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A Pan-Canadian Ethanol Feedstock Study to Benchmark the Relative Performance of Triticale

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Introduction

Triticale (X *Triticosecale* W.) is a man-made cereal crop that is well-suited as a carbohydrate platform for renewable industrial products. One of the short term objectives for the Canadian Triticale Biorefinery Initiative (CTBI) is to benchmark the relative performance of triticale to wheat classes (*Triticum aestivum* L.) currently utilized for ethanol production.

Materials and methods

Ten cultivars: three triticale, two Canada Prairie Spring (CPS), three Canada Western Soft White Spring (CWSWS), one Canada Western Red Spring (CWRS), and one General Purpose (GP) from eastern Canada were grown across Canada from 2007 to 2009 (Table 1, Fig.1). Yield and protein concentrations were calculated at 13.5% moisture content. Starch concentration was determined for each location on a composite sample from all replicates using AACC approved method 76.13. Days to maturity, seed weight (weight per 1000 kernels), test weight, and crop biomass (dry matter basis) were also recorded. Ethanol data was generated at the University of Alberta using the shake-flask fermentation procedure.

Table 1. Description of test locations for ethanol feedstocks study.

Location	Trial Years	Agroecological Zone	Soil Zone	2007 Growing Season Precipitation (mm)	2008 Growing Season Precipitation (mm)	2009 Growing Season Precipitation (mm)
Western Canada Sites:						
Fort St John BC	2009	3	2	n/a	n/a	222
Dawson Creek BC	2009	3	2	n/a	n/a	240
Donnelly AB	07,08,09	3	2	270	234	107
Edmonton AB	07,08,09	3	1	181	159	147
Falher AB	07,08,09	3	2	270.4	234.4	106.8
Lacombe AB	07,08,09	3	1	357	230	279
Lethbridge AB Dry	07,08,09	1	3	163.9	379.9	241.3
Lethbridge AB Irr	07,08,09	1	3	290.9	456.1	342.9
Westlock AB	07,08,09	3	2	238	178	150.2
Neapolis AB	2009	3	1	n/a	n/a	114.3
Melfort SK	07,08,09	3	1	350.8	189.6	243.4
Saskatoon SK	07,08,09	1	3	278	180	214.5
Swift Current SK	07,08,09	1	4	152.1	337.3	198.5
Watrous SK	07,08,09	1	3	210	238	256
Indian Head SK	07,08,09	2	1	275	217	210
Regina SK	07,08,09	1	3	189	228	155
Scott SK	2008,09	1	3	n/a	207	172.7
Lake Lenore SK	2008,09	3	1	n/a	178.2	226
Brandon MB	07,08,09	2	1	256.8	367.2	241.2
Rosebank MB	07,08,09	2	1	388.2	315.6	268.8
Roblin MB	2008,09	3	2	n/a	308	287
Arborg MB	2008,09	3	5	n/a	466	386.5
Melita MB	2008,09	2	1	n/a	257.7	213
Carberry MB	2009	2	1	n/a	n/a	235.4
Portage MB	2009	2	1	n/a	n/a	208.7
Eastern Canada Sites:						
St Isidore ON	2009	4	5	n/a	n/a	351.4
Ottawa ON	07,08,09	4	5	346	337.2	488.2
Elora ON	07,08,09	4	6	251.5	419.7	274.6
Renfrew County ON	07,08,09	4	5	442.4	418.3	338.6
Normandin QC	07,08,09	5	6	253.2	339	321.6
St Foy QC	07,08,09	5	5	499	559	465
St Hyacinthe QC	07,08,09	5	5	351	487.4	409.4
Charlottetown PEI	07,08,09	6	6	388.1	463.6	531.4

Agroecological Zones: 1=W. Prairies, 2=E. Prairies, 3=Parkland, 4=Ontario, 5=Quebec, 6=Maritimes (Charlottetown, PEI)
Soil Zones: 1=Black, 2=Grey Wooded, 3=Dark Brown, 4=Brown, 5=Dark Grey Gleisolic, 6=Podzol

The experimental design was a RCBD. Data were first analysed using PROC MIXED of SAS® with cultivar, location, and their interactions as fixed. For analysis by geography and agro-ecological zone, location and rep (location) were treated as random effects.

Fig. 1. Map of Canada with corresponding test locations for Pan-Canadian ethanol feedstock study. 2007-09.

Results and discussion

When averaged over all environments, the grain yield production of the triticale class was similar to the highest yielding wheat class (Table 2). The triticale cultivars AC Ultima and Pronghorn generally produced similar or superior grain yield to the hard red spring wheat class and similar yield to the CWSWS class (Table 2).

Table 2. Least square means for cultivar and wheat class grain yield (kg ha^{-1}) performance averaged over sites across Canada. 2007-09.

	Western Canada			*Eastern Canada*					
Cultivar	**W. Prairies**	**E. Prairies**	**Parkland**	**Ontario**	**Quebec**	**Maritimes**	**W. Canada**	**E. Canada**	**Overall**
5700PR (CPSR)	4925 cd [z]	4716 b [z]	5503 de [z]	2969 ab [z]	2921 b [z]	1957 bcd [z]	5156 d [z]	2776 c [z]	4544 f [w]
AC Andrew (CWSWS)	6075 a	5314 ab	6552 ab	3128 ab	3738 ab	1628 d	6126 a	3072 bc	5377 cd
AC Crystal (CPSR)	5041 bcd	4767 ab	5794 cde	2591 b	3370 b	1715 cd	5327 cd	2759 c	4709 f
AC Ultima (Triticale)	5950 a	5631 ab	6270 abc	3295 ab	3419 b	3505 a	6049 ab	3366 abc	5343 cd
Bhishaj (CWSWS)	5860 a	5214 ab	6399 abc	2860 ab	3230 b	1636 d	5665 ab	2836 c	5181 de
Hoffman (GP)	5692 ab	5665 ab	6843 a	3680 a	4738 a	2894 abc	6195 a	4016 a	5697 a
Pronghorn (Triticale)	6077 a	5725 a	6502 ab	3342 ab	4105 ab	3738 a	6211 a	3703 ab	5618 ab
Sadash (CWSWS)	6080 a	5233 ab	6856 a	2930 ab	3683 ab	2243 bcd	6230 a	3231 bc	5443 bc
Superb (CWRS)	4762 d	4718 b	5316 e	2875 ab	3385 b	1937 bcd	5025 d	2928 c	4546 f
Tyndal (Triticale)	5520 abc	5138 ab	6051 bcd	3265 ab	3452 b	2989 ab	5689 bc	3274 bc	5070 e
$LSD_{0.05}$	772	997	621	901	1237	1183	437	682	201
Class Comparisons									
Hard Red Spring Wheat[v]	5105	4967	5864	3029	3603	2126	5426	3120	4874
Soft White Spring Wheat	6005	5254	6602	2973	3550	1836	6107	3046	5334
Triticale	5849	5498	6275	3300	3659	3411	5983	3448	5344

[z] Values within columns followed by the same letter are not significantly different (P<0.05; Tukey-Kramer procedure).
[v] Hard red spring wheat mean is the aggregate mean of cultivars from the CPS, GP, and CWRS classes.
[w] Values within columns followed by the same letter are not significantly different (P<0.05; Bonferroni procedure).
Abbreviations: CPSR, Canada Prairie Spring Red; CWSWS, Canada Western Soft White Spring; GP, General Purpose.

Additional attributes of these two cultivars was low grain protein (Table 3) and starch and ethanol concentrations similar to the highest performing cultivars, which were usually CWSWS (Tables 4 and 5). However, test weight of all triticale cultivars was lower than the other classes, and pentosan levels were at times elevated (data not shown). Crop biomass and seed mass of the triticale cultivars was superior in all environments, but crop maturity was generally 1 – 2 d later than the other classes (data not shown). The overall performance of triticale was better in eastern Canada with the exception of ethanol in the Maritimes, however, the ethanol data is only based on 2007 and results could change once the full analysis is completed.

Table 3. Least square means for cultivar and wheat class grain protein concentration (%) averaged over sites across Canada. 2007-09.

	Western Canada			*Eastern Canada*					
Cultivar	**W. Prairies**	**E. Prairies**	**Parkland**	**Ontario**	**Quebec**	**Maritimes**	**W. Canada**	**E. Canada**	**Overall**
5700PR (CPSR)	14.7 b	14.1 b	13.4 b	13.5 ab	13.9 ab	13.7 b	13.9 b	13.7 b	13.9 b
AC Andrew (CWSWS)	13.3 cd	12.8 d	11.6 c	12.5 bcd	12.4 c	13.4 b	12.4 d	12.6 cd	12.5 d
AC Crystal (CPSR)	14.4 b	13.7 bc	13.0 b	12.8 bc	13.0 bc	13.6 b	13.5 b	13.0 bc	13.4 c
AC Ultima (Triticale)	11.0 f	10.7 g	10.1 ef	10.9 f	10.3 d	11.6 d	10.4 g	10.8 e	10.6 g
Bhishaj (CWSWS)	13.0 de	12.8 d	11.7 c	12.5 bcd	12.6 c	13.0 bc	12.3 d	12.6 cd	12.5 d
Hoffman (GP)	14.0 bc	12.9 cd	12.0 c	12.1 cdef	12.2 c	12.9 bc	12.8 c	12.2 d	12.7 d
Pronghorn (Triticale)	11.2 f	10.9 fg	9.9 f	11.0 ef	10.4 d	11.9 cd	10.5 g	10.9 e	10.6 g
Sadash (CWSWS)	12.4 e	12.3 de	10.9 d	12.3 bcde	12.2 c	12.7 bcd	11.7 e	12.3 cd	11.9 e
Superb (CWRS)	16.1 a	14.9 a	14.7 a	14.6 a	14.6 a	15.7 a	15.2 a	14.7 a	15.1 a
Tyndal (Triticale)	11.5 f	11.6 ef	10.5 de	11.5 def	10.7 d	12.2 cd	11.0 f	11.3 e	11.1 f
$LSD_{0.05}$	0.8	0.8	0.6	1.3	1.2	1.2	0.4	0.7	0.3
Class Comparisons									
Hard Red Spring Wheat[v]	14.8	13.9	13.3	13.3	13.4	14.0	13.9	13.4	13.8
Soft White Spring Wheat	12.9	12.6	11.4	12.4	12.4	13.0	12.1	12.5	12.3
Triticale	11.2	11.1	10.2	11.1	10.5	11.9	10.7	11.0	10.8

Table 4. Least square means for cultivar and wheat class starch concentration (%) averaged over sites across Canada. 2007-09.

	Western Canada			*Eastern Canada*					
Cultivar	**W. Prairies**	**E. Prairies**	**Parkland**	**Ontario**	**Quebec**	**Maritimes**	**W. Canada**	**E. Canada**	**Overall**
5700PR (CPSR)	58.7 ab	58.2 ab	58.7 ab	58.5	59.8 abc	59.4 ab	58.7 bcd	59.1 ab	58.9 ab
AC Andrew (CWSWS)	58.9 ab	59.6 ab	58.9 ab	57.0	59.6 abc	57.3 ab	60.0 ab	58.4 ab	59.2 ab
AC Crystal (CPSR)	58.5 ab	58.4 ab	58.5 ab	56.9	59.5 abc	58.0 ab	59.1 bc	58.1 ab	58.6 bc
AC Ultima (Triticale)	60.4 ab	59.6 ab	60.4 ab	58.2	60.8 abc	61.4 a	59.9 ab	59.7 a	59.6 ab
Bhishaj (CWSWS)	62.0 a	60.1 a	62.0 a	56.9	61.7 ab	59.1 ab	62.0 a	60.1 a	60.7 a
Hoffman (GP)	58.2 ab	57.4 ab	58.2 ab	58.5	62.6 a	58.8 ab	58.7 bcd	60.4 a	59.2 ab
Pronghorn (Triticale)	58.6 ab	57.9 ab	58.6 ab	59.3	61.1 abc	59.6 ab	58.9 bcd	60.0 a	59.2 ab
Sadash (CWSWS)	60.0 ab	59.5 ab	60.0 ab	57.9	62.4 a	59.7 ab	60.9 ab	60.3 a	60.6 ab
Superb (CWRS)	56.7 b	56.3 ab	56.7 b	55.8	58.7 bc	54.5 b	56.6 cd	56.9 b	56.7 cd
Tyndal (Triticale)	56.3 b	53.6 b	56.3 b	55.3	57.7 c	57.0 ab	56.1 d	56.4 b	56.1 d
$LSD_{0.05}$	4.7	6.2	4.7	4.2	3.5	5.5	2.8	2.7	2.2
Class Comparisons									
Hard Red Spring Wheat[v]	58	58	58.0	57.4	60.2	57.6	58.2	58.6	58.4
Soft White Spring Wheat	60.3	59.7	60.3	57.3	61.3	58.7	61.0	59.6	60.2
Triticale	58.5	57.0	58.5	57.6	59.9	59.3	58.3	58.7	58.3

Table 5. Least square means for cultivar and wheat class ethanol concentration (%) averaged over sites across Canada in 2007.

	Western Canada			*Eastern Canada*					
Cultivar	**W. Prairies**	**E. Prairies**	**Parkland**	**Ontario**	**Quebec**	**Maritimes**	**W. Canada**	**E. Canada**	**Overall**
5700PR (CPSR)	12.1 ab	12.0 ab	13.5 abc	12.6 abcd	12.5 cd	13.5 a	12.7 ab	12.7 abc	15.2 ab
AC Andrew (CWSWS)	11.4 bc	10.7 cd	13.9 a	11.8 d	13.4 ab	12.8 ab	12.3 abc	12.6 abc	14.9 bc
AC Crystal (CPSR)	11.7 ab	11.7 abc	14.0 a	12.3 bcd	13.1 abc	10.4 d	12.7 ab	12.4 abc	15.0 abc
AC Ultima (Triticale)	12.6 a	11.4 abc	13.3 abcd	12.8 abc	13.1 abc	10.4 d	12.7 ab	12.6 abc	15.0 abc
Bhishaj (CWSWS)	11.7 ab	11.5 abc	13.6 ab	13.4 a	13.6 a	11.3 cd	12.5 ab	13.1 a	15.1 abc
Hoffman (GP)	11.2 bc	11.3 bc	13.6 ab	12.4 bcd	13.5 a	12.9 ab	12.3 bc	12.9 ab	14.9 c
Pronghorn (Triticale)	12.1 ab	12.6 a	13.7 ab	13.1 ab	13.1 abc	10.6 d	12.9 a	12.7 abc	15.3 a
Sadash (CWSWS)	10.2 c	11.1 bcd	13.1 bcd	12.1 cd	12.7 bcd	11.7 bcd	11.7 cd	12.3 abc	14.5 d
Superb (CWRS)	11.0 bc	10.0 d	12.7 cd	11.8 d	12.5 cd	12.7 abc	11.5 d	12.2 bc	14.1 e
Tyndal (Triticale)	11.1 bc	11.1 bcd	12.6 d	12.4 bcd	12.2 d	11.2 d	11.7 cd	12.1 c	14.3 de
$LSD_{0.05}$	1.2	1.2	0.8	1.0	0.7	1.4	0.6	0.7	0.3
Class Comparisons									
Hard Red Spring Wheat[v]	11.5	11.3	13.4	12.3	12.9	12.4	12.3	12.6	14.8
Soft White Spring Wheat	11.1	11.1	13.5	12.4	13.2	11.9	12.2	12.7	14.8
Triticale	11.9	11.7	13.2	12.7	12.8	10.7	12.4	12.5	14.9

Conclusions

Results so far indicate that triticale has potential as an ethanol feedstock in most of agricultural regions of Canada; and Pronghorn or AC Ultima are better-suited for this end-use over Tyndal. These results will be validated in pilot scale runs at ethanol plants.

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