings can be used in future technology transfer publications.

3. Basic research should be continued in small scale studies at government and University labs, to fill remaining informational gaps:
   a. Develop a W. Canadian nutrient database from multiple samples of different triticale cultivars, to provide a better reference data set about the mean and variability of grain composition, for application in linear programming feed formulation applied to the Canadian crop.
   b. Determine feed intake levels for all ages and types of swine, using various ration combinations, emphasizing triticale use supplemented with canola meal. Most published studies so far have used soy-meal, but canola meal would be a suitable local substitute. The purpose of this work is to obtain local feed quality data validation with local varieties, particularly for use in extension activities.

c. Specific studies to determine whether trypsin or chymotrypsin inhibitors are a problem in new varieties, and how to remediate any such problem (by feed alterations, or by breeding for lower content).
d. In collaboration with breeders, to select low phytate cultivars, so less phosphorus occurs in manure. These studies should be supplemented with agro-ecological modeling to determine the environmental value of reduced P in manure applied in cropping systems which involve heavy manure applications to fields.
e. Studies of economic returns using triticale for all swine feeding situations, to determine relative merit vs other feedgrains, and to precipitate a reliable price discovery process for triticale.

In the opinion of this author, and because of the potential large and predictable grain demand that could quickly develop, the swine feed market is the grain market that should be targeted as first priority, especially as most of the lack of market seems to be the result of lack of information transfer, combined with a lack of a supply stream. This is especially the case at this time of rapid expansion of the swine industry in Alberta, and is further justified because of the pressure that will be placed on developing additional feed grain supply as a result. The higher grain yields of triticale compared to barley can contribute to an overall increase in feed supply in W. Canada, on a limited resource base of arable land suitable for cropping.

6.3 Triticale feed for Poultry

For purposes of this review much of the information on this topic was sourced from the literature, from discussions with Dr. Doug Korver (University of Alberta), and from a draft paper by Ms Kyla Kotke (student, University of Alberta). Triticale use for poultry is not a significant event yet in W. Canada, because sufficient basic research and local adaptation studies have not yet been completed to merit the risk of investment in its use, compared to other readily available feeds. Comparative, commercial scale, feed value tests have not yet been done, but are planned at the University of Alberta, because of the promising results reported in some of the literature from elsewhere. A proposed University of Alberta study for 2001 would involve the Alberta Chicken Producers, and a full feeding and processing run with 60,000-90,000 broilers at the LilyDale Poultry Cooperative, Spruce Grove. It is believed that this would be the first such commercial scale study in W.Canada, comparing triticale with wheat. Data from such studies can be used to work backwards in an econometric model to determine the competitive feed replacement price for triticale, compared to wheat, for example. Price discovery for triticale is difficult now, because of lack of consistent supply in the market.

Despite the importance of such a study, it still suffers from numerous limitations, including (a) high cost for the study, including contingencies to cover potential commercial losses, (b) logistical difficulties in accessing sufficient seed quantity of a single triticale variety (and check seed) for the study, in the timing of deliveries, processing and access to birds at the correct stage, (c) the limitation of this being a single variety study, (d) the lack of industry experience in knowing how to optimize the ration and processing and enzyme supplementation of a triticale based ration, and (e) the necessity to rationalize the feeding protocol to a single treatment, to keep the trial at a manageable size. It would be useful to identify a number of smaller sized poultry feeding operations at which smaller scale commercial-run studies could also be conducted to compare variety performance, varied processing procedures, varied enzyme use and varied feed formulations, preferably on a prairie-wide collaborative project basis, for both meat and egg production. Ideal operations for this work would be those that grow their own feed, that process it and formulate it in their own facilities, using commercial feed supplements as needed, and that would agree to this on-site research evaluation of triticale grain compared to their normal feed grain source. This approach should be a high priority for research fund investment in triticale at this time, as differences and/or deficiencies thus discovered in the grain as a feed for W. Canadian poultry production can then be researched in detail later, in laboratory level studies at Government and University facilities.

Dr. Korver suggested that triticale use for egg production might be less of a problem than for broilers because layers tend to be more tolerant of feed limitations than broilers, and are able to better compensate by increasing feed intake. However, Canadian research on triticale use for egg production has not yet been done. Work to study the energy levels of triticale for poultry is underway at AAFC, Agassiz (Dr. Tom Scott's lab), but no triticale work is going on at Saskatoon (Dr. Hank Klassen lab). High levels of NSP (non-soluble polysaccharides) are known to be a potential problem limiting energy level etc. in poultry, but can be managed using enzymes. In discussion it was agreed that since triticale is never likely to become a major food grain in Canada, not commanding food grain prices equivalent to wheat, its long-term price structure may remain more compatible with those suitable for feed application, and not be subject to increases like those to which food wheat is cyclically subjected. The potential fit in the integrated grower / processor / feeder closed-loop operation mentioned earlier is seen as the most likely place for the development of a triticale feed market for poultry. However, this will not occur in the short-term, until studies are published indicating the economic benefit compared to other grains.

The balance of this section for the report highlights significant prior publications about triticale feed use for poultry, and also presents results from a pilot study with broilers recently completed at the University of Alberta (personal communication, Dr. Korver).

As indicated in earlier parts of this review, compared to wheat or corn, triticale is generally reported as having superior levels and availability of important amino acids for monogastric animals, including lysine, arginine, aspartic acid, alanine, and threonine, but sometimes lower tryptophan. However, protein concentration in the grain of newer varieties is often not as high as wheat, depending on specific variety comparisons. (See McGinnis, 1973, for a description of protein performance in the early era, high protein varieties, at 14-29% protein levels). Findings about protein quality in newer varieties with lower % protein (10-13%) have been completed in Saskatchewan by Salmon (1984), and elsewhere by Johnson and Eggum (1988) and Myer et al (1996), but lead to continuing interest in triticale for broiler diets. Despite the perceived protein superiority of triticale, its use in the poultry diet has often resulted in poorer production compared to wheat or corn. Negatively affected performance traits in broilers have included reduced final weight, weight gain, feed efficiency and carcass yield (Charalambous et al, 1986; Gerry, 1975; Ruiz et al, 1987; Proudfoot and Hulan, 1988; Smith et al, 1989; Vierra et al, 1995). Leeson and Summers (1987) also reported negative effects for laying hens, on egg production, increased feed intake, and shell quality.

Several studies have focused on possible explanations for cases where triticale performance was worse than the standard feed grain. In list form these include at least five possibilities, but no single one of these has yet explained all differences.

1. Limiting levels of lysine and threonine in triticale grain (Gerry, 1975; Maurice et al, 1989)
2. Problematic diet formulations with triticale, including too high protein content and nitrates limiting feed intake, but also varying by genotype, location and environmental effects (Gatel et al, 1985)
3. Antinutritional factors not present in wheat and corn, including high acid detergent fiber (ADF), and cultivar specific (lowered) digestibility of specific amino acids (Johnson and Eason, 1988).
4. Pentosans (5C-polysaccharides, from the rye parent), with high water holding capacity and viscosity, causing poor digestibility, pasted vents and/or sticky feces,

that need to be reduced (Boros, 1999; Maurice et al, 1989; Ruiz et al, 1987; Proudfoot and Hulan, 1988; Smith et al, 1989; Rakowska,1992).

5. Anti-nutritional factors such as trypsin inhibitor, alkyl resorcinols, or pectins (Smith et al, 1989). Rakowska et al (1992) indicated that resorcinols, that lead to lower palatability and feed intake, ranged from 400 to 600 mg/g in triticale (similar to wheat) but were from 900 to 2000 mg/g in rye. Trypsin inhibitor was at 0.6 to 1.6 in triticales, close to wheat, but was much higher in rye.

Although some studies have indicated that negative effects of triticale do not occur when the triticale grain fraction in the diet is limited to as little as 15% of the grain portion of the diet, other studies with broilers and egg production have demonstrated no differences in productivity, even up to 100% inclusion rates (Maurice et al, 1989; Karunajeewa and Tham, 1984; Boros, 1999; Leeson and Summer, 1987; El-Yassin Fayez et al, 1996; McNab and Shannon, 1975; Yaqoob and Netke, 1975). Savage et al (1987) reported that increasing the triticale content in the diet actually improved the physical and sensory quality of cooked meat from turkey toms.

The existence of cultivar to cultivar variability is underscored in a number of studies, and it can affect productivity and feed value, so that one cultivar may perform worse than wheat, and another better (Salmon, 1984; Johnson and Eason, 1988; Pettersson and Aman, 1990). Maurice et al (1989) suggested that newer cultivars performed better than older ones, because of genetic improvement in grain plumpness combined with lowered protein levels. In Polish studies, Boros (1999) compared feed quality of triticales with different ploidy level, and concluded that cultivars with less rye complement in them (especially hexaploids) appeared to have improved feed performance for poultry. Boros also indicated that the better hexaploid cultivar (of two tested) could serve as the sole cereal grain feed source for the diets of young broiler chicks. In this context it should be re-iterated that, although the chromosomal complement of current Canadian cultivars is not definitively known, they are all believed to be complete hexaploids.

Kotke and Korver (unpublished personal communication, 2001) recently completed a small study at the University of Alberta using three strains of 300 day old chicks, to compare effects of two diets (triticale or wheat based), on broiler productivity and carcass quality. The triticale variety used was not specified in the draft copy seen. Although differences were not large (and could possibly be removed by manipulation of the total feed formulation), birds fed on wheat had superior growth rates and final weights compared to those fed triticale. Using triticale, extra feeding time (1-2 days ?) would be needed to reach comparable final weights. In 12 of 21 carcass quality characteristics measured, no significant differences were found between the two treatments. In most cases where significant differences were found, the result from the wheat treatment was superior. In one case, (for total breast weight) the triticale ration was superior to the wheat ration. Results from this single Canadian study were sufficiently in favor of triticale to catalyze plans for further experiments to determine the best way to optimize triticale use in poultry rations for broilers.

6.3.1 Future needs to develop triticale as a poultry feed in Canada

In order for triticale use for poultry feed to become significant in W. Canada the following information and activities will be needed, listed in 'action priority' order.

1. Assembly and/or reporting of specific proximate analysis data of modern W. Canadian triticale varieties for characteristics of importance in a monogastric feed, and to poultry in particular. Samples or data sets for this may be available from other triticale studies recently conducted in Alberta, in sources not normally accessed by poultry feeders. If these data are unavailable, trials should be conducted to acquire the samples and to conduct the assays. It is suspected that many of these data may already be in place in different research reports, or that data or suitable grain samples are being collected in current triticale research projects unrelated to poultry production interests.

2. The 'integrated grower / processor-miller / feeder' poultry production operations of W. Canada referred to in the text should be identified, and those willing to cooperate and to conduct production facility level studies on feed value of triticale varieties, formulations and processing systems. The optimum approach would be to do this work with cooperators in all three prairie provinces, so that localized extension of results can be carried out, and replication of the studies in different facilities can be achieved prairie-wide. This research will also require localized grain production (variety specific) for the study, on which proximate analyses etc. can be conducted in collaborating research laboratories, and this activity will also serve to promote triticale prairie-wide. The concept is for multi-province funding of such a project, with the leadership for it being a partnership of AAFC (Federal) and AAFRD (Alberta), as the primary breeding agents in Canada for this crop. In Alberta terminology, this multi-facility trial would be an 'on-farm demo', the reasons for which are justifiable from the literature, but for which the W. Canadian adaptation studies have not yet been done. These studies should target broiler production as priority 1, and egg production as priority 2, based on the potential grain markets that could develop by replacing feed wheat. Results will be incorporated in extension materials about how to use triticale grain efficiently in poultry diets.

3. Basic scientific understanding of any negative aspects of triticale use for poultry is needed, and can only be obtained from studies conducted in specialized research facilities, such as those at the University of Alberta, or in Agassiz and Saskatoon. Continuing work of this type is essential in parallel to the 'on-farm, production facility' level research. These studies should continue, but will benefit from a greater focus on characterizing specific negative attributes in feeding, conducted at a variety specific level, once the studies above are completed. These studies will continue to be based on finding understanding of feeding processes using triticale, and how feeding difficulties can be remediated. The research group capabilities and facilities for doing this work in W. Canada are excellent, perhaps even better than those in other countries that already feed triticale to poultry on a commercial basis. As new scientific discovery occurs in these labs, the results can be publicised and used

immediately in the production-facility studies, to validate the results, and to optimize the overall efficiency of feed use.

As part of an expanded triticale research network based in W. Canada (8 participants from 3 research institutions) one such poultry research proposal to assess the processing needs and enzyme supplementation needs, plus growth and conversion rates etc., at an 80% cereal inclusion rate in the diet, has been submitted to AARI for funding in 2001. It is suggested that Dr. Korver be approached to join this team, so that capacities and potential funding assistance from poultry industry supporters of the University of Alberta Poultry Research Center facility, including meat quality assessment and egg production, can be exploited in future projects.

6.4. Triticale grain feed for ruminants

Sherrod (1976) evaluated some of the first triticales grown in the US in grain feeding trials with Hereford steers, compared to wheat and sorghum, in self-feeding regimes. In comparison to the sorghum rations, the triticale resulted in improved feed conversion rates, higher digestibility, similar carcass and meat quality, but an overall lowered rate of gain, the latter completely explainable by a 25% reduced rate of feed intake for the triticale. In a second trial with sheep (including 50% roughage) TDN and DE was higher for triticale than for sorghum grain, and intakes were similar. This study also confirmed that there can be an acceptability problem for 100% dry triticale fed to steers, and that the lowered intake could hinder rates of gain. In subsequent trials at a 50% triticale incorporation rate no intake problems were found. Sherrod quotes numerous papers indicating that high levels of wheat also reduce acceptability and consumption of ruminant rations. Steam rolling of triticale was recommended as a way of improving triticale acceptability. Prior reports of negative effects of wheat and triticale on liver abscesses were also confirmed in this study, and it is known from 1960's work that high levels of triticale in a ruminant diet may also damage the rumen epithelium.

In discussions with various contacts about triticale grain feed for ruminants, two themes often recurred. The first was that were a number of 'feed them and weigh them' studies of animals that occur that do not lead to any real understanding of the feed quality or the feed needs, and that more basic research is needed to gain that understanding. For example, researchers still seek better ways to determine the value of a feed before it is fed, not after, and ways to predict its feed value. The second observation, about triticale for feed, is that when commercial operations do feed it they like the high energy value compared to barley feed, and will use it if the price per unit weight is low. Compared to barley they may also get a protein boost. Thus, triticale enters ruminant rations only if it is low priced, so that yield potential becomes all-important in this market. At the present time the absence of a significant supply stream restricts a major commitment to it as a feed for ruminants, where large quantities are needed, but feeders can fit it in when some is available at a low, discounted, price. Also, the extra cost of separate binning for an additional feed source of unreliable supply could rarely be justified in this ruminant feed application.

Information about triticale grain use in ruminant rations, especially for Canadian situations, was very sparse and difficult to find. Dr. Kennelly (AFNS, University of Alberta) suggested that this was because very little research has been done on this topic, a view re-iterated by Dr. Gary Mathison (Ruminant nutritionist, AFNS, University of Alberta). Although it is known that triticale is fed successfully to ruminants in many parts of the world, in Canada it most likely only ever enters the ration as a low priced, high energy, feed substitute, when spot quantities are available, not on any very large regular basis. Also, a large supply chain would need to exist for feeders in this market to consider it as a regular feed source, and this simply does not exist. A number of large feeder operations in W. Canada do use triticale grain for cattle, often in combination with triticale silage and other grain or legume silage. Such operators mentioned in discussion include Lakeside Feeders, Lethbridge; City Packers, Lethbridge; Highland Feeders, Vegreville; Grandview Cattle Feeders Ltd., Lethbridge; Riverside Feeders, Lethbridge; Thorlakson Feedyards, Airdrie; Highway 21 Feeders, Acme; and Westlane Feedlot, Leader, SK. Efforts are underway to obtain more information from these sources. Competitiveness with barley would be needed to see expansion of triticale grain use in this market, and this is unlikely to be achieved any time soon in the absence of large volumes of triticale grain in the feed market. Spot markets may well exist.

In studies comparing a ration with 70% corn with a 38% corn plus 38% triticale ration, fed to steers or fed heifers, Hill and Utley (1989) found that Beagle 82 triticale could be substituted completely for corn and the supplemental protein without reducing metabolic efficiency or weight gain. This work, endorsing the use of triticale as a major feed grain potential for the southeastern USA, confirmed their previous findings with finishing steers (Hill and Utley, 1985).

In Canadian work Zobell et al (1990) compared grain diets in combinations with barley silage and vitamin premix, to study body weight, average daily gain, feed intake, and feed: gain ratio. No significant differences were found between the 100% barley control, 100% triticale, 50% triticale + 50% barley, or the 25% triticale + 75% barley treatments. Thus triticale could be successfully substituted for barley at a 25 – 100% rate in these trials. Other feed studies that found favorable results from feeding triticale grain to ruminants include Males and Fulen (1984), Hadjipanayiotou et al (1985), Kochstova et al (1987) and Pace et al (1986).

In consideration of a sparse literature, and from feedlot experience, the following conclusions and recommendations are made

6.4.1. Recommendation about use of triticale grain for ruminants

1. Triticale grain appears to be substitutable for barley grain in cattle feeder rations, without detriment
2. A technical level, detailed survey of feedlots using triticale grain should be conducted, to learn their method of use and to assess their success and/or problems using it, and returns
3. Extension materials should be developed, to publicise the value of triticale as a substitute for barley in feed rations, and how to use it
4. A basic research study should be conducted (low priority) to determine the extent, if any, of varietal differences in feed value for feedlot cattle. Differences would be expected to be small in this feeding situation. Any such studies should carry through to study of weight gain, and also include carcass and meat quality determinations.

7. Experience-based use of triticale forage in Canada

7.1. Whole plant triticale for silage (10 years of progress, 1990-2001)

The expanding scope for triticale to be used in this market was first clearly recognized at the 1990 2nd International Triticale Symposium (in Passo Fundo, Brazil) and the following highlights from the meeting summarize the consensus of that time about this new silage source.

1. The notably consistent and positive feature of triticale as a silage was its high nutritive value and high dry matter yield, compared to local conventional silage crops for which it could be substituted.
2. Studies of optimum physiological time to harvest triticale for silage generally concluded that the milk-ripe to mid-dough stage was optimal, as earlier harvest lowered yield, but later harvest allowed fiber content (especially lignin) to reach too high levels. Some differences in optimum harvest date were seen in different reports, and this appeared to be a topic which would require local adaptation trials to assess local variety differences, with product quality to be determined using studies where silage was fed from varied harvest dates, to determine optimum harvest management. As with other cereal silage, management should be such as to optimize water soluble carbohydrate levels, for good fermentation at a low pH. The specific harvest process also has to avoid problems with yeast, from liquid losses, and avoid anaerobic conditions, as well as achieving the lowest possible lignin content.
3. In studies from Brazil, Argentina and the USA, a number of desirable plant traits associated with good silage and grazing properties that were suggested were:
    a) Narrow to medium leaf width, and medium stem width
    b) Abundant tillering, and a high frequency of fertile spikes
    c) Good rates of re-growth after grazing
    d) Avoidance of high lignin content, which in Argentina studies was associated with tall varieties, high leaf/stem ratios, and high sclerenchyma or epidermis content.
4. In the USA the best potential for triticale was described as being jointly from forage potential and grain applications, with very favorable forage applications as follows:
    a) For poor soils, as forage, and in high altitude locations where wheat does poorly
    b) As a dairy farm forage source, where access to maize silage or grain is limited, or on acid soil fields (e.g. after potatoes) for soil conservation

7.2. Recent evaluations about triticale for forage

Acreage adoption figures for forage use and multi-country studies reported in the two most recent triticale symposia (1996, 1998) all continue to support the advantages of triticale forage as greenfeed or silage, over wheat and other cereals, for yield superiority combined with good forage quality (Salmon et al, 1996; Anon, Kansas State University, 1996; McLeod et al, 1998; Lozano et al, 1998; Kolding, 1998; Baier et al, 1998; Zobell et al, 1992; Khorasani et al, 1993; Baron et al, 1992, 1993A, 1993B, 1994; Salmon et al, 1993). These advantages are also capturable in triticale x 'other crop' mixtures, as demonstrated by Carride et al (1998) in Portugal, although research on this aspect has been limited in Canada. Dr. Stan Blade (AAFRD) is currently doing a study on triticale mixtures with barley and peas, not yet completed. An extensive study has also just been completed by Elston Solberg et al (2001, AAFRD) examining both grain and forage potential for triticale. (Results unavailable at time of this draft report). Kolding and Metzger (1996) indicated that triticale could be a suitable roughage source for over-wintering range cows

In interview with Dr. John Kennelly (dairy specialist, AFNS, University of Alberta) it was concluded that for triticale to significantly enter any market niche it must either offer a new advantageous feature, or offer a significant improvement over current alternatives in at least one important aspect. In the case of annual forages the comparison must be to the long-term, well-established alternatives of corn, barley, fall rye, or spring or winter wheat. Studies to date indicate that forage quality (including silage) can be as favorable as the cereals compared, but that the greatest advantage lies with the superior yield ability of triticale. Although variety differences in forage quality are found, they are not as large as the differences found between species. The 'new era' triticale varieties can be used in most forage applications, either as 100% or in mixtures with other cereals, with relatively few disadvantages showing up, although some are known. Typical Canadian results with modern varieties were reported by Salmon (1996) as follows.

Table 20A Yield potential and forage quality of spring triticale, barley and oat when harvested at the early dough stage (from Salmon et al, 1996)

	Yield, t ha^{-1}	Protein, %	IVDOM, %	NDF, %
Triticale	16.9	8.6	67.2	44.0
Barley	12.4	10.0	68.2	46.6
Oat	16.0	11.6	61.6	48.9

IVDOM = *in vitro* digestible organic matter; NDF = neutral detergent fiber

Table 20B Performance of a spring seeded binary combination of winter triticale and spring barley compared to perennial grass as a pasture in central Alberta (from Salmon et al, 1996)

	Triticale/barley Steers	Perennial grass Heifers
Rainfall (mm)	264	274
Initiation	July 1	May 29
Completion	Oct.23	Sept.9
Grazing days	115	103
Stocking rate (animals / ha)	0.38	0.38
Daily gain (kg / day)	0.94	0.74
Total gain (kg / ha)	23.6	19.3

Kennelly (Pers.comm., 2001) also offered the view that, unless forage yield differences are very great from barley, it would be difficult for triticale spring types to replace barley in silage form. The traditional use of barley, and its own high yields, offer a major obstacle to triticale adoption. In the winter types, and especially applicable to dairy herds, the situation is different because of the high extra yield, and the availability of an early season harvest, not available with other cereal forages. The combination of the 'high yield plus timing factor' of a winter triticale silage offers forage security in the dairy feed system, especially in dry springs when other forages fail.

This opinion does require re-validation in W. Canada by studying the forage yield and quality of spring vs winter triticale silage for dairy herd use, including the study of effects on milk production and milk characteristics (compositional and sensory). Although recent studies indicate that varietal influences on product yield and quality can be found, they appear to be small compared to species differences (Pers.comm., Kennelly, 2001).

Since triticale was first studied for silage use, problems with silage preparation and packing have often been observed, often with negative effects on feed intake, and productivity. Early studies with cows (Fisher, 1972) indicated that triticale was insufficient in energy compared to corn. However, modern varieties are very different in forage composition and are improved in energy potential compared to the early varieties (McLeod et al, 1998). Triticale stems are large and hard to chop (Anon, KSU, 1996), and studies are needed to find ways to better prepare the silage to solve this problem. The reduced-awn character is desirable in all silage varieties, and is a partial solution to improving feed acceptability. In recent work Kennelly and Khorasani (2000) presented their findings comparing barley, oat, triticale, and an intercropped triticale/barley silage, and monitored the effect of harvest date on silage quality. They recommended that the soft dough stage was the optimum time for harvest, to balance quality potential and yield. Solberg et al (2001, pers. Comm. via DeMulder) indicate that the milk stage offers a better compromise between optimum quality and yield.

In Alberta work, Khorasani et al (1996) were able to clearly demonstrate that, when comparing alfalfa, barley, oats and triticale (each used in a 50:50 concentrate:forage ratio) fed to cows, milk yield was unaffected by the forage used, although there were marked differences in the type of end product arising from the carbohydrate and protein digestion. Protein content in the milk from the triticale ration was significantly higher than that from any other ration. The gross efficiency (kg of milk / kg of dry matter intake) was also significantly better for triticale than for alfalfa. (Table 21). Thus triticale appears very suitable as a forage for cows in this regime, although these results also show the reduced intake of the triticale based ration compared to barley and alfalfa.

In work near Beijing, China, Sun et al (1998) also confirmed triticale silage yields 30 to 50% higher than barley silage, compositional values similar to those reported elsewhere, and milk quality similar or superior to that from using barley (Table 22)

Table 21. Influence of diet on feed intake, milk yield and milk components (from Khorasani et al, 1996)

	Diet: Alfalfa	Barley	Oat	Triticale	SEM
Dry matter intake					
Kg/d	19.6a	18.6a	16.7b	17.2b	0.42
% of Body wt.	3.29a	3.12a	2.83b	2.90b	0.06
Milk, kg/d					
Yield	31.6	31.5	30.1	30.2	0.51
4% FCM	29.1	27.7	27.3	26.6	0.78
Fat	1.10	1.01	1.01	0.97	0.05
Protein	0.95	0.96	0.90	0.94	0.02
Lactose	1.47	1.50	1.42	1.43	0.03
Milk composition, %					
Fat	3.50	3.23	3.45	3.21	0.14
Protein	3.01b	3.07b	3.04b	3.14a	0.03
Lactose	4.67b	4.80a	4.76ab	4.75ab	0.03
Milk energy, Mcal/d	21.4	20.9	20.4	20.0	0.44
Gross efficiency,					
Kg of milk/kg of DMI	1.61c	1.69bc	1.80a	1.76ab	0.03
Body wt., kg	596	596	590	591	4.9
Body wt. Changes, g/d	-264	74	473	464	301

Means in the same row with different letters differ (P<0.05)

Table 22. Cereal biomass, and milk quality from different cereal forages (from Sun et al, 1996)

	Biomass kg/mu
Triticale H1890	901.7
Wheat Fengkang No.8	673.0
Rye AR132	661.0
Barley Cuan	583.0

	Milk quality: Protein, %	Fat,%	Lactose, %
Triticale	3.14	3.38	4.67
Corn	3.03	2.83	4.59
Barley	3.05	3.30	4.60

Several other papers reiterate the high forage yield / silage potential of triticale, and its suitable forage properties. Brignall et al (1989) compared it to rye at various growth stages, and found the quality of the spring types to be superior to that of the winter types. However, cultivar variability for *in vitro* digestible energy existed, and they recommended selection for better energy level in the winters, to combine that with the higher yield potential. Miller et al (1996), in Florida, examined concentrations and ruminal degradabilities of amino acids from wheat and triticale forage and grain, using fistulated cows. Their conclusion was that triticale may produce forage and grain yields equal to or better than winter wheat, while providing a better source of ruminally undegradable essential amino acids, all desirable feed attributes in a ruminant animal.

Winter triticale is proving to be a very suitable replacement for winter wheat in the USA, in areas where the latter is used as forage for graze, cutting or silage. One such report from Jody Bellah (see website reference), a Texas rancher, concludes “Triticale has a place here on the Rolling Plains, as long as you match its grazing and forage potential to your particular cattle situation, your grain and grazing land percentages, and your economic goals for these enterprises”. Their use includes fall grazing, followed by a fall silage cut (the latter averaging 4 t/acre, at 13-15% protein content, and 61-65% TDN). They expect to maintain a stocking rate on triticale graze of over 200 heifers per 177 acres, to achieve a weight gain of over 2 lb per day. Texas conditions are very different from those in Alberta, but the nutritional suitability of triticale in this application is nevertheless evident.

As mentioned in earlier parts of this report, forage uses for triticale are diverse, including use as early spring or late fall graze, for greenfeed, as hay, or as silage, alone or in mixtures with legumes or other cereals. Use of spring or winter types with varied seeding and harvest dates, and the existence of differential variety responses, makes the number of management combinations far greater than can be evaluated, studied or afforded under research protocols. Many of the best protocols for management can probably be learned from producers already using these methods, if detailed surveys of triticale producers and users are conducted. Research should probably be confined to gaining a better understanding of the nutritional aspects of the uses that will account for the majority acreage. Exhaustive survey of the literature has not been attempted in this review, but would be an excellent project suitable for students in a senior research course at the University of Alberta, an approach which could also be used for assembling information about other triticale uses. Information thus assembled would then be used in the proposed Triticale Manual. Although local research about triticale forage comprises much of the newest literature on the topic, there is much basic research that still needs completion, some recommended later. In discussions with Dr. Gary Mathison (Ruminant feed specialist, AFNS, University of Alberta), it was agreed that future silage research with triticale could well focus on the special needs of the dairy herd, as information learned there would equally well apply to the feedlot cattle situation, where quality differences are much less critical. Although the potential for use in feeder cattle is very great, it may not be necessary to conduct research specifically for that group, since they are already adopting this crop to a significant degree. On-site study of their many ways of using triticale would be very useful for the industry as a whole.

The most recent and extensive data collection about triticale silage production and quality has been carried out in joint research by AAFC (Lacombe and Lethbridge) and AAFRD (Agronomy Unit, Edmonton), involving Solberg, DeMulder, Clayton and McKenzie, at Alberta sites through 2000. Results from several different kinds of studies, including variety and species comparisons between barley, spring and winter triticale, winter wheat, spring and fall rye, and examining nutrient level responses and effects of cutting times on quality have been completed. Results have been presented at many producer meetings during the winter of 2000-2001. The studies reconfirmed the higher yield potential of triticale compared to barley, and stronger straw strength, of value in high nutrient (including highly manured) conditions. One interest in this work focused on the balance between delaying cutting for silage to increase silage yield, balanced against decline in feed quality or acceptability of samples from later harvest. (This issue is also highlighted elsewhere in this report and in the recommendations for future research). During review of presentation materials used by this research group, the following table was noted, describing maximum acceptable guidelines for Acid Detergent Fibre (ADF) percent, where a value of 35% or lower was 'good' or better. In the many charts showing data from the many experiments of Solberg et al at many sites, ADF% for triticale alone or in mixtures never exceeded 37%, even at non-optimal harvest dates.

Slide / chart from 'Triticale as an Alternate Crop for Silage' (from Stettler, 1999 presentation, copied with permission from DeMulder, 2001)

- ADF or acid detergent fibre is the fibrous, least digestible portion of roughage, consisting of cellulose and lignin
- Roughages high in ADF are lower in digestible energy than roughages that contain low levels of ADF
- Digestible energy (Mcal/kg) is a function of ADF

ADF %	Quality
<31	Excellent
31 – 34	Very good
34 – 39	Good
39 – 41	Fair
>41	Poor

7.3. Questionnaire results about feedlot use of triticale silage

A survey was sent to a small number of known feedlot users of triticale silage to enquire about why they used this type of feed, and the advantages and disadvantages of so doing. Their views about what needs improving in triticale silage were also sought, as well as their estimates of potential future expansion for the triticale silage crop.

Questionnaire: For feedlot users of triticale silage

Your name / organization here____

Q1 How many years have you fed triticale silage, what is the type of animal fed, and how many animals do you typically feed at one time?

Years of experience with triticale______; Class of animal fed________; Animal number?_____________

Q2. List the main reasons that you use triticale silage in your ration, in order of importance

Q3. List any additional advantages, and disadvantages of triticale silage, rating each from 1 – 5 in relative importance (5 = Very important; 4 = Important; 3 = Neutral importance; 2 = Unimportant; 1 = Very unimportant; Indicate your rating inside the brackets)

Q4. The land base near my feedlot would be enough to accommodate a doubling of the triticale acreage I used for my enterprise if that was my need (Circle one on a scale of 1 – 5)

1 = Very much agree; 2 = Somewhat agree; 3 = Not sure; 4.= Probably not; 5 = Definitely not

Q5. On heavily manured lands near your feedlot which crops do you grow? Circle as appropriate and indicate % used each year

Barley silage____%; Triticale silage_______%; Barley grain_________%; Other (what?)________%

Q6. In some research studies, triticale silage is sometimes less preferred by cattle, resulting in reduced feed intake. How important has this factor been, (1 – 5 scale), in your experience of feeding triticale silage?

5 Very important; 4 Important; 3 Neutral importance; 2 Unimportant; 1 Completely unimportant;

Q7. Only answer this question if triticale silage resulted in reduced feed intake in your feedlot. To what do you attribute any reduced feed intake? (Circle those that apply)

1. Variety / genetic problem of plant material from triticale silage
2. Inadequate chopping, processing, packing of triticale silage
3. Custom harvesters unfamiliar with best harvesting methods for triticale silage
4. Optimum harvest date for triticale silage not yet known
5. Fiber content in silage too high
6. Other – specify ____

Q8. List up to 6 items, in order of importance, for which a more extensive informational database about triticale silage would help your operation in its use of this feed resource

Q9. In your opinion, to what extent do you think that W. Canadian triticale silage acreage should increase in the next 5 years, and how much do think it actually will increase, compared to acreage in 2000? (Circle numbers that apply)

Desirable % increase	0	25	50	75	100	150	200
Expected % increase	0	25	50	75	100	150	200

Q10. By how much does your own operation expect to increase (or decrease) its use of triticale silage in the next 5 years? (Indicate % change expected)

Decrease by ____%, OR No change, OR Increase by ____%

Q11. What specific attributes of triticale silage need improving for it to be of increased value in your feeding operation? Please list them here

Questionnaire response:

Response levels for this questionnaire were very poor (2 out of 12), sufficiently so that no generalized conclusions can be reached from them. Very likely the poor response rate was the result of a timing clash with suddenly heightened concerns at the feedlots about quarantine needs related to ensure continued freedom from foot and mouth disease, making this topic of low importance or priority at this time. This survey should be re-attempted in the future, as this cohort of users is the most important one for the future of the crop, in the opinion of this author. Any future survey should be preceded with a 'phone-ahead' approach, as was done with the very successful seed grower survey in this study.

In the two responses received, advantages of triticale as a silage crop were listed as:

1. Value in crop rotation, to break disease cycles and for diversification
2. Flexibility of use as a forage
3. Flexible timing of harvest, in different uses throughout the year
4. Significantly higher yields than barley silage
5. Nutritional value at least equal to barley, if cut early (milk stage)
6. Good straw strength under irrigation, compared to barley
7. Corn is the other alternative as a break crop for diseases, but has become unaffordable because of high input costs for chemicals, machinery, power for irrigation, and shortage of water to pump, plus harvest date too late in the fall (September snows interfere)
8. It requires less irrigation than corn
9. No special cropping equipment needed, compared to growing corn

Disadvantages of triticale silage were listed as:

1. Extra moisture in the silage crop at harvest can be problematic
2. Harvest window for optimal quality is fairly narrow. If window is missed, feed intake definitely drops
3. Triticale silage is harder to cut and requires more power
4. It requires more seed per acre (3 bushel/acre rate, vs 2 bu/acre rate for barley)

Both respondents were using land that was heavily manured for their silage production. One allocated 80% of this land to barley silage and 20% to corn silage. The other used 25% for barley silage, 25% for triticale silage, 25% for barley or wheat seed production, and 25% for canola seed. One of the two felt that doubling of triticale silage production on their farm would be desirable and achievable. This respondent (in S. Alberta, feeding 7,000 cattle) also felt that a 200% increase in triticale silage use would be desirable in W. Canada, but that only a 50% increase would likely be achieved.

Improvements recommended for triticale as silage were shorter awns, and increased silage yields.

Shortage of information on triticale (by the S. Alberta respondent) was identified in the following areas:

1. Nutritional aspects
2. Fibre content data
3. Localised data about optimum harvest date for the silage
4. Yield response to varied seeding dates
5. Relative merit of spring vs winter triticale for silage
6. Comparative data about variety differences for silage production

7.4 Recommendations to assist in promoting triticale use for forage

Continuing the rapid adoption of triticale use for forage is seen by the author as the way to achieve the largest potential gain in triticale acreage and use in W. Canadian cropping systems at this time. (The second largest potential is seen for triticale grain use in swine, replacing barley). The following actions are recommended:

1. Conduct a W. Canadian survey of existing growers and users of triticale forage, to gather and determine the range of W. Canadian applications and experience in triticale silage processing and feeding, and a measure of the results obtained on animal productivity. The approach used should be similar to that of the barley grain production survey of many years back, so that responses can be analysed sectorally, to identify common factors where the best results are obtained. Information and 'best practise' protocols thus identified would be entered in the proposed Triticale Manual, and also would be widely used in extension activities. The primary focus of the

survey should be on silage use for feedlot applications, where the largest potential use likely lies.

2. New Canadian based technology transfer chapters should be written about triticale forage use, based on local results as far as possible, for use in publications and on the web. Current materials are either very insufficient or badly out of date.

3. Several new research projects should be initiated to determine (a) optimal harvest dates for silage production, balancing yield and quality, and (b) to find the best timing and ways to cut and process triticale silage to minimize any acceptability and intake problems, as sometimes reported to occur. These should focus on the tough straw problem, and studies of chop length etc., intake, and energy conversion in particular. These studies can be combined if a large project is planned. It would take 3-5 years to complete, and would be similar in nature to the project recently completed on barley silage. This work could be done at the University of Alberta, and would include linked analysis of field production data, processing data, feeding data, chemical composition of the forage, rumen analyses, in the herd milk productivity and composition, as well as milk sensory tests. Multi-year testing is necessary to estimate year effects on the quality of triticale silage. Comparisons to barley silage are essential, to estimate triticale silage value as a replacement. Cultivar studies could be included, but are of lower priority.

   A study of this kind was proposed by Progressive Seeds Ltd. in their 2000-2001 work plan, that would conduct research at 8 designated feedlots, and it was also indicated that these cooperators were interested in participating. ‘On-feedlot’ research would focus on answering the questions of high priority to those cooperators which were;

a. For feedlot operators	- Triticale standability on heavy manure
	- Silage yield vs barley
	- Palatability and quality
	- Ease of harvest – lodging and ease of cutting
b. For dairy operators	- Quality (improved protein + low ADF)
	- Triticale standability on heavy manure
	- Ease of harvest
	- Silage yield vs barley

   Data are available at Progressive Seeds Ltd. for 2000, and it is expected that this work will be continued, subject to funding.

4. AAFRD should continue its agronomic trials to expand and refine the methods by which triticale can be used (a) to extend the forage season and to provide high quality forage early in the season, (b) as a crop for highly manured lands, to remediate excessive nutrient loading and run-off problems, and (c) as a low input crop and rotational break crop in sustainable mixed farming systems, including effects on weed dynamics and control of barley diseases.

5. Results from recently completed (or ongoing) AARI triticale projects, or AAFRD or AAFC triticale forage research projects, should be summarized and posted on the Triticale website as results become available. There needs to be a sense of urgency about the importance of this new information as it is obtained, for immediate application to a potentially increasing triticale acreage. Current efforts are underway to extend the information, but are not enough. Website technology can be used to get faster, additional and wider exposure of the new information. The information must be presented pragmatically, without ‘over-hyping’ triticale prospects, as occurred in the past.

6. The major users of silage should be identified, and information packages should be sent to them directly, comparing performance of triticale silage with barley silage, or other silage they use. If crop displacement towards triticale is going to happen, it will require targeted technology transfer activities, events, and materials printed or electronic, to gain attention of potential users. ‘Lead adoptees’ of triticale should be used as speakers at extension functions on the topic, backed up by researchers with their newest local data, and the results from the user survey. The timing now is excellent to target this approach, when so many animal producers are having difficulty handling their manure problems, and feed and forage of any kind is in great demand.

7. The cattle and dairy industry should be lobbied to gain support for a Chair in Forage Harvesting and Processing Systems at the University of Alberta, that could work on numerous crops and applications, but that would have a primary focus on silage technology for Alberta (or W. Canada). No such position exists in W. Canada, to the author’s knowledge, which is a remarkable lack of investment in such a valuable commodity for the animal industry. This position, when established, would provide a focus for W. Canadian joint projects, integrating research at multiple sites and done by multiple agencies, including those already working on the beef/forage interface in Alberta. Work on triticale silage would be part of the program. The position should also be tied in with the proposed new ‘Feeds Institute’.

8. Results from prior AARI ‘On-farm triticale forage demos’ do not appear to be available readily for examination or review (e.g. AARI Projects 99NE05; 99E17; 99NW08, and others). Progressive Seeds has also completed an AARI Matching project examining triticale use on heavily manured land. Results from these studies should be reported immediately on the triticale website. It should be suggested to AARI that all annual and final reports to them by recipients of grants for triticale research and development be required to submit web ready material for placing immediately on the Triticale Homepage (to be established), as received. This would provide immediate access to the newest research information, not now possible.

8. Triticale grain use for flour based food products, including bread

The initial, most popularized deficiencies recounted for triticale were shriveled grain, low milling yield, pre-harvest sprouting leading to high flour α-amylase, low water absorption of the flour, and weak gluten. In modern varieties improvements have been made in all of these, except that gluten strength, although improved, is still weak compared with that of most bread wheats in the world. Gluten strength of new varieties is good enough for 100% triticale flour breadmaking, however, if adjustments are made to the process. More typically, however, triticale flour for breadmaking is milled as a 30-80% admixture with wheat flour. In some markets (eg. Brazil) it is milled interchangeably with wheat.

Modern CIMMYT triticale varieties do now have gluten quality equivalent to CIMMYT wheats, and are fully exchangeable with wheat flour, except for the deficiency of ‘ sticky dough’, that can be a problem in large through-put bakeries. The latter problem is solvable by blending down the triticale with breadwheat flour, as done in Brazil. In Colorado Lorenz (1973) used US grown spring and winter triticales to demonstrate that triticale was completely exchangeable with wheat for making white bread (given process adjustments), white rye bread (from 100% triticale), egg noodles, and extruded breakfast cereals. Flour yields of modern triticale varieties are now close to those of wheat, but rarely superior. Test weight (grain density) is equivalent to that of wheat, but the larger kernel size with softer grain requires different milling settings than wheat.

Today’s Canadian triticale varieties are well suited to food products that require doughs or batters with relatively low protein content and water absorption, and minimal resistance to extension. In these applications triticale could be completely substituted for CPS wheat, for example, because functional properties are very similar to CPS. This is what would be expected on the basis of the rather limited functional quality data base available for triticale. However, this expectation for quality has not yet been confirmed in modern Canadian varieties, because the research has not been done.

More is known internationally about triticale for food use than for Canadian triticale, because food product related quality data are not needed to register new Canadian varieties. For example, commercial production of unleavened bread products using triticale flour has included chapatis, tortillas, concha (a sweet Mexican bread) and Ethiopian injera (as 50% mix with teff and/or buckwheat where injera is the local staple). Triticale leavened breads have been sold in the past in Canada, but can no longer be found, nor can other triticale based products. A search for this product in Edmonton failed, except for discovery of use in Weston Bakeries ‘7 Grain Harvest Bread’, and nor were others familiar with its continued existence. In N. America, processing of triticale for bread incurs extra costs because of special blending and processing requirements, and the need to have extra storage facilities for the triticale. Although triticale products enjoyed a ‘novelty’ food market status in Canada some years back, this special demand no longer seems to exist, nor is there evidence of any industry intent to reinvest in this area using triticale. (After extensive searching, two sources of triticale flour were located, from a supplier at Little Red Hen Mills, New Norway, Alberta, and the other at Rogers

Foods, Armstrong, B.C., who also were a supplier for TritiRich in the past, and now supply for Weston Bakeries, Calgary).

Triticale is also very suitable for use in cereal foods that are not baked, such as noodles, cereal bars, breakfast cereals, extruded products, cookies, crackers and porridge, but no new demand seems to be developing, despite the novel taste aspect. It has also been successfully used for beer making in several countries, including Canada. One report, unconfirmed scientifically, suggests that the triticale cell-wall polysaccharides (from the rye parent) give stability to the foam on the beer.

One constraint to use in foods may be the lack of guaranteed supply and constancy of grain quality, due to triticale's immaturity as a crop, and the lack of price discovery. Despite the likely suitability of triticale for a number of novel food uses that could be developed, there as yet appears to be no Canadian incentive for these markets to develop or expand. For the kinds of products described above, spring or winter types should be equally suitable, although laboratory based research to confirm this has also not been done.

8.1. Triticale Flour Quality (10 years of progress, 1990-2001)

Although not individually reviewed here, numerous reports at the 1990 2nd International Triticale Symposium (in Passo Fundo, Brazil) from a number of different countries, especially Brazil, Poland and India, reported on the strengths and weaknesses of triticale flour for processing purposes. Although considerable improvements in varieties have been obtained worldwide since then, the characteristics reported there are generally still typical of many triticales in many countries in the new millennium, including Canada. In list form these continue to be as follows, even in 2001, but are notably very little different from the assessment of food use potential made by Lorenz in 1972.

1. Generally low protein content, low gluten strength and low sedimentation value compared to wheat.

2. Flour yield generally lower than that for wheat, but generally superior in complete triticales compared to substituted triticales.

3. Low bread volume when processed as 100% triticale flour, compared to wheat, and generally poor performance in most rheological (gluten strength) tests.

4. When used in blends with strong gluten wheat flour, from 25-35% up to 50% triticale, bread products obtained are very satisfactory. India, Poland and Brazil are already doing this commercially.

5. A higher Hagberg Falling Number value is desirable, as triticale remains very prone to pre-harvest sprouting, much more so than wheat.

6. Higher test weights would also be desirable, to improve both flour extract and value as feed.

7. 100% triticale flour is very satisfactory for products that do not require high gluten strength, such as cookies, biscuits, pastry, chapatis, cakes, and some noodle products. In these markets Canadian triticale would have to compete with the excellent quality attributes of the CPS wheat class, a class specially designed for these markets. Although triticale fits well in this market, it is not likely to compete well because of lack of a supply stream, excepting if special flavors are of consumer interest, as specialty triticale products. (Just at the completion of this review, the author noted that Weston Bakeries, Calgary, does include triticale as an ingredient in its 7-grain specialty bread. No other local food uses were found, in a quick survey of food outlets).

8. Extensive reports from India described numerous applications for 50% triticale flour mixed with 50% wheat flour in indigenous foods, (results from which might also offer insight into potential novel product applications in N. American specialty food markets). A lengthy list of Indian ethnic foods for which the 1:1 mix produced an excellent and tasty product included jamoor, kesaribath, porridge, makmal poori, samosas, uppittu, halwa, shankarpoli, poori, and 10 other ethnic food items. Malts from triticale were also judged as being very suitable for food use applications (being high in α amylase and proteolytic activity). For these various uses it was recommended that new varieties be produced with harder kernels, an amber color (preferred to red in India), higher test weight, and lowered enzyme levels associated with pre-harvest sprouting. These positive attributes of triticale used in a 50:50 blend with wheat were reconfirmed in the 1998, Bakhshi et al report, which indicated very acceptable consumer response to triticale based Indian foods, including flavor improvement. These products included wholemeal atta, chapati, poori, paratha, and idli, matthi, mattar and samosa, halva, pinni and jalebi.

9. Other whole grain (non-flour) specialty uses of triticale that are commercialized in a small way are as specialty malt for micro-breweries, and as sweet green seed (in the USA for canning, as a novelty food).

Anderson et al (1976) presented a fairly complete review of the dry milling and wet milling characteristics of triticale, including their own findings, and concluded that 'triticale grain can be dry milled readily into flour, which can be further milled and air classified into fractions with desirable physical and chemical properties. Starch and gluten can also be recovered from triticale grain or flour by conventional wet processing'.

Remarkably little research on triticale flour use for human food end-use applications has been done in recent years, and almost none on the new varieties of the 1990's and 2000's, that are likely to differ greatly from the earlier varieties in their functional properties. This lack of recent research information was evident as early as 1990 when Bushuk, who reviewed milling and baking characteristics of triticale, was unable to cite any publications later than 1986. In a panel discussion at the same meeting, Briggs (1990) pointed out that in many potential markets triticale products would have to compete with well-established products from wheat, which might be competitively difficult. However, niche and novel markets for human food could also be developed, based on (a) distinctive flavor components (the 'nutty' flavor of triticale), (b) market demands for products from low input, 'green', nutritionally advantaged crops (in which triticale fits), or (c) foods derived from value-added fractionated extracts from cereals, many yet to be researched and discovered. Other papers at the 1990 meeting basically supported the findings listed as 1-9 above, reporting incremental breeding improvements of the grain properties over time.

In a further review of triticale for food use (Pena, 1996) commercial examples of satisfactory acceptance of triticale for human food were described, but in all cases it was being used as a substitute for either wheat or rye, or as a blend (Table 23). Pena (1996) also points out that in many countries factors unrelated to the functional grain quality limit adoption as human food, including competitiveness with other crops, lack of a supply chain, non-acceptability as a substitute in traditional foods, lack of a reliable pricing structure, and lack of awareness and promotion. (Most of these constraints still apply to triticale in Canada in 2001). Also, because triticale is a 'small' and novel crop with a small supply stream, many processors are unwilling to experiment with it in their commercial facilities, unless they perceive a significant economic gain in the outcome, ahead of time, with the prospect of a suitable supply chain, and this is often difficult to demonstrate (Pena, 1996).

Table 23 Food uses of triticale in some major triticale producing countries (from Pena, 1996)

Country	Product	Proportion of triticale flour
Australia	Breads, cookies, biscuits	100%, or blend
Brazil	Variety breads	40-100%
Germany	Leavened bread	40%
Poland	Rye-type bread	100%
Russia	Rye-type bread	100%, or blend
USA	Layer cake	50%

In the most recent international triticale symposium in Canada (1998), major progress was reported in programs attempting to improve the gluten strength by breeding, to make it more like wheat (Pena et al, 1998; Lukaszewski, 1998), and further progress can be anticipated.

As previously indicated, an extensive search by the author located only two current commercial milling sources for triticale in Canada, although numerous contacts and the author do remember seeing triticale food products for sale in the stores in the past (including bread, cookies and crackers, mostly under the TritiRich label). Numerous web-sites in the USA were found that supply small volume local sources of triticale grain or flour for local home recipe use, but no single major supplier was located for the human food market. Two growers of organic triticale were located in Alberta, but the extent and consumer use of their product was small. One of these organic growers described a lack of interest for this product, and a general lack of knowledge about triticale by consumers.

Thus, the current and future status of Canadian triticale use for food products does not seem encouraging, despite its suitability for many different kinds of products. Consumer awareness and demand for triticale based foods seems negligible at this time, and there is little evidence of interest for investment by processors in what seems to be a very small market potential. There may be some potential for small operations to provide local sources to small specialty markets (eg. farmer markets etc.), and the home recipe market, but this will likely only develop on an *ad hoc* basis, as was evident from the USA web-site search. The 'recipe book' and promotional approach for food use that was successfully used in S. Australia does not appear to have a willing promoter with sufficient resources to duplicate this approach in Canada.

8.2 Extrusion characteristics and products from triticale flour

Rheological and other properties required for extruded products are different from those needed for bread products, and triticale has performed well in those applications. A very recent report of Konstance and Strange (2000) demonstrated that triticale can be used exchangeably with wheat to make 'snack bars' with up to 40% oat bran content, far higher than the fiber content in any bars currently available on the market. Triticale-based bars were harder than wheat-based bars, likely reflecting the higher fiber content in them, but did not otherwise differ in sensory or taste properties from the wheat-based bars. This product was seen as an attractive one for a US consumer market that is seeking higher fiber content in its diet, often through supplementation, or through nutraceuticals (Sloan, 1999). Work on this type of triticale product has not been done in Canada.

These results affirmed the early findings of Wu et al (1978) that triticale can be a very satisfactory source for making extrusion products, including breakfast cereals in their study. They also found that the high protein co-product of an alkaline extraction process possessed good hydration capacity, excellent emulsifying activity (near 90%), and excellent emulsion stability (around 85%), which makes it attractive for use as a protein supplement in various food applications. It could be used as a fat emulsifier or as a water-absorbing agent. Such properties have not yet been assessed in Canadian varieties.

Favorable triticale performance in extruded products (eg. snack foods, flat breads) was also reported by Wesper et al (1986?), who studied 7 triticale varieties at 7 locations, compared to wheat and rye, using a range of processing protocols. Extrusion and enzymatic characteristics were examined, and were found to be satisfactory for all varieties, although varietal differences were also found.

9. Fractionation of triticale, to seek value-added components

Literature on this topic is very limited, depends on the value of the component sought, and is absent for Canadian produced triticale cultivars. Therefore no literature review is presented here, due to the lack of information. However, an extensive research proposal has been submitted to AARI (January, 2001) to determine the potential value-added component structure of Canadian cultivars (Pronghorn, Bobcat, AC Ultima and AC Cora) grown at multiple locations. Prior to having such data available it is premature to consider prospects for market development of value-added derivatives, as triticale competitiveness with other cereals cannot yet be estimated. Grain components of interest for this project, for basic study and research at this stage, are:

Protein	Lipids	Ash
Starch (amount and type)	β - glucan	Pentosans (high and low)
Soluble / insoluble fiber	Phenolics	Tocols (tocopherols + tocotrienols)

Functional property investigations that would also be of value in these basic studies include:

Viscosity	Foam properties	Emulsion stabilizing properties
Water binding capacity	Anti-oxidant properties	Extrusion properties (components)
Noodle, pasta, baked goods	Use in specialty products (nutrition bars, breads, pancakes)	

In a recent publication from Australia (Cooper and McIntosh, 2001) attention is once again drawn to the potentially high level of dietary fiber and lignans in triticale compared to wheat and rye in whole grain (Table 24). 24 hour outputs of enterolactone and enterodiol (the end-products of fermentation of Seco and Matair in the human intestines- see table) have been shown to correlate inversely with breast cancer incidence in women in case-control studies (Ingram et al 1997). Using human flora in *in vitro* studies, Thompson et al (1991) have shown that triticale was superior to other grains assayed with respect to mammalian lignan production.

Table 24 From Cooper and McIntosh (2001): Dietary fibre and lignan contents of triticale, wheat and rye

	Triticale	Wheat	Rye
Dietary fibre, g/100g DM	14.5	11.0	15.5
Lignans - Seco = Secoisolariciresinol, mg/100mg DM	30.6	16.6	21.6
- Matair = Matairesinol, mg/100mg DM	11.1	18.6	30.2

Data provided by H. Adlercreutz et al, Diet and prevention of cancer. Proc. Int. Conf., Tampere, Finland 1999

High levels of such phytochemicals in the diet may be correlated with opportunity to reduce incidences of cancer, coronary heart disease, and maturity onset diabetes, and could increase longevity (Hill, 1998; Jacobs et al 1999; Slavin et al 1999 and 2000). Further investigation of these linkages to products expressing in triticale grain at a high level are warranted, to see if such putative advantages for reducing breast cancer risk could be captured in triticale based food products or derivatives.

9.1 Future needs to develop value-added human food products from triticale

Compared to the large grain volume potential for triticale in other areas (as feed or as forage) the short-term prospect for developing the human food market is small, and the market potential is also small, possibly except for specialty niche foods. Past niche food products in the Canadian market appear to have failed. Two separate streams in approach are needed if these markets are to be developed or redeveloped, especially because of shortage of basic information about the suitability of current Canadian varieties for these uses.

1. The literature indicates a high level of suitability of triticale for a large number of uses outside the bread market, but these have not been confirmed with Canadian varieties. Research is therefore needed to examine their suitability for a wide range of potential flour-based products, in studies which also include taste panels, consumer preference trials and assessment, and discovery of true market potential. Such research can readily be done at the University of Alberta, Department of Agricultural, Food and Nutritional Science. If suitable specialty products can be determined (such as high fiber bars etc.) the potential for processed product export to the US market must also be investigated. A major impediment to development of this area now is the absence of a local triticale miller, and absence of a variety specific, IP-based, grain supply stream in W. Canada. Also, the influence of locational and yearly variability on grain quality for such a market must be determined through basic research.

2. The potential for value-added activity through fractionation and isolation of specific grain components from triticale grain, both for food and nutraceutical application, needs to be determined. Almost no information is available about these properties in new Canadian varieties. The current proposal to AARI to conduct this work should be supported, as this basic research work is needed before any future market potential can be assessed.

3. At a more detailed level, the following research topics have also been listed as urgent in priority, before food markets can be further developed. In the absence of this research, incorporation of triticale at the 50% rate appears feasible for most conventional wheat-based food products, although vital gluten supplementation may still be necessary for bread-based applications (as is the case for the 7-Grain Harvest Bread of Weston Bakeries).

    a) Full rheological testing of flour samples of the newest Canadian triticale varieties grown at varied locations, to establish a reference quality database for the crop
    b) Milling trials to determine milling yields, extraction rates and other milling parameters
    c) Proximate analysis of samples, including determination of amino acid profiles, starch characteristics, mineral and vitamin content, in work cross-referenced with other projects establishing a feed quality data-base.
    d) Analysis of, and determination of the extent of the ‘sticky dough’ problem in Canadian varieties. How big a problem is this in Canadian varieties?

e) Studies with locally grown grain, to determine if there is a special advantage of triticale to replace wheat use in very high fiber snack bars (Onwulata et al, 2000). This work could be conducted in the lab of Dr. Buncha Ooraikal (AFNS, University of Alberta), in collaboration with local snack bar producers. This would be an excellent, low cost project for the senior undergraduate course in product development at the University.

10. Triticale for ethanol fuel production

10.1. N. American backgrounder re: potential of ethanol fuel production from triticale grain

Interest in ethanol as a fuel has been renewed in many parts of the world because:

1. It is cleaner burning than gasoline,
2. It can be produced from renewable resources and
3. The production of ethanol promotes rural diversification

(Cited from http://aceis.agr.ca/pfra/sidcpub/sidcft3.htm)

Increased potential demand for ethanol as a fuel source in N.America is primarily driven by global concerns about seeking cleaner fuels to reduce carbon based emissions and other fuel related pollutants, and by individual country concerns about seeking less dependence on non-renewable and/or imported fossil fuels. It has finally been realized that gasoline is not the ideal fuel for cars because it is a fuel with limited supply. Brazil has already achieved 50% of its cars running on pure ethanol (produced from sugarcane). Also, the actual cost of gasoline refining and extraction does not reflect the cost of environmental damage from using this fuel source. This is particularly recognized in the USA, where air pollution standards are continually being raised, and gas prices fluctuate along with the supply of petroleum. This demand for ethanol in fuel is driven by its incorporation in gas for cars, by moves to incorporate ethanol in a similar way in bio-diesel and new technology fuel-cell cars, and by a desire to ban and replace the fuel oxygenate MTBE (methyl tertiary butyl ether, a pollutant) with ethanol. MTBE, a derivative from the oil and gas sector, is known to cause soil and water contamination, whereas ethanol, a renewable fuel source, is environmentally friendly. Ethanol already constitutes 1.2%* of the US gasoline market (Grain J. 28: p185, 2001). 567m bushels of corn (>5% of the total US production) are grown annually for use in biofuel. In October 2000 the USDA announced a 2 year $300 million subsidy program to promote corn use for biodiesel, ranging from 29-40% of the cost of the crop. Research efforts to achieve a 100% replacement of diesel with ethanol are well underway, as part of a US National Energy Security project. Also, US dependency on imported energy sources continues to increase. By August of 2000 ('BioFuel Brouhaha', Grain J.28: No. 3: 152-153) it was estimated that US ethanol production was over 110,000 barrels per day, an all time high, and increasing (Figure 4).

(* NB: Other website sources have placed current USA use of ethanol use in gasoline at a much higher level, at 9% or 12% of all gasoline use. Graintek has so far been unable to confirm the correct value).

For the USA, the Renewable Fuels Association outline statistics and studies that value ethanol production for fuel for many reasons: Increasing net farm income (mostly from corn), boosting of employment, increasing State tax receipts, improving the US balance of trade (by $2 billion in 1997), net savings to the federal budget ($3.6 billion in 1997), reduced carbon emissions, reduced use of alternate polluting oxygenates in fuel, reduced fuel costs, a method for recycling carbon based waste products from other industries (eg. ligno-cellulose use in some processing plants), increased fuel octane levels using ethanol, value-added agriculture and bi-products, and fixation of carbon in roots and soil as carbon sink.(Source: www.ethanolrfa.org/outlook99/99industryoutlook.html)

Expansion of ethanol production happened in the US in anticipation of the US Clean Air and related Acts, that came on stream in 1970, 1985 and 1990, that eventually stipulated that oxygenates must be used in US fuels to ensure clean burning. Similar incentives do not yet generally exist in Canada, but are being considered; their absence, and absence of related tax incentives, diminishes Canadian interest in major investment in ethanol for Canadian fuels. Some investment has occurred, however, and ethanol produced in Canada is already marketed in Canada and in the expanding US market. The USA is working towards E85 vehicle standards (cars that can burn 85% ethanol), ethanol use in or to replace diesel fuel, and ethanol as the preferred fuel source in fuel cell cars. When the US auto industry moves to an ethanol based fuel more extensively, Canada will need to develop a parallel fuel industry, also based on ethanol.

Key components for success of any ethanol project that uses grain as a feedstock are:

a) a market for the co-products
b) a distribution channel for the ethanol; and
c) existence of sufficient taxation or other incentives for ethanol to be able to compete with gasoline in the fuel market

(Cited from: http://aceis.agr.ca/pfra/sidcpub/sidcft3.htm)

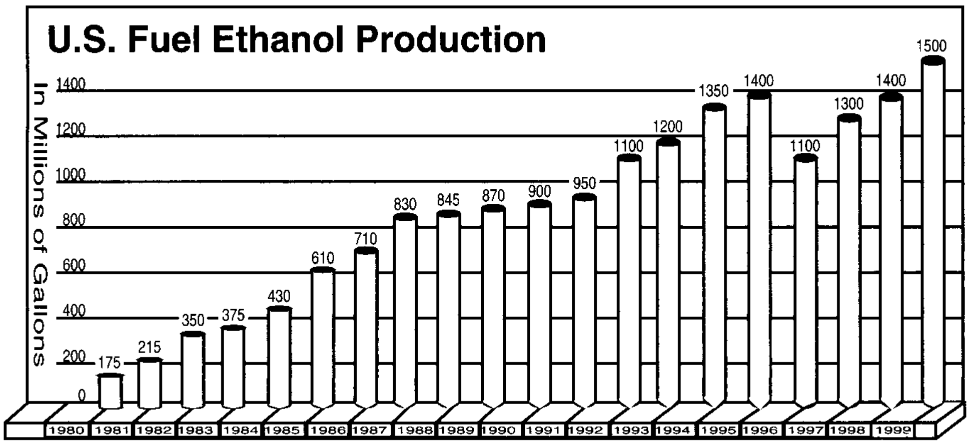
As in the USA, the demand for more ethanol has been met in Canada by increases in plant capacity, which was estimated to reach 675m litres per year by the turn of the millennium, as follows (Cited from: http://www:greenfuels.org/ethaprod.html).

		L per year	Commodity / use
Mohawk Oil, Canada Ltd.	Minnedosa, MB	10M	Wheat-based
Pound-Maker Agventures, Ltd.	Lanigan, SK	12M	Wheat-based + cattle
Commercial Alcohols, Inc.	Tiverton, ON	23M	Corn-based
Commercial Alcohols, Inc.	Chatham, ON	150M	Corn-based
API Grain Processors	Red Deer, AB	26M	Wheat based
Tembec	Temiscaming, QB	17M	Forestry-product base

Other potential plants planned (listed from website source)

Seaway Grain Processors, Inc.	Cornwall, ON	66M	Corn-based
Commercial Alcohols, Inc	Varennes, QB	150M	Corn-based
Commercial Alcohols, Inc	Chatham, ON	+150M	Corn-based
Metalore Resources Inc.		75M	Wheat-based

Figure 4 US fuel ethanol production, 1980-1999 (From 'BioFuel Brouhaha', Grain J.28: No. 3: 152-153)



Source: Energy Information Administration and Renewable Fuels Association

Clearly, even in the absence of a strong national directive to replace oil and gas energy fuel sources with renewable energy sources in Canada, considerable expansion of processing capacity is occurring in this sector. Triticale appears not to have been researched as a potential feedstock for the ethanol market, but if it proved to be a suitable competitor or substitute for wheat, it could become a significant new cropping option for the bio-energy market of W. Canada.

It is the author's understanding that Poundmaker, Saskatchewan, does already have experience using triticale grain as a source for ethanol production.

10.2. Prospects for ethanol processing of triticale grain

Ethanol production from grain (Some notes by K. G. Briggs, following visits to API Grain Processors, Red Deer, Alberta, in December, 2000)

The processing of grain for ethanol production does not occur in isolation, as there are other co-products of the process which must also contribute to the overall processing margins. For example, at the API plant in Red Deer, Alberta, three main products are marketed, plus a feed co-product

a) Ethanol (blended with 5% gasoline for non-food use)
b) Vital gluten
c) Bakery flour
d) Mill-run co-product, and 'spillage' from the ethanol process, for feed use

Other processors of cereal grain (eg. distillation at Poundmaker) also create a feedgrain co-product.

Late in this review it was discovered that one distiller in Highwood, S.Alberta, has been accessing triticale grain for distillation, and they would like to expand their throughput.

Two meetings were held with Ms. Tracy Knowles at API, along with Dr. Don Salmon (triticale breeder, AAFRD) in early December 2000, to examine the current process used there, which substantially uses CPS wheat as source, much of it accessed on a contract basis. The remainder is accessed from the Canadian Wheat Board, including other wheat classes as needed. The latter may include CWRS or CWES wheat, as a source for boosting gluten strength in blended flours for specific flour customers. 70% of the grain processed is accessed within an 80 mile radius from Red Deer, beyond which shipping costs become limiting. From the discussions the following key points were learned, that bear on the suitability of different grains for processing. (Views expressed are those of the author, and do not necessarily reflect views held by API).

1. High starch level in the grain is desired, in a low priced grain. CPS wheat (especially AC Crystal in 2000) has proven to be a suitable, price-competitive source. Some problems are found in accessing enough CPS with high enough protein content in this class to meet the specifications of flour purchasers. Feed wheat is also attractive because of low price. A 12.8% protein minimum is desirable in purchased grain, to meet needs on the gluten extraction side. CPS wheats have proven satisfactory for all aspects of the processing procedures, although increasing price may present a problem in the future. Year round supply is essential, as the plant can process 230 t/day, approximately 84,000 t/year. CPS is also attractive because local growers obtain a high yield compared to CWRS wheat, and delivery contracts are readily signed in the region. The Canadian Wheat Board requires a minimum 25% of deliveries to API to be done through permits, and this is also possible for CPS deliveries by local growers.

2. For triticale to compete with CPS in this process several key questions would need to be answered. (The same questions would also be asked for winter wheat as a potential alternative grain source for ethanol processing).

a) How does triticale starch compete in ethanol productivity with CPS? The literature indicates the answer would be that triticale would be equal to or better than wheat, but no local data with local varieties and samples are available about this.

b) For a switch to complete triticale, which variety would be best, and could there be a year round supply to satisfy processing demand, with an attractive price and returns to growers? Available yield data suggest yields for triticale are higher than for CPS, and that price, although not well established, is lower than for CPS.

c) The product run performance of triticale in the API plant cannot be known in advance of an actual pilot scale run. However, sources have advised API that a perceived problem with 'stickiness' of triticale in processing equipment exists, and that triticale should not be used, especially in the milling process. Although there is literature that shows the dough stickiness of triticales elsewhere in the world can limit use in large scale baking process plants, it is not known that this is a problem for the newest Canadian varieties. Both Canadian triticale breeders believe that this is probably not a problem for Canadian varieties. However, only testing could resolve this important question with certainty. No Canadian research data exist on the topic.

d) The economics of ethanol production from grain is favorable when (a) energy prices are high, and (b) grain prices are low. At other times potentially low returns on the ethanol production side have to be balanced by enhanced prices for other products. The absence of a well established supply of triticale grain in W. Canada hinders ability to establish a reliable costing base for use in forecasting economic returns under various market price scenarios. It is unlikely that a processing plant would switch to a new grain in the absence of substantial background triticale production in the region, unless advantages in the processing itself, or in expected price, were great enough compared to wheat to merit commitment to contract production. Although triticale yield potential compared to CPS is excellent, the maturity of winter types is no earlier than CPS wheats, and the spring triticale varieties are later maturing, suggesting potentially increased production risk. If the maturity issue can be handled, adapted local acreage at least as large as that now contracted to CPS by API should be readily achievable within an affordable delivery radius, based on agronomic considerations already known for the region of C. Alberta.

e) Currently most of the ethanol produced at API is exported to the USA, where most potential expansion for energy ethanol sales probably exists. In Canada, ethanol enhanced gasoline (e.g. as sold by Mohawk) is only available in premium gas grades, which in today's high gas price scenario are not at all promising as an expanding market. Thus, since API is not engineered or certified for human ethanol production, future expansion of the ethanol market for API in Canada would be dependent on a radical shift in government policy and action that recognizes the environmentalist lobby to clean up automobile fuels, similar to current developments in California. Unfortunately, despite the sale of many vehicles in Canada that can already or could be fitted to meet the 'E85' specification for burning ethanol in car engines (meaning the engine could use an 85% ethanol fuel), there appears to be no local, provincial or federal interest or incentive to move in this direction, or to offer this source of fuel more widely. Other Canadian ethanol plants face a similar market constraint in Canada, suggesting that the market will be primarily an export one in the foreseeable future, in competition with US-based ethanol processed from US corn.

10.3. A summary of the likely constraints for ethanol production from triticale

1. Processing properties of triticale for ethanol at a plant scale at API are not known, compared to grains currently used. Equivalence or superiority of triticale vs CPS needs to be researched at the plant scale.
2. Triticale grain supply for ethanol production is not in place. Could adequate sustainable supply be profitably grown within a suitable delivery radius of the plant? Agronomic information to answer this question may already be in place for Alberta, as AAFRD has just completed a major long-term study on triticale productivity compared to other grains. However, this study does not consider ethanol productivity as one of its market prospects.
3. In the absence of a reliable supply, price competitiveness of triticale is not known.
4. The economics and demand side for ethanol processing in the future is not known, as this is an industry still in its infancy compared to other energy sources. Its' future will be dependent on provincial, federal and international policies in energy, agriculture and the environment, that will affect energy and grain prices alike. It should be noted, however, that the USA is investing heavily in bio-fuel research, as it views this area to be one of national security, because of future concern about US sources of energy and the desire to develop cleaner burning fuels. If the consolidated US demand for bio-fuel continues to develop, the prospects for Canadian bio-fuel provision in that market will obviously improve, thus expanding market opportunity. It would seem prudent to determine which cereals would be the optimum ones for use as feedstock in an expanding market.
5. Existing Canadian triticale varieties probably differ in their efficiency as an ethanol extraction source, but little information is available on these differences at this time, except that next described in this report. Even basic research on this topic is minimal for modern Canadian varieties produced under Canadian conditions. It is also not known whether the extent of genetic differences available would merit specific breeding goals to produce varieties especially suited to the ethanol processing market. Additional laboratory level research on the extent of any such differences in the most recent Canadian varieties is immediately desirable.

Some W. Canadian research on the comparative suitability of triticale for ethanol feed stock was completed in 1997. McLeod et al (1997) grew replicated trials of spring cereals (11 wheat, 8 triticale, 6 barley, and 6 oat cultivars) at 7 sites throughout W. Canada over 4 years, and 2 winter cultivars each of rye, wheat and triticale at 3 locations. Biomass yield was highest at Lacombe, and triticale biomass exceeded wheat biomass by around 13%. Triticale grain yield exceeded that of wheat by around 10% on average, and usually ranked first or second in all trials. On average (across cultivars) triticale had lower NDF (neutral detergent fibre), ADF (acid detergent fibre), cellulose (CELL), ash content (ASH) and protein (PROT), but higher hemicellulose (HEMI), lignin (LIG), and organic matter digestibility (OMD) than wheat. (Table 25).

Table 25 Overall mean fiber yield of triticale vs wheat averaged over cultivars, years and experimental sites (from McLeod et at, 1997)

	NDF	ADF	HEMI	CELL	ASH	LIG	PROT	OMD
Triticale	76.8	49.7	27.0	40.6	8.8	3.4	3.8	43.3
Wheat	78.4	52.1	26.7	42.3	9.5	3.0	4.1	40.6

Samples from the McLeod et al (1997) study were analyzed by Sosulski and Tarasoff (1997) for grain components that relate to estimation of potential ethanol productivity. Individual cultivar x site analyses were completed for starch, fermentable sugars, pentosans and potential ethanol yields, and the means (with SD across locations) were reported (Tables 26a and 26b).

Table 26a Starch (S), fermentable sugars (FS), pentosans (P) and potential ethanol yields (EY, liters per tonne) from wheat cultivars. (+/- SD over 7 locations and 3 years, in brackets)

Class	Cultivar	S %	FS %	P %	EY(S + FS) $L\ t^{-1}$	EY (P) $L\ t^{-1}$
HRS	Grandin	63.0 (2.5)	0.9 (0.3)	na	369 (13)	na
HRS	Katepwa	62.1 (1.8)	0.9 (0.2)	na	364 (12)	na
Durum	Plenty	63.7 (2.1)	0.8 (0.3)	na	373 (12)	na
SWS	AC Reed	65.1 (2.0)	0.9 (0.3)	8.6 (0.9)	382 (13)	40 (6)
SWS	AC Taber	64.5 (2.3)	1.1 (0.2)	9.0 (1.0)	379 (14)	41 (6)
CPS	HY617	65.6 (2.2)	1.1 (0.4)	9.9 (1.1)	385 (12)	45 (8)
CPS	SWS109	65.5 (2.2)	1.2 (0.2)	8.9 (0.5)	386 (9)	41 (4)
CPS	HY612	65.1 (2.3)	0.9 (0.3)	10.2 (0.9)	382 (14)	47 (7)
CPS	HY395	64.8 (1.6)	1.2 (0.3)	9.7 (1.3)	381 (10)	44 (7)
CPS	Biggar	64.4 (2.1)	1.2 (0.4)	10.4 (1.4)	379 (13)	47 (9)
CPS	Genesis	64.3 (1.8)	1.0 (0.3)	10.2 (1.3)	377 (10)	49 (8)
HRW	Norstar	67.2 (3.2)	1.3 (0.3)	na	392 (10)	na
HRW	Kestrel	66.0 (1.6)	0.5 (0.2)	na	386 (10)	na

Table 26b Starch (S), fermentable sugars (FS), pentosans (P) and potential ethanol yields (EY) from triticale and rye cultivars. (+/- SD over 7 locations and 3 years, in brackets)

Class	Cultivar	S %	FS %	P %	EY (S +FS) L t^{-1}	EY (P) L t^{-1}
S.triticale	T124	64.9 (2.1)	1.2 (0.2)	8.9 (1.0)	382 (16)	41 (4)
S.triticale	Banjo	64.5 (1.9)	0.6 (0.2)	9.8 (1.2)	377 (12)	47 (5)
S.triticale	AC Certa	64.3 (2.3)	0.7 (0.3)	9.2 (0.7)	376 (17)	43 (3)
S.triticale	Wapiti	64.3 (2.1)	0.7 (0.2)	10.4 (1.4)	376 (12)	47 (6)
S.triticale	T128	64.1 (1.9)	1.2 (0.3)	10.2 (0.9)	377 (12)	48 (5)
S.triticale	Frank	63.7 (2.0)	0.8 (0.3)	10.1 (1.3)	373 (12)	46 (5)
S.triticale	AC Copia	63.5 (2.2)	0.7 (0.1)	10.7 (1.4)	371 (14)	49 (6)
S.triticale	T122	63.3 (2.4)	1.0 (0.4)	12.1 (1.9)	365 (15)	55 (8)
S.triticale	AC Alta	62.5 (2.2)	0.7 (0.2)	9.6 (0.7)	366 (10)	44 (3)
S.triticale	T114	62.3 (2.0)	0.8 (0.1)	11.0 (1.0)	365 (13)	51 (6)
W.triticale	Pika	65.0 (1.9)	0.7 (0.3)	na	377 (16)	na
W.triticale	Wintri	62.8 (2.4)	0.4 (0.2)	na	366 (13)	na
Winter rye	Prima	65.0 (1.2)	0.6 (0.3)	na	366 (7)	na
Winter rye	Musketeer	61.0 (1.0)	1.0 (0.4)	na	355 (8)	na

From these results Sosulski and Tarasoff (1997) concluded that the relative crop ranking for potential ethanol production was HRW wheat > CPS and SWS wheat > durum, spring and winter triticale and hulless barley > HRS wheat and fall rye. At the cultivar level the suitability was described as Norstar HRW wheat > Kestrel HRW wheat, SWS 109 and HY617 CPSW wheat > T124 spring triticale, HY612 CPS wheat and AC Reed SWS wheat. However, the cultivar site to site variability (indicated by standard deviations) exceeds the mean differences reported for the cultivars, such that the ethanol potential from the best triticales is at least statistically equivalent to those of any other cereals (author's interpretation).

<u>10.4. Some notes on gluten co-product production from triticale grain</u>

The gluten product from API after milling for ethanol extraction is sold as Vital Wheat Gluten. The gluten is used in markets which require gluten strength supplementation in various wheat and other products. In the specifications, water absorption and minimum protein content are key items, which will depend on the properties of the specific grain which is processed, including the species, the variety and the environmental effect of the growing conditions. Rheological and functional properties of the gluten are not specified, although they are monitored. At API in 2000, CPS wheat is the source of most of the gluten, although supplemental gluten from CWRS can enter the gluten stream. Applications for the use of this product are varied, and can include flour milling, baked goods, breakfast foods, pasta, batters, meats and meat analogues, pet foods, and aqua-culture. Specialty breads that have high content of low gluten flour, or added ingredients (eg. raisin, barley, whole wheat, light rye, frozen dough, or multi-grain, etc.) require addition of vital gluten (or CWES flour) in order to achieve satisfactory physical product qualities. (In some markets vital gluten could be in competition with strong gluten flour from CWES wheats, although this class does not seem to be growing in market share very much as of the beginning of 2001).

Triticale, given its relatively weak gluten and low protein content characteristics compared to CWRS wheats, would probably not normally be considered as a prime candidate as a gluten source. Indeed, the international literature indicates that gluten strength characteristics in whole triticale flours may be undesirable in bulk processing equipment, due to potential problems with ‘gumming’ or ‘stickiness’ around equipment. In addition, it is not known if the unique flavor components of triticale would express themselves in products fortified with triticale vital gluten. However, and although the data base for this is minimal, the protein content of triticale varieties in Alberta is probably similar to that of CPS wheat, or not much lower.

A further potential disadvantage for triticale is that new Canadian food labeling laws would probably require vital gluten and flour products from triticale to be separately labeled as triticale, not as wheat, and this would create extra cost and technical difficulties in blended products. A new ‘Vital Triticale Gluten’ product would also probably meet resistance from buyers who have become accustomed to purchasing ‘wheat gluten manufactured from clean, fresh, premium quality, spring wheat flour’, as described on the API packaging. Thus, even if triticale proves meritorious in the ethanol stream, there is no guarantee that the gluten extracted could readily enter the food stream. If not it would have to be marketed in the feed stream, perhaps at a discount. On the positive side, it can also be argued that the novel characteristics of a triticale gluten, if they exist, could be exploited in a whole range of novel food products that could be devised to capitalize on them, to create novel foods based on this novel product. Research on the functionality of triticale gluten is desirable, as well as consumer acceptability studies by consumers of products from it (including taste), and has not yet been done with modern Canadian varieties. At this time the prospects for value-added use of triticale gluten by-product nevertheless remain speculative and nebulous, except for use in a feed stream.

10.5 Recommendations for evaluating triticale for ethanol and co-product production

10.5.1 Triticale for ethanol production – plant scale study

Agronomic performance and prior Canadian grain quality information all lead to the conclusion that triticale could be a superior feedstock to CPS wheat in the central Alberta region. The only information lacking is how it would actually perform at the plant scale at API. Triticale has been used for this purpose at PoundMaker, Saskatchewan. Therefore only one recommendation is made:

1. Conduct a plant scale run (or several with different varieties) at API using triticale, to determine the processing parameters, productivity and economics when substituting triticale for CPS wheat. This is rated as a very high priority value-added project, because of the impact that favorable results would have on ethanol processing and on crop diversification in the central Alberta region. The cost of this project should include project insurance for downtime, cleanouts or other losses that could occur because of the project. Dialogue should be immediately opened between the Alberta Government, API and other interested parties, to determine the enablement of this pilot run.

10.5.2 About triticale gluten

In the gluten market triticale does seem to have more negative aspects than positive at this time. The extent of these problems would require localized research on local product, of the following kinds:

1. Laboratory based research to compare the functional, rheological properties of vital triticale gluten with that of vital wheat gluten, compared to local CPS and CWRS wheat varieties. Will it compete with or could it replace wheat gluten, or can it develop its own niche market? Both scenarios seem unlikely, but without research this conclusion cannot be confirmed.
2. Plant scale run(s) to determine if the perceived but as yet unmeasured 'dough stickiness' problem for triticale in processing really is a problem for modern Canadian varieties, in a plant such as that at API.
3. Market analysis is needed to determine if extracted triticale gluten would be an acceptable product in the primary markets that now use wheat gluten, blended or otherwise. Can triticale gluten be satisfactorily blended with wheat gluten without detriment?
4. If gluten / protein by-product from ethanol extraction with triticale is unsuitable for a gluten market, what are the nutritional and economical prospects for diverting this product into the feed processing stream?

10.5.3 Triticale use for bakery flour (as associated with other processing at API)

The bakery flour stream from API is used in many baking applications, including use for hamburger buns for McDonald's national market. CPS is the primary class milled, and the functional protein level and quality type from this class would be expected to be ideal for this purpose. It was indicated, however, that obtaining high enough protein level (>12.8% minimum) is not always easy for CPS production within an 80 mile radius of Red Deer. Some customers are requesting protein levels as high as 19%, which likely requires gluten supplementation in most cases. 19% protein levels would rarely be found in any class of wheat in W. Canada, especially in CPS varieties, unless supplementary N fertilizer was applied at flowering time under suitable environmental conditions. Data from W. Canadian Cooperative trials indicate that triticale protein levels should be similar to (or slightly lower than) those of CPS wheat, perhaps with similar gluten strength in the strongest gluten varieties, although the latter trait is not regularly measured. In the literature triticale flour is known to be suitable or equal to wheat for many of the products where CPS quality is desired. However, detailed milling, rheological and product processing tests have not yet been done that compare Canadian CPS wheats and new Canadian triticales for these properties.

Confirmation of the suitability of triticale flour for the current markets for API bakery flour, for example, would require the following research. Favorable results might also encourage other bakeries to consider milling triticale for niche, novelty food markets, although this market appears small to negligible at this time.

1. Laboratory level analysis of CPS and triticale varieties grown at common sites in W. Canada, for protein content, milling, baking and rheological properties, and for use in specialty food products, this being work that has been completed in other parts of the world, with favorable results. Samples from at least two years of production should be tested, drawn from a range of eco-agricultural production zones in W. Canada.

2. Data should be collected from a full-scale pilot run of triticale grain through the API or equivalent milling plant, followed by a baking test run of the flour product suitability for the very large hamburger bun market, in particular. Special attention should be paid to determining whether the 'stickiness' problem is real or not in this market application.

3. Economic and market acceptance studies of triticale flour for baked products of various kinds, including taste panel assessments, for which the University of Alberta research facilities and others in the province are well equipped. This work should especially emphasize the effect of the 'nutty' flavor of triticale reported in similar studies in other parts of the world.

4. Product development research to determine the possibility of marketing novel baked goods or other novel or ethnic foods that exploit the 'nutty' flavor of triticale, separate from the wheat flour market.

5. A review (if not already completed) of agronomic performance of triticale for grain compared to CPS wheat in the Parkland zone (within the 80 mile radius from Red Deer, for example), to determine comparative yield potential, production risk, expected grade patterns, protein levels and potential economic return for producers.

SECTION D

11. Other issues for triticale

11.1. Minor use herbicide registrations for triticale

Several times in discussions, and in questionnaire responses, concern was expressed by growers of triticale that registered herbicides for this crop were few in number, and more registrations were needed. Therefore, since triticale behaves very similarly to wheat, some producers were applying herbicides registered for wheat, although this use is not approved. This is not an acceptable situation either from an environmental or food safety and health point of view. Discussion with Dr. Linda Hall (AAFRD) was entered on this topic, and she indicated that several minor use registrations do exist, likely enough for normal production circumstances. However, sufficient data likely exist for a number of other herbicides (minimum 3 site-years of data needed) for which the minor use registration could be applied, including some tank mix results. Interested producer groups can make these minor use applications if they are interested. Herbicide manufacturers and government agencies are not permitted to make applications for minor-use, but the perceived problem could likely be quickly solved by interested growers / organizations taking on this role.

In discussions with Dr. Mirza Baig (Editor, Alberta Herbicide 2001 'Blue Book'), the following weeds (not in priority order) are the ones most likely to be a problem in winter triticale. The spectrum of weeds for the spring triticale type will be similar to that for wheat.

> Shepherd's purse; stinkweed; flixweed; narrow-leaf hawk's-beard; downy brome; yellow whitlow; common pepper grass; quackgrass; canada thistle; perennial sow thistle; foxtail barley (saline areas - mainly in the south); dandelion.

The following lists indicate herbicides in each of several 'current status' categories, as indicated by Dr. Baig (Pers. comm., February 2001):

The Chemicals Presently Registered for Weed Control in Triticale are as follows:

For **grass control** (wild oats, green foxtail, yellow foxtail, barnyard grass and persian darnel):
1. Achieve (tralkoxydim)
2. Avenge (difenzoquat)
3. Hoegrass (diclofob-methyl)
4. Hoegrass II (diclofob-methyl + bromoxynil)
5. Matavan (flamprop-methyl)

For **broad leaf weed control** (tartary buckwheat, wild buckwheat, night-flowering catchfly, chamomile, cow cockle, common groundsel, knawel, kochia, lamb's quarters, wild mustard, nightshade, pig weed, stink weed, smart weed, russian thistle)

1. Hoegrass II
2. Pardner (bromoxynil)

Note that Hoegrass II will provide broad spectrum control of both grassy and broadleaf weeds.

Some of the chemicals that can probably be safely used in triticale (but that are not currently registered) are as follows:
1. Ally (Metsulfuron methyl)
2. Refine Extra (thifensulfuron methyl + tribenuron methyl)
3. Buctril M (bromoxynil + MCPA)
4. 2, 4-D (amine and ester formulations)
5. MCPA (amine and ester formulations)
6. Achieve Extra Gold (tralkoxydim + bromoxynil + MCPA) - broad spectrum weed control
7. Clovitox Plus (MCPB + MCPA)
8. Tropotox Plus (MCPB + MCPA)

Information about the efficacy of some of the last mentioned chemicals is probably available through Agriculture Canada, or Alberta Agriculture, Food and Rural Development, who may already have on hand enough data to support additional minor use registration requests.

During discussions on this topic it was also pointed out that triticale itself, being very weed competitive, can be used in a 'green' approach in crop rotations to reduce weed seed banks, as when seeded early and under good conditions it will crowd out many weed species, and can serve as a single season substitute for herbicides. This approach would be of particular interest to organic growers, who could use this crop for partial control of weeds in their rotations. Use of triticale in this way has not been promoted in any of the extension literature available in W. Canada. Although the 'competitiveness' is known, there is not a large data base about triticale effectiveness for weed control when used in this manner. Lemerle and Cooper (1996) in Australia indicated that triticale was a better weed competitor against grass weed annual ryegrass, compared to wheat. This would be an excellent research area, for application in further efforts in developing sustainable, lower input, farming systems for W. Canada, and organic cropping systems.

11.2. A proposal to counter negative effects of 'brown-bagged' triticale on the seed industry

The very negative effect of 'brown-bagged' seed on the current status and future of the pedigreed seed sales of triticale was seen as a high priority impediment to the future of the crop, as indicated by seed growers and others. This problem occurs for all varieties, not only those protected by Plant Breeders Rights. It results in a lack of incentive for seed-grower investment in triticale promotion. 'Brown baggers' likely do not expect any legal action against them either under PBR, the Seeds Act, or the Advertizing Act for illegal seed sales, because this is seen as a low value forage / feed crop of low unit value. There has been some pressure for the Alberta government to take action on some AAFRD varieties, but there is as yet no public action on this front.

Progressive Seeds Ltd., the rights holder for AAFRD varieties, has proposed an alternative approach to prosecution, which rather focuses on finding a way to increase the amount of seed on which a levy is assessed, even on common seed. This proposal was presented to GrainTek for consideration, and is further presented here. It is an approach which could readily be developed for a small crop such as triticale, but the concept could be expanded to larger acreage crops if it proved successful.

This proposal was presented by Mr. Graham Ogilvie (January17, 2001) on behalf of Progressive Seeds Ltd., Red Deer, Alberta, as follows.

"We feel that that it would be possible to collect royalties on all triticale cleaned in Alberta through municipal plants, seed-growers, and private seed cleaning facilities. There are many reasons why it would be difficult, but also many reasons why it should be attempted. Since triticale is a small volume crop, it would be a good test of a system devised to implement such a concept. We recognize that there would be leakage in the system, some people in the chain would not tell the truth, but a workable model for other crops may be developed. Such a process would put the 'grown from' trade on a more level playing field with the pedigreed seed system and it may encourage greater use of pedigreed seed. Plant breeding institutions would have better revenues from this system as the common seed would be contributing as well. The following statistics have been collected from the municipal and seed plant organization:

1. *Approximately 330,000 bushels was cleaned in these plants, some pedigreed*
2. *42 plants cleaned at least some triticale*
3. *The largest amount at one plant was 28,000 bushels, the smallest 224 bushels*
4. *Thirteen plants cleaned between 10,000 and 30,000 bushels*
5. *Six plants cleaned between 5,000 and 10,000 bushels ...*

Plants forwarding royalties would retain a portion to cover their costs. We would like to see discussion of this proposal amongst appropriate organizations. Progressive Seeds Ltd. would be in favor of seeing such an approach used Canada wide on all pedigreed seed, but it can be tried first on triticale."

It is recommended that the Alberta government join with other triticale breeding organizations, marketers, seed industry partners, CSGA and CFIA, in a workshop to discuss the legal, administrative, economic and R and D implications of this approach, with a view to trying it as a test system for seed royalty collection in triticale. Such discussions should be open to all interested partners, including grain producers and grain buyers. The desired outcome from this approach will be lowered cost per unit of seed used by producers, compared to current legal seed costs, and a larger volume of grain on which the varietal levy can be assessed, at a lower levy level than now done. Returns to the breeding organizations would increase substantially. A secondary expected effect would be an increase in pedigreed seed use, because of a smaller price spread between pedigreed seed and 'own, cleaned, seed', and a reduced incentive for 'brown-bagging'. The discussion of this approach is recommended at high priority, also because of the implications for possible implementation in other W. Canadian grain crops.

11.3. A proposal to lower the price of pedigreed triticale seed by eliminating the royalty on seed sales of publicly bred varieties: What effect would this have on promoting pedigreed seed sales, or on the public breeding programs?

From the questionnaires and other discussions it was learned that high price and volume of seed (especially for commonly used high seed rates) was a significant part of input costs, and that ways should be found to lower this. One way to reduce the cost would be for breeding institutions (all public) to waive future royalty levies on seed sales. It is estimated that this would reduce the income available for breeding by only an average $15,000 per year at AAFRD (data from P. Dzikowski, AARI), based on a levy of 7% on the market price of the seed. In 2000 the amount earned was much higher, at $39,000, based on release of new varieties. The equivalent figure for AAFC / SPARC is an average $5,000 royalty income per year (last five years) from triticale seed sales. These levied amounts (approximately 5% of sales), although put to good use, are small compared to the public line budget investment in the annual breeding costs at each institution (quoted by the AAFC / SPARC Station Director at 0.2 FTE, around $80K per year including support staff).

Although it is recognized that this crop does not have any other method for raising funds for research or marketing support (notwithstanding periodic grants and efforts by the new commodity organization, members of the seed industry, etc.) the dominant cost center for development of this crop continue to be in the public sector, which is appropriate. This situation is unlikely to change in the near future, and it is unreasonable to expect the royalty revenues of a small developing crop to carry its own developmental costs. This has not been successfully achieved with any other crop in Canada, and is an ill-conceived strategy, in the opinion of this author. Certainly triticale is not yet well enough developed to stand alone and finance its own R and D future. Lowered seed costs by removing the royalty will help promote triticale use and pedigreed seed sales, help to reduce the price difference between pedigreed and 'brown-bagged' seed, and help increase acreage overall. As crop acreage increases, introduction of a checkoff or royalty could be considered at a later date, if the production economics allowed for this extra tax on triticale production.

Other recommendations in this report would require a very considerable additional investment in triticale R and D from the public sector, Federal and Provincial. If these are adopted, the additional revenue from royalties would certainly become less significant. To avoid inappropriate price competition for seed of different varieties, such a levy removal would have to be applied to all varieties, following agreement amongst all the affected parties that breed and market triticale varieties in W. Canada. It is recommended that these parties should engage with government and others in discussion of this proposal, to determine its possible merits and impact.

In the event that the royalty earning procedure remains in place, it is recommended that for a two year period following receipt of this report, all AAFRD and AAFC revenues from royalties be used only for crop promotion and technology transfer, not for breeding or agronomic research. These amounts would cover most of the costs for developing the proposed Triticale Manual, an improved public triticale website, and related materials, for ready user access throughout the Western prairies.

The recommendation to eliminate royalty levies is, of course, very different in nature to the one proposed by Progressive Seeds Ltd., which is levied at the seed cleaner, and is focused on retaining the royalty levy, and maximising fair receipt of royalty income from a larger volume of seed use. This recommendation, by contrast, focuses on lowering production costs for the pedigreed seed user. Both recommendations can be acted on if levies are moved to the seed cleaning operation, and removed from the pedigreed seed sale.

11.4 Producer oriented publications and other media about triticale

Most users / producers contacted indicated that this was a very limiting item for triticale, perhaps the most serious one, and that available materials were either generally poor, out-of-date, or unavailable. This view is confirmed by the author of this report, who found sources to be scattered, unfocused, or unavailable in many case. For example, several otherwise excellent forage publications do not even mention triticale as a forage (Alberta Forage Manual, ISBN 0-7732-6127-3, Pub 1981, reprinted 1998; Agdex 420/56-1 1998 Introduction to swath grazing in W. Canada). The most recent Alberta Triticale publication, 1993, is 8 years out of date, and includes no information on new uses for forage, annual silage, (alone or in mixtures), for grazing, or for grain use for swine or cattle feeding. Information about triticale silage digestibility is lacking, and there is no extension information about feed quality or rates of gain using triticale for different classes of animal. None of the publications make much (if any) reference to the advantages and applications of winter (or spring) triticale for erosion control or as a means of managing crop rotations and disease control in areas where heavy applications of manure are made, or indicate how the crop can be put to use in those situations. Thus, well-known positive features of this crop are not being presented to potential users in any complete or readily available form, and this must be remedied. A complete review of the kinds of extension materials needed, and their format for maximum accessibility and impact for producers, is needed.

11.4.1 Recommendations to achieve improved information about triticale

Several recommendations to improve the amount, quality and accessibility to available information are proposed:

1. A production and utilization manual should be prepared for triticale, similar in scope and content to the Canola Grower's Manual. It should be available in printed and electronic form, the latter at a Triticale Homesite, to be established within the Ropin' the Web address. Progressive Seeds Ltd. has indicated interest in being the HomePage for triticale, but given that most of the available information of interest is in the public domain, it is more appropriate for the public sector to take the initiative in setting up the site, or expanding their current one. PSL could develop its own materials as needed, linked to Ropin' the Web. The site should contain detail, not generalizations, and present referable data to the fullest extent, especially about nutrient characteristics of the Canadian grown crop, for feed and forage. Emphasis should also be placed on the interactive advantages of triticale in farming systems, about which nothing is yet available in the extension literature. This would cover intensive livestock situations and analyses, and the forage value for recycling manure outputs (e.g. Cattle / manure / forage / silage system; Swine / manure / feedgrain for swine system; Grain production / local processing / poultry feeding / production system; Grain production for ethanol feedstock; etc.).

2. The primary focus on extension (producer meetings, travelling workshops, etc.) should be on use for forage where the special advantages of triticale are already known, and on swine feed where advantage is just starting to be recognized (although many years in recognition behind other countries). Considerable effort has been made on this during 2000/2001 by the Agronomy Unit at AAFRD, Edmonton, and many thousands of producers have heard presentations about the completed project. The two areas of forage use and swine feed use offer a prospect for at least doubling triticale acreage within three years, if responsible and effective technology information transfer can be continued and expanded, using limited extension budgets strategically, in collaboration with federal resources and with those in other provinces.

3. Alberta forage extension literature needs to have information about triticale presented within it. If these publications will not be reprinted soon, then this information should be assembled and released in some new triticale forage pamphlets, also put on the website. Organised and accessible information about triticale forage potential and use is very sparse in extension materials.

4. Triticale should be the subject of a 2 day professional update workshop for Alberta grain and forage specialists (1 day on grain, 1 day on forage, each including feed considerations). This is necessary to bring a focus onto triticale potential and to increase staff knowledge on the topic. Provincial staff from Saskatchewan and Manitoba should also be invited to this workshop, to gain a prairie wide re-focus on the crop. Technical presentations by Canada-wide experts can be captured for use in the Triticale Homesite and the Triticale Manual.

5. There is little capacity for the private sector to absorb the costs of this technology transfer program, because of the small size of the crop at this time, and the special shortage of private sector funds for promoting forage crops. It is recommended that

AAFC and AAFRD should be the primary funders for this triticale extension initiative, which logically completes the process started by their investment in the breeding programs. A special two year effort on this is strategically desirable at this time, given expanding demands for forage and feed. Additional support from the livestock sector should also be sought.

6. In the case of triticale for feed use of all kinds, a special workshop should be developed focused on the feed attributes of triticale in all classes of feed use. This workshop would be repeated at key locations in the prairie provinces, to serve prairie-wide needs. Feed formulators (and private feedlot operators) should be the primary target audience, but the workshop must focus on how triticale can be used in rations. For silage applications, harvesting and processing information would be covered, and differences from barley silage stressed as appropriate. Different parts of the workshop would focus on the different animal classes. Presentations would be by feed nutrition experts (national and international) who have research experience with triticale, and their presentations would also be entered into the Triticale Manual and the website. The main purpose of this workshop is to gain the attention of feed manufacturers and formulators who currently generally ignore triticale as a potential ingredient in their rations, or indicate only medium to low knowledge levels about it, or only medium interest. If they were to express more interest in using this crop, there could be a correlated acreage response for feed grain as well as forage use.

7. There is a need for a high content website that contains detailed information about Triticale. This can best be done at the Ropin' the Web site of AAFRD (which turns up very often when 'triticale' web searches are done), and should also be linked to the Infoharvest www.seed.ab.ca site, which handles seed related matters. There could also be a role for Progressive Seeds Ltd and/or other collaborating organizations to develop seed related or other aspects of this information at their own (linked) website, using financial assistance in the short term from Alberta government sources. PSL also wishes to develop a comprehensive seed + management promotion package, to assist in its role for promoting this crop, and it may be advantageous for a private sector group to take on at least some aspects of this role under current conditions (eg. information about the seed business / seed availability aspects). A comprehensive electronic information site about triticale could also serve as a model for establishing similar sites in other grain crops. It is strongly recommended at this time with triticale because of the need to achieve information transfer and information access very quickly in this crop, whose potential is under-realized because possible users do not know enough about it. 'Run-on' publicity about triticale can also be achieved by widely publicising the 'electronic extension information' approach that will be used to make updated agricultural information more widely available, more quickly. Such a site could also include feed mixture model calculators, for individual farmers to use on-line, for example, and have links to animal, forage and grain commodity sites.

8. Support establishment of a triticale 'Users Group and Chatline' linked to the triticale website, where triticale growers and suppliers can share information and experiences about the crop. This would probably best be managed in the private sector, and could

also be an extension of activities in this area already started by Progressive Seeds Ltd.. The site should be button linked to the Triticale Homesite and all other significant triticale sites in W. Canada and elsewhere (eg. Winter Cereals Canada). PSL has expressed interest to this author about its desire to take on the central role for future agronomic extension about triticale, currently assigned to the Alberta government. This would be achievable if they were running the chatline, and became the *de facto* industry centre for discussions and developments about this crop.

9. Consistent with the Triticale network proposal recently submitted to AARI, the network group should meet immediately and determine extension and research programs and budgets as now needed, combined with a determination of the best approach to disseminating information to growers, grain users and feeders in the most effective manner. A single W. Canadian approach to the needs is needed, involving all parties. To accommodate development of potentially multiple and new crop uses prairie-wide, additional members to the network should be considered as needed.

10. In view of the novel use of triticale as a breaker of disease cycles in crop rotations, as a novel source of high quality, high yielding silage and forage, and because of other potential uses (industrial, nutraceuticals etc), it is strongly argued that triticale be considered as one of the crops that would be eligible for new and additional funding through the Alberta New Crop Development Fund, starting in 2001. If the necessary continuing research for this new grain crop use is not done by Alberta with its partners, useful sustainable agricultural and environmental benefits from this crop will not be available to Alberta producers.

11. Very useful and extensive agronomic research about triticale production and use is ongoing in AAFRD both at Lacombe and at Edmonton. Both groups were very useful sources to this reviewer, and farmer oriented extension activities by the Edmonton group about triticale have been very extensive during the 2000/2001 winter. What is less obvious to the author is the extent to which the extension and research activities of the two groups are internally coordinated, or priorities jointly set for the crop. In addition, research linkages to feed quality research and the feed industry sector appear so far to have been limited to a project basis, rather than to any longterm coordinated feed industry/government planning approach to the needs for triticale feed research. AAFRD is encouraged to hold a working session to evaluate these issues within the context of the many other recommendations made in this report. It should also determine the optimum joint operational mode that will best use joint research and development resources for the maximum benefit of this crop. How will the new ‘Feeds Institute’, for example, fit R and D needs of the triticale crop into its mandate?

12. With the exception of specific recommendations that are not intended for wide release, the author recommends that any information in the report which is already in the public domain be made available in an edited form in printed or web media format for the general public, to gain the widest benefit from this review process. All respondents in this review have expressed a wish to have access to the contents of this

report, although at the time of submission it will still be confidential to the Government of Alberta. Such interest also underlines the industry demand for any new information about triticale and its potential.

12. Estimating the potential future acreage of triticale in W. Canada

A number of methods for estimating what this might be were considered based on possibilities of projecting feed, forage and other demand. This approach was finally considered of low benefit, largely because data on even the current triticale acreage and its use in different markets are very limited, and potentially unreliable. Instead, the approach is taken of projecting the future based on the already known advantages and now-emerging strengths of the crop. Most of the discussion about this took place with parties in Alberta, since current adoption, and/or interest and knowledge about triticale potential in Manitoba or Saskatchewan appears very limited. Certainly Saskatchewan and Alberta dominate the current acreage of triticale, with only minor adoption in Manitoba so far.

In overall consideration the following mega-factors all contribute to a favorable outlook for considerable acreage expansion potential for triticale.

1. Greatly increasing demand for forage and silage for an expanding W. Canadian beef herd in all provinces, especially in Alberta. Triticale is a crop which can offer better buffering against droughty conditions than other forage crops, and it responds well under high moisture conditions. This aspect is of increasing importance to feeders trying to establish sustainability in their enterprises. The higher yields of triticale can offer an increased size of silage crop, without use of additional land base. In the 1997 Alberta Government review of 'Resources for beef industry expansion in Alberta' (www.agric.gov.ab.ca/livestock/beef) the following conclusions were set out. An ability to double the 1997 feedlot capacity in Alberta was seen. Expansion of triticale clearly fits into the needs that were seen, although the role for triticale as a new forage source seems not to have been considered by that review team:

   ' …..Expansion opportunities are limited to improved pasture'….because…. 'native range pastures are stocked at capacity'…… 'Tame pasture management should be a priority for the cattle industry and government. Substantial areas in cow/calf production do not have enough pasture if conventional pasture management practices are used. Techniques like rotational grazing, grazing alfalfa, fertilizer applications and forage species management must be adopted to reduce the current risk and provide resources for expansion. Alternative feeds like straw and chaff could be important winter feed substitutes'….. 'Drought or high hay prices can significantly pressure cattle operations in key cattle production areas'….. 'Maximum haul distances for silage …are around 6 miles'….so silage must be grown where the cattle are fed…….. 'Silage production can be increased on cropland adjacent to feedlots'.

2. Silage costs are a significant part of the feed cost both for feeder cattle and for backgrounders. The Alberta Government website gives an example for feeder cattle starting at 400 lb weight, fed for 228 days, and gaining 2.3 lbs per day. In this example the silage cost is $61.56 (plus $254.79 for the barley), constituting around 20% of the feed cost. For backgrounders, the silage cost is $43.75 (plus $65.19 for the barley), constituting 40% of the total feed cost. Thus, if triticale silage can be produced at lower cost than barley silage, this can improve the margins for feed cattle production. At least several large Alberta feeders have already recognized this advantage, and have incorporated it in their cattle rations. In discussions with Progressive Seeds Ltd., a figure of 1.6m acres of total silage production in Alberta was circulating, and it was felt very reasonable as a target that 25% of this should convert from barley silage to annual triticale silage, which would be a total of 400,000 acres per year in Alberta alone. Much of this increase in Alberta would be located in the drier, southern part of the Province, where barley silage is relatively less productive, but triticale silage production is suited to all parts of the W. Prairies. Don Milligan (Beef specialist, AAFRD, Red Deer) also agreed that a target for triticale to constitute 25% of all Alberta silage was reasonable, and that this would have a major effect on breaking serious disease infestation cycles that are now evident in barley for silage and grain.

3. Following on favorable preliminary work in Alberta on silage use for dairy, winter triticale silage could be adopted for dairy herd use, to provide a high yielding, high quality silage for dairy in the early spring period, when other forage may be less available, especially during droughty years. More dairy herd research is needed before this adoption can be realized, but its use in this way could add security and sustainability to the silage supply for the dairy industry.

4. Special adaptation of spring and winter triticale for forage (grazing and silage) in farming systems where heavy manure applications are made to the soil, thus contributing to a more sustainable farming system, and improved environmental response, especially as affecting groundwater quality. This activity and use of triticale will occur in close proximity to feedlots.

5. Expectation that the Canadian swine industry will continue to (newly) recognize the special nutritional advantages of triticale compared to other grain feeds used in the past, and that significant adoption will be seen for the grower-feeder enterprises for swine.

6. Potential (after some more research) that the poultry broiler industry may also start to adopt some triticale use, by grower-processor-feeder operations.

7. Subject to successful plant-scale pilot-run trials and economic studies (potentially at API), the ethanol industry could consider triticale use to replace CPS wheat use in central Alberta, to make a contribution to the value-added goals of the Government of Alberta in the cereal sector, also achieving crop diversification. Low grain prices combined with high fuel prices make for favorable economics in this sector in the

short-term, at least, and the potential for replacing CPS wheat use with triticale needs to be established.

8. Continuation of the two W. Canadian triticale breeding programs, to further improve the agronomics and market value of triticale varieties suited to W. Canada, for use in the niche applications where triticale has a clear advantage over other cereal grains.

9. As a presumption, that the Alberta Government, in collaboration with others, will significantly invest in an information transfer program about triticale, for potential growers as well as feed and forage users. This will bring the advantages of this crop for specified uses (particularly for forage and silage use) much more into the view of potential users prairie-wide, using recent research results based on the newest W. Canadian varieties. The general knowledge level about triticale for those who could produce it, and those who could use it, is rather poor, but can be improved very quickly by using a targeted crop use profiling approach, one that at the same time does not oversell the potential.

12.1 A realistic acreage target for triticale in the next 3 to 5 years

Forecasting the future, especially in agriculture, has always proven to be a very risky business. This report nevertheless strongly recommends adoption of the following target acreages for triticale in W. Canada, on the presumption that the most important recommendations in this report are acted on, particularly the prairie-wide technology and information transfer activities proposed. If this expansion did occur, the seed industry will have no problem in servicing the supply of seed that will be needed for crop use, especially in the expanded annual forage market. This projection does not include potential triticale sales to the USA, which up to this time appear to have been mainly spot market seed sales, often without repeat business. The projection also ignores the reported Statistics Canada leveling off of acreage that occurred in 2000, as it is believed that these figures do not take into account the large acreage of 'home-grown' seed used for the forage industry. Consistent sales to the US market (mostly a seed market for forage establishment) would be more readily achieved in the future when the Canadian production base it is at a much higher threshold level. To avoid brown-bagging in the USA, only seed sales of PBR varieties should be encouraged, which do receive protection there. A larger crop base in Canada would offer improved continuity of supply and access to seed from a more active and stabilized Canadian triticale seed marketing supply.

Goals for W. Canadian Triticale Production

By 2004 - Double the 2001 acreage (mainly from forage use increase)

By 2007 - At least triple the 2001 acreage (as triticale feed grain use increases, displacing some barley use)

- Triticale constitutes 25% of all silage use in W. Canada

- Triticale becomes a significant W. Canadian feed for swine, competing with hulless barley, and it gains some Canadian use for poultry

By 2011 - Triticale becomes the grain of choice for production of ethanol based fuels (depending on Canadian political approaches to fuel and pollution issues)

- Significant value-added potential develops in the human food market, plus use(s) of fractionated grain components, some for non-food industrial applications

Notes about potential acreage increases, and Statistics Canada reported acreage:

1. Most persons contacted during this review indicated a poor confidence level in the reported acreage provided by Statistics Canada, in many cases suggesting that the current acreage may be as much as 50% under-reported. Manitoba figures in particular appear very 'rounded'.

2. Reasons for under-reporting include high triticale use for forage, and a known but unquantifiable amount of 'brown-bag' acreage and seed market. Many (including the author) were surprised and skeptical that the acreage leveled off or dropped in 2000, and attribute the discrepancy to those factors.

3. Other factors that could combine to limit achievement of the future triticale acreage goals set out include:
   (a) Inability to displace other annual crop acreage (silage and other) that offer better returns.
   (b) Insufficiency of suitable land base for triticale forage expansion, close to feedlots, especially in S. Alberta.
   (c) Emergence of other competitive silages (eg. forage barley varieties).
   (d) Slow or limited development of a triticale grain supply stream, matched with a ready supply of alternate grains for protein feed, such as peas etc.
   (e) Ergot occurrence in triticale feed grain, as a real or perceived problem.
   (f) Uncoordinated W. Canadian approach by industry, Federal and Provincial Governments to developing and using extension information for targeted user clientele for triticale.
   (g) Reduced or minimal research investment in triticale, particularly in the forage and feed processing aspects of this feed source, for grain or forage and silage use. Expansion of feed quality assessment work is an essential key item at this time, to capture triticale's role in supporting the value-added goals in the animal production sector, with cattle, dairy and swine.

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Appendices

Appendix I . Canadian Triticale Varieties (from 2001 Cereal Research Report, Field Crop Development Centre)

Triticale Varieties

Spring Triticale

AC Alta was developed by Agriculture and Agri-Food Canada Research Station at Swift Current and registered in 1994. AC Alta yields approximately 6% higher yielding than the check cultivar Wapiti and has similar levels of disease resistance. For seed production this cultivar is best suited to the brown soils of the prairies but like other spring triticale cultivars has excellent forage potential as silage in both the black and brown soil zones.

AC Certa was developed by Agriculture and Agri-Food Canada Research Station at Swift Current and applied for registration in 1995. AC Certa has excellent disease resistance, improved test weight, sprouting resistance and is one day earlier while maintaining grain yield.

AC Copia was released in 1993 by Agriculture Canada, Swift Current. Its yield is similar or superior to Wapiti under Alberta conditions. It has a high test weight with good disease resistance.

AC Ultima was developed by Agriculture & Agri-Food Canada, Swift Current and registered in 1999. It has improved quality for food end use (Hagberg falling number), good disease resistance and 1 day earlier than other current spring triticales. It has a lower test weight than AC Copia and AC Certa.

Banjo was developed by the University of Manitoba and registered in 1990. It has out yielded the other triticale varieties in cooperative tests with better lodging resistance, good test weight and the highest 1000 kernel weight, however it has a lower protein content. Banjo is similar to Frank for disease resistance.

Pronghorn was developed by Field Crop Development Centre, Lacombe and registered in 1995. Pronghorn is two days earlier and has yields equal or superior to the check cultivars. It is adaptable in the long growing areas of western Canada and is moderately susceptible to certain races of stem rust.

Sandro was developed by the Swiss Federation of Agriculture Research and was registered in 1998. It is equal to Pronghorn in maturity, has good lodging resistance with height equal to AC Alta, and good test weight. The test weight is only equal to Pronghorn. We do not have much information on this Eastern Canada variety. It requires a long growing season.

Wapiti was developed by Alberta Agriculture at Lacombe and registered in 1987. Wapiti is a spring triticale with maturity, height, test weight, lodging resistance and sprouting susceptibility similar to Carman but with improved yield and test weight. Wapiti also has resistance to leaf rust, stem rust, loose smut, and bunt that is similar to Carman. Wapiti provides greater resistance to common root rot than Carman as well as a yield advantage in the Brown and Black soil zones. The potential for silage production is comparable to the best barley varieties in the high rainfall areas of Alberta and superior in the dry areas.

Winter Triticale

Bobcat was developed by Alberta Agriculture, Lacombe and registered in 1999. It is about 20 cm. shorter, 10% higher yielding, and has similar winter survival to Pika in the parkland areas. It is easy threshing and has short awnlettes which may improve greenfeed production. However, it is lower yielding than Pika in the brown soils.

Pika was developed by Alberta Agriculture Crop Research, Lacombe, Alberta and released in 1990. Pika is similar to Norstar winter wheat in hardiness and higher yielding than Wintri winter triticale. Due to early maturity, Pika may be more suited to seed production in the higher rainfall areas of Alberta than currently available spring triticales. When spring seeded with barley and oat or seeded on its own Pika provides a high yielding long duration pasture in the high rainfall areas of Alberta. Mixtures with oats and barley also provide a high quality silage and fall pasture.

Wintri was developed by the Ontario Agricultural College in Guelph and released in 1980. Wintri is lower in winter hardiness than the winter triticale Pika. Due to early maturity, Wintri may be more suited to seed production in the higher rainfall areas of Alberta than currently available spring triticales. When spring seeded with barley and oats or seeded on its own Wintri provides a high yielding long duration pasture in the high rainfall areas of Alberta. Mixtures with oat and barley also provide a high quality silage and fall pasture.

Appendix II. List of historical Canadian triticale varieties released since 1972 (from 2001 Cereal Research Report, Field Crop Development Centre)

Historical Triticale Collection

Triticale Variety	Year released in Canada	Where Developed	Characteristics
Rosner	1972	University of Manitoba, Winnipeg	Spring
Welsh	1977	University of Manitoba, Winnipeg	Spring
OAC Wintri	1980	Ontario Agric. College, Guelph	Winter
Carman	1980	University of Manitoba, Winnipeg	Spring
OAC Triwell	1980	Ontario Agric. College, Guelph	Spring
OAC Decade	1984	Ontario Agric. College, Guelph	Winter
Beagueleta	1986	Ag. Canada, Charlottetown & CIMMYT	Spring
Wapiti	1987	Alberta Agric., Field Crops, Lacombe, AB	Spring
OAC Trillium	1988	Ontario Agric. College, Guelph	Winter
Frank	1988	Ag. Canada, Swift Current, SK	Spring
Bura	1989	CIMMYT, Mexico	Spring
Pika	1990	Alberta Agric., Field Crops, Lacombe, AB	Winter
Banjo	1991	University of Manitoba, Winnipeg	Spring
AC Copia	1993	Ag. Canada, Swift Current	Spring
AC Alta	1994	Ag. & Agri-Food Canada, Swift Current	Spring
AC Certa	1995	Ag. & Agri-Food Canada, Swift Current	Spring
Pronghorn	1995	Alberta Agric. Crop Research, Lacombe	Spring
Sandro	1998	RAC Swiss Federal Research Station	Spring
Bobcat	1999	Alberta Agric. Crop Research, Lacombe	Winter
AC Ultima	1999	Ag. & Agri-Food Canada, Swift Current	Spring

Appendix III. Questionnaire sent to W. Canadian triticale seed growers

Keith G. Briggs
GrainTek, 10903-35 Avenue
Edmonton AB
T6J 2V2

Ph/Fax 780-434-4472
Email: keith.briggs@ualberta.ca
http://www.infoharvest.ca/graintek

Dear Colleague

I am contacting you with this short survey as you are listed as a source of triticale seed in Alberta or elsewhere in W. Canada. Because of this you have valuable experience to share, about the merits of triticale as a seed crop, and about its potential use in various feed, forage and food markets in your region. I have been retained by the Government of Alberta to evaluate and report on the future potential of triticale as a crop in W. Canada, and your inputs as a seed grower of triticale would be very helpful to me in this review.

To obtain your input I would be very grateful if you could complete the enclosed questionnaire, and return it to me no later than December 22, using the enclosed, self-addressed envelope. I hope that completion of the questionnaire will not take more than 20 – 30 minutes of your time. The confidentiality of your return will be held by GrainTek – only the summaries of responses and comments will be included in the report to the Government of Alberta. The final report and recommendations to them will be made public by Alberta Agriculture, Food and Rural Development at a later date.

As with any crop, your role as a supplier of pedigreed seed is a vital part of the development of triticale as an alternative crop. In addition to the specific questions asked, I also encourage you to comment (on the back of the form) about specific advantages and disadvantages for this crop, and opportunities that you could see for it in the next 5 – 10 year time frame which have not yet been properly or fully exploited.

Your inputs are much appreciated. Also please feel free to contact me directly by phone, fax or by email if you would like to discuss triticale or the report I am preparing in more detail.

Thank you for your assistance,

Keith Briggs Ph.D, P. Ag

Chair, Alberta Cereal and Oilseeds Advisory Committee, and
Professor Emeritus, University of Alberta

Enclosure: Triticale seed production and marketing questionnaire

Appendix III, continued

Production and marketing questionnaire for Triticale pedigreed seed growers

Please complete and send the questionnaire in the supplied return envelope to Dr. Keith Briggs, GrainTek, 10903-35 Avenue, Edmonton AB T6J 2V2, no later than December 22, 2000 if possible. Thank you very much for your valued input and for sharing your experience with triticale seed production.

PART I PRODUCTION ASPECTS: **YOUR NAME HERE** ______________

Triticales for grain production:

Q1 Name varieties you have grown ____________ ____________ ____________ ____________

Q2 How many years have you grown triticale for seed ? ____________

Q3 How do your spring triticale yields usually compare to that of other cereal grains ?

(a) Average yield obtained:	Triticale ____	CWRS wheat ____	CPS wheat ____	Winter wheat ____
(b) Highest yield obtained:	Triticale ____	CWRS wheat ____	CPS wheat ____	Winter wheat ____
(c) Lowest yield obtained:	Triticale ____	CWRS wheat ____	CPS wheat ____	Winter wheat ____

Q4 Compared to other cereal grains, do you consider grain yield stability of triticale to be
(a) Much worse, (b) Somewhat worse, (c) Equal, (d) Somewhat better, or (e) Much better ?
(Please circle one of the 5 categories)

Q5 How does spring triticale perform for you compared to (name the compared cereal) :
(Circle one choice)

Under drought conditions, compared to ________________(1) Worse (2) Equal (3) Better
Under wet conditions, compared to ____________________(1) Worse (2) Equal (3) Better
Under low fertility conditions, compared to ____________(1) Worse (2) Equal (3) Better
On difficult to manage soils__________________________(1) Worse (2) Equal (3) Better

Q6 Do you find spring triticale to be a better competitor with weeds than other spring cereal grains ?
Please circle one of the 5 choices:
In comparison to (name cereal here) ___________ triticale as a weed competitor is
(a) Much worse, (b) Somewhat worse, (c) Similar, (d) Somewhat better, or (e) Much better

Q7 Most spring triticales are relatively later maturing than other spring cereals. Compared to different wheat classes indicate how many extra days to maturity are needed.

	Compared to named CWRS	Compared to named CPS
Named triticale variety________	Variety ________ + days	Variety ________ + days
Named triticale variety________	Variety ________ + days	Variety ________ + days
Named triticale variety________	Variety ________ + days	Variety ________ + days

Appendix III, continued

Q8 What diseases, if any, have been problematic in your triticale production or that of your seed customers ?

Disease__________________ Severity_____________ (0= None, to 5 = Very severe)

Frequency_____________ (0 = None, to 5 = Very frequent)

Disease__________________ Severity_____________ (0= None, to 5 = Very severe)

Frequency_____________ (0 = None, to 5 = Very frequent)

Disease__________________ Severity_____________ (0= None, to 5 = Very severe)

Frequency_____________ (0 = None, to 5 = Very frequent)

Disease__________________ Severity_____________ (0= None, to 5 = Very severe)

Frequency_____________ (0 = None, to 5 = Very frequent)

Q9 From the field production point of view as a seed grower, list in order of importance (priority) the spring triticale varietal characteristics that are advantageous and disadvantageous

Advantageous	Disadvantageous
1.	1.
2.	2.
3.	3.
4.	4.
Other	Other

Q10 If different from Q9, list priorities for genetic improvement that breeders should be incorporating in new spring triticale varieties, in your opinion

Priority 1

Priority 2

Priority 3

Priority 4

Other

Appendix III, continued

Q11 List priorities for genetic improvement that breeders should be incorporating in new winter triticale varieties, in your opinion

Priority 1

Priority 2

Priority 3

Priority 4

Other

Q12 For winter triticales, rate the value of the winter type for each of the production characteristics listed (Circle one for each character)

Earliness of the winter grain crop
(1) very unimportant, (2) unimportant, (3) neutral, (4) important, or (5) very important

Redistributing seeding and harvest time, to spread cropping work
(1) very unimportant, (2) unimportant, (3) neutral, (4) important, or (5) very important

Adds extra choices in the crop rotation, including forage, green manure, dual purpose, or sileage use
(1) very unimportant, (2) unimportant, (3) neutral, (4) important, or (5) very important

Control of soil erosion
(1) very unimportant, (2) unimportant, (3) neutral, (4) important, or (5) very important

Higher yield potential than spring cereals
(1) very unimportant, (2) unimportant, (3) neutral, (4) important, or (5) very important

Q13 How many days earlier in maturity are winter triticales than spring types listed, in your experience ? (Please indicate variety names in the comparison)

Triticale variety__________ Compared to CWRS________ - days Compared to CPS________ - days

Triticale variety__________ Compared to CWRS________ - days Compared to CPS________ - days

Triticale variety__________ Compared to CWRS________ - days Compared to CPS________ - days

Q13 Write in this space (or as comments on reverse side) other reasons that winter triticale is an attractive crop for you as a seed grower. Also indicate known limitations.

- Re-vegetation ____________ ____________ ____________
- Other (specify) ____________ ____________ ____________

(NB This is a very long list, but triticale is already used for one or more of these purposes in one part of the world or another, or research towards that end is in progress)

Appendix III, continued

PART II MARKETING AND USE OPINION

Q14 Much of the triticale production so far in W. Canada has been directed toward forage / sileage use, but other markets are also emerging, often localized. Indicate what you feel is the level of localized research knowledge on (I) Production Agronomy,and (II) Product Quality / Value for each of the indicated potential market uses. For (I) and (II) use the following scale :
1=Very lacking, 2= Somewhat lacking, 3=Adequate, 4=Fairly good, or 5= Excellent

On the same table in column (III) indicate your priority ratings for future research directions, if you were in charge of research funding for triticale in W. Canada (a hard call, but perhaps the most important one ?) As there are 28 possible end uses listed, rank these from 1 (most important) to 28 (least important). It may help you in ranking if you lump together some of the categories at the same priority level. Remember this is a prioritization for all of W. Canada, not just your local need.

Potential uses		(I) Production Agronomy (Score, 1-5)	(II) Product Quality (Score, 1-5)	(III) Research Priority (Rank, 1-28)
Feedgrain	- Beef cattle	______	______	______
	- Dairy	______	______	______
	- Poultry	______	______	______
	- Swine	______	______	______
	- Other (specify)	______	______	______
Forage	- Greenfeed	______	______	______
	- Sileage – Dairy	______	______	______
	- Sileage – Beef	______	______	______
	- Under-seeding	______	______	______
	- Relay cropping	______	______	______
	- Mixed cropping	______	______	______
	- Other (specify)	______	______	______
Human food	- Consumer acceptance	______	______	______
	- Specialty foods	______	______	______
	- Health foods	______	______	______
	- Organic production	______	______	______
	- Nutritional studies	______	______	______
	- Malting/distilling	______	______	______
	- Other beverages	______	______	______
Value - added products / processing:				
	- Ethanol / energy	______	______	______
	- Grain components	______	______	______
	- Straw processing	______	______	______
	- Nutritional extracts ?	______	______	______
	- Flavor extracts ?	______	______	______
	- Other (specify)	______	______	______
'Exotic novel uses'				
	- Reclamation	______	______	______
	- Re-vegetation	______	______	______
	- Other (specify)	______	______	______

(NB This is a very long list, but triticale is already used for one or more of these purposes in one part of the world or another, or research towards that end is in progress)

Appendix III, continued

Q15 The last question (and much easier to do than Q14, I believe). Rate the following broad marketing issues from 1 – 5, in relation to how each <u>may be limiting the further adoption or expansion</u> of triticale as a crop in W. Canada
(1 = Very much, 2 = Somewhat, 3 = None, 4 = Probably a non-issue, or 5 = Completely unimportant

Triticale has a special value as a non-board grain ______

Production economics of triticale not well known vs other crops ______

Shipping costs to potential markets limit crop adoption ______

Potential growers un-informed about triticale ______

Potential users un-informed about triticale ______

Lack of promotion / extension about triticale potential ______

Limited current supply chain discourages user commitments to this novel crop ______

Poor returns for triticale vs other cereal grains ______

Poor scientific local data base describing modern adapted varieties for various end uses ______

Potential grain export markets only partially explored ______

Current perceptions of triticale inaccurately based on obsolete early varieties ______

Seed supplies limiting ______

Triticale seed market compromised by 'brown-bagging' ______

Other (specify) ______

Other (specify) ______

This completes the questionnaire – thank you for your patience in answering all the questions. Results from your inputs will be summarized in the report to AAFRD. Your inputs will be acknowledged in the report preface by name, unless you check the following box, in which case I will not include your name, if that is your preference. Your specific inputs will not be traceable to you as source.

Put checkmark here, if you prefer not to be acknowledged in the report ____________________

Please indicate your name here, so that I can follow up on your comments if necessary ______________

**** Your further comments and opinions about any aspects of triticale production and marketing are welcomed, and you can write them on the reverse side of the questionnaire sheets. Suggestions about topics not covered in the questions are particularly welcome. This survey is only one part of an extensive revies about future prospects for the crop in W. Canada.

Thank you for your inputs – and Merry Christmas and Happy Holidays to you and your family !!

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