Improved Triticale Production through Breeding

Report prepared for the Co-operative Research Centre for High Integrity Australian Pork

By

Jeremy Roake and Richard Trethowan

Plant Breeding Institute, Cobbitty,
PMB 11, Camden, NSW, 2570

June 2013

An Australian Government Initiative

Established and supported under the Australian Government's Cooperative Research Centres Program

Executive Summary

Triticale is an important source of feed for the pork industry. This is attributed to the advantage of triticale in the growth of piglets when mixed in the diets, and the presence of both industries in the same location in southern New South Wales, Victoria, and South Australia, which reduces the cost of grain transport. Triticale can also be grown in the pork producing areas of Western Australia.

Triticale is on average 10% higher yielding than wheat, and is much more tolerant to abiotic stresses. These include low pH soils (4.0-4.5) which are high in aluminium, high boron soils, and soils low in zinc and copper.

The project had two aims. These were:

1) To evaluate hybrid triticales produced from the previous project
2) To evaluate inbred varieties to identify higher yielding, triple rust resistant lines.

The hybrids did not express sufficient heterosis to justify commercial production. Though heterosis levels were 10-20% higher than the old variety Tahara, they were similar or lower than the current top inbred varieties. This was thought to be due to the low levels of diversity present in the triticale germplasm pool.

Three inbred lines, ISR936-144, ISR936-263, and ISR936-269 were identified as possible candidate lines for release. Each line had high yield and resistance to stem, leaf, and stripe rust. On the basis of results from multi-location trials conducted by AGT, it was decided to increase ISR936-263 as it performed best at evaluation sites in New South Wales, Victoria, and South Australia. The grain quality of the three lines when compared to Berkshire, were equivalent or better for both faecal and ileal digestibility, % starch, Englyst neutral detergent fibre, and insoluble and soluble non-starch polysaccharides. This line is currently being evaluated in the National Variety Trials in 2013 across these three states. The line is also being increased for possible commercial release in 2015.

The release of a new high yielding, triple rust resistant line will improve the productivity of triticale in areas relevant to the pork industry. This will increase economic returns to grain producers and improve the reliability of supply of triticale to the pork industry.

Table of Contents

1. Introduction

Background and rationale for conducting the research

Triticale (*X Titicosecale* (Witmack)) is an intergeneric hybrid cereal, produced from combining durum wheat (*Triticum durum*) and cereal rye (*Secale cereale*). The hybrid combines the hardy features of rye with wheat. This makes the plant more tolerant of abiotic stresses when compared to wheat. These include tolerance to highly acid soils with high exchangeable aluminium (pH 4.0- 4.5, 15% aluminium), boron tolerance, high pH soils, and soils low in zinc or copper. Its yield is 10% higher than wheat in most years. These features, combined with low transport costs to local producers, make it a profitable option comparable to wheat.

The main diseases of triticale are the three cereal rusts; stem rust (*Puccinia graminis* var. *tritici*), leaf rust (*P. triticiana*), and stripe rust (*P. striiformis* f.sp. *tritici*). The most important of these in Australia is stripe rust. The exotic introduction in Western Australia in 2002 of a new stripe rust pathotype (WA pathotype) has had a major impact on triticale. The WA pathotype was later detected in eastern Australia in 2003. The original pathotype was virulent to a major gene in triticale, Yr 9, which had an impact on varieties protected only by this gene. In 2006, a new virulence appeared on the triticale variety Jackie (WA J+), which increased rusting on a number of varieties, including Berkshire. The WA J+ pathotype underwent two further separate changes; the first on the variety Tobruk, where the adult plant gene was overcome, and the second for a wheat gene, Yr 27, which further increased the rusting of the old spring variety Tahara. The search for new rust resistant germplasm lines became an important aim in triticale breeding.

The main production areas of triticale in Australia are the southern NSW slopes between Albury and Young, and the cereal growing areas of Victoria and South Australia. Between 600,000 and 700,000 tons of grain are produced annually. The grain is used in the animal feed industries, especially the pork and dairy industries, which are located in these areas.

The key deliverable in Subprogram 1A ”Innovative Grain production” to be addressed by this application is “Commercial quantities of cereals (triticale and barley) and pulses (peas and lupins) that grow close to pig-producing regions, and have a high yield, cost-effective agronomy and acceptable nutritional characteristics for pigs”.

This project aimed to produce triticale varieties with increased grain yield and consistent and/or higher energy for pigs, as well as resistance to the major diseases of triticale; stem, leaf, and stripe rust. Lines with improved metabolisable energy and/or lower levels of fibre could lead to improved food conversion efficiency (FCE), and thus a reduction in the cost of feed in pig diets. The project also aims to grow more triticale in pig producing areas.

2. Methodology

The previous project identified two lines with higher yield and improved DE for pigs. One of these lines, Berkshire (JRCT74), was released to growers in 2009. The other line, JRCT101, was released to growers in 2011. JRCT74 was also identified as a maintainer or "B" line for hybrid seed production, and backcrossing was used to produce the corresponding male sterile "A" line.

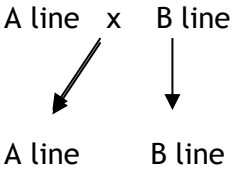
The project was comprised of two complementary components: the concurrent development of F1 hybrids and high yielding inbred lines suitable for release.

The two aims work together in that the new inbred lines can be used in the hybrid program as either restorers or maintainers.

1) Development of Hybrids

The hybrid system used was the cytoplasmic male sterile system. This system involves the use of a different cytoplasm to induce male sterility in certain genotypes of the species.

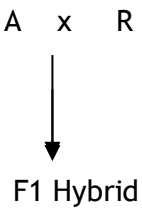
In the case of triticale, the cytoplasm of *Triticum timopheevii was* used to induce male sterility in certain genotypes. The male sterile line is denoted as the 'A' line. The 'A' line is crossed to the isogenic maintainer (or non-restorer) line to maintain and increase seed. These materials have normal triticale cytoplasm and are therefore fertile and are called 'B' lines.



This process can be repeated every generation.

New maintainers were found by crossing to the male sterile line and observing if the next generation is male sterile or not.

The next step was to find lines that restore fertility and also express high heterosis. This was achieved by simply crossing restorer lines ('R' lines) to the 'A' line.



The initial hybrids were based on Berkshire (as the male sterile 'A' line) as it was a high yielding genotype and also a maintainer. Lines identified as high yielding with good levels of heterosis in previous experiments and disease resistance were

used as restorer parents to produce F1 hybrid seed. These were then yield tested initially at 3 sites.

The establishment of a new National Triticale Program allowed new top performing lines to be evaluated in AGT's yield trials at their cost, thus project outputs were tested in SA close to pork production areas. The aim was to identify a restorer in combination with the male sterile Berkshire suitable for commercial hybrid seed production.

2) The development of new inbred lines.

This work is based on materials partially developed in the previous project. The breeding process began with crosses among parental lines that represented the genetic variability desired in the new variety. This included high yield, disease resistance and high DE values. These crosses were made in the field and the F1's advanced in the greenhouse over summer. The F2 generation was space planted in the field in large populations in the following winter and the nurseries were inoculated with rust. Selected plants were bulked and sown in large plots in the following season and individual plants again selected. The process continued until the F4 generation when individual plants were maintained in discrete plots. The selected plots, based on visual selection for agronomic type, disease resistance, flowering time, plant height and DE measured using NIR were harvested and tested in preliminary yield testing at one site in the following year. The highest yielding lines were than tested at 3 sites in stage 2 trials and at 6 sites in the stage 3 trials. Potential lines for release were then identified using yield and yield stability in multilocational trials, disease scores and DE.
The triticale breeding program at Sydney University has released 6 triticale varieties over the last 9 years, and has an active dual-purpose program.

The PBI supplied glasshouse and field facilities at both Cobbitty and Narrabri. Trials in central and southern NSW were contracted to NSW DPI who are experienced at conducting yield trials. Stage 2 trials were conducted at 2 or 3 sites in NSW. NSW DPI currently runs the National Variety Trials for a number of crops throughout the state in addition to breeder selection trials. They have a number of mobile units throughout the state and linkage to most areas through their district agronomists. Entries have been placed in irrigation trials sponsored by GRDC run by NSW DPI around these areas over recent years. In addition, the top yielding lines produced by this Program were evaluated in South Australia by AGT as part of their commitment to the National Triticale Program. Those trials conducted at Camden and in the Narrabri region (where irrigation is available) were managed by the University. There were additional trial sites for stage 3 trials; one in South Australia and one in Victoria in proximity to the pig industry. These trials commenced in 2010. Potential varieties were then tested in the NVT network once they are two years from release (as stated in NVT rules).

All new varieties are marketed through the network of the Pork CRC, and Waratah Seeds who will produce and commercialize the seed.

3. Outcomes

1) Hybrid Triticale Results

The hybrid lines TCLHY89 (ms M116/JRCT117) and TCLHY94 (msM119/JRCT336) were the two best performers over 2 sites and 2 years, being 11.8% and 9.8% higher yielding than Tahara, respectively (see Table 1). The hybrid lines made with Berkshire as the female, TCLHY104 (male: JRCT336) and TCLHY99 (male: JRCT117) were respectively 19.1% and 9.7% higher yielding than Tahara in 2010, and were the best performing of the Berkshire based hybrids in both trials. TCLHY89 was 28.8 % higher yielding than Tahara in the 2010 trials. Thus, it can be concluded that the best hybrid combinations occur among the more divergent germplasm, as the M116 male sterile comes from a winter germplasm pool, whereas the Berkshire male sterile originates from the same gene pool as the restorers (the CIMMYT gene pool) where it is more difficult to find genetically divergent germplasm.

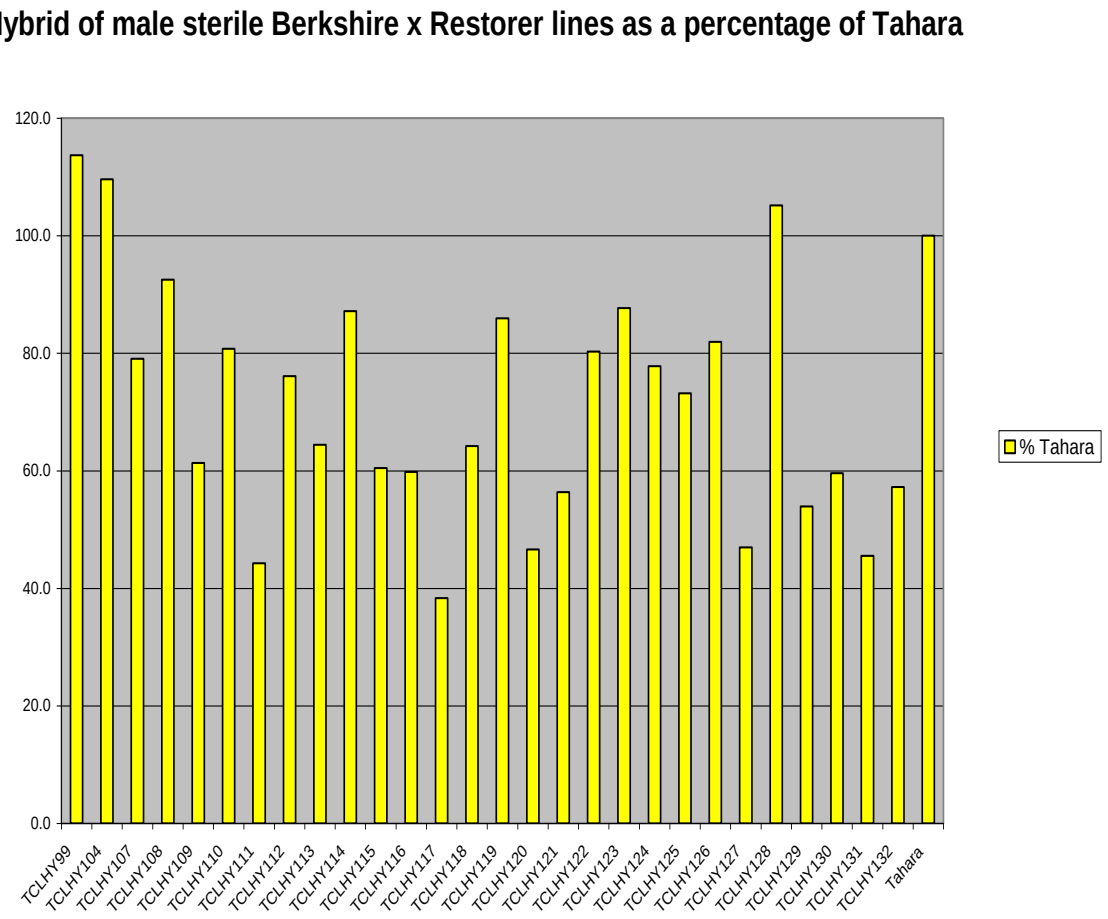
These results indicate that it is better to produce triticale hybrids using the winter germplasm pool as the maintainer and the spring germplasm as restorers.

A yield trial at Cowra with male sterile (ms) Berkshire was conducted in 2011. The hybrids based on an msBerkshire are shown in the graph below. Only 3 hybrids with msBerkshire had higher or equivalent yield to Tahara, the rest being much lower in yield. This was due to either low heterosis or partial male sterility. The highest yielding lines were again based on the restorer (male) lines JRCT117 (TCLHY99 – 113%) and JRCT336 (TClHY-104 – 109%). These were the same male parents that produced the highest yielding lines when combined with the other high yielding msM116 line (Table 1). The only line that had reasonable yield was the male line ISR936-300 (TCLHY-128 – 105%).

Table 1: Summary of Triticale yield trials at Cowra (TFA09COWA & TFA10COWA) and Gerogery (TFA09GERO & TFA10GERO) in 2009 and 2010.

	TFA09COWA				TFA09GERO			TFA10GERO			TFA10COWA				
ID	Grain Yield T/Ha	% Trial mean	% Tahara	Rank	Grain Yield T/Ha	% Tahara	Rank	Grain Yield T/Ha	Rank	% Tahara	Grain Yield T/Ha	Rank	% Tahara	% Tahara 2 years, 2 sites	% Tahara 2 sites 2010
TCLHY89	1.89	107.8	110.1	27	2.86	79.6	25	6.20	1	131.0	7.25	5	126.6	111.8	128.8
JRCT117	2.07	118.1	120.6	17	3.10	86.4	15	4.99	25	105.4	7.94	1	138.5	112.7	122.0
JRCT336	1.92	109.5	111.9	24	1.99	55.4	51	5.85	5	123.7	6.62	14	115.6	101.6	119.6
JAYWICK	2.27	129.3	132.0	10	3.78	105.2	6	5.67	10	119.7	6.84	10	119.5	119.1	119.6
TCLHY104								5.87	3	124.0	6.60	15	115.1		119.6
CANOBOLAS	2.51	143.4	146.4	5	3.38	94.1	13	5.75	8	121.6	6.68	12	116.6	119.7	119.1
HAWKEYE	2.69	153.4	156.7	2	4.03	112.1	3	5.30	16	112.0	7.16	8	124.9	126.4	118.5
TCLHY94	2.27	129.6	132.3	9	2.98	82.9	18	5.65	11	119.5	6.00	29	104.6	109.8	112.1
M116	2.01	114.8	117.2	18	2.23	62.2	41	5.39	13	113.9	6.13	27	107.0	100.1	110.4
TCLHY99								4.97	26	105.1	6.56	17	114.4		109.7
BERKSHIRE	2.29	130.7	133.4	8	3.98	110.8	5	5.01	24	105.9	6.38	19	111.4	115.4	108.6
TAHARA	1.72	97.9	100.0	36	3.59	100.0	9	4.73	33	100.0	5.73	35	100.0	100.0	100.0

Note: triticale hybrids denoted by green highlight, female denoted by pink, and male denoted by blue.



2) Yield of Inbred Lines

The yield results of inbred lines tested in 2011 are presented in Table 2. The highest yielding lines over the 3 NSW sites with resistance to stem, leaf and stripe rust, were ISR936-263 (11.1% higher yielding than Tahara), ISR936-144 (15.6% higher yielding than Tahara), and ISR 936-269 (20% higher yielding than Tahara). These inbred lines were equivalent or better than the other higher yielding varieties in these trials (Bogong, Hawkeye, Jaywick, Canobolas, and Berkshire).

The three lines, ISR936-144, ISR936-263, and ISR936-269, were included in the AGT stage 2 trials in 2012, the results for each state are shown in Tables 3, 4, and 5. The line ISR936-263 was the most consistent performer across sites, yielding 98.4%, 104%, and 100.4% of Hawkeye in NSW, Victoria, and South Australia trials, respectively.

A small seed increase of ISR936-263 yielded 45 kg of clean seed, of which 35 kg is currently being increased at Wagga Wagga under irrigation. This line was also entered into the triticale National Variety Testing scheme, and stage 2 AGT trials.

Table 2. Yield Trial Results of Inbred Lines tested at 3 Sites in NSW in 2011.

ID	TMA11COWA Grain Yield (t/ha)	Rank	% Tahara	TMA11GERO Grain Yield (t/ha)	Rank	% Tahara	TFA11TEMO Grain Yield (t/ha)	Rank	% Tahara	%Tahara 3 Sites
ISR936-269	4.825	1	138.1	6.62	11	110.6	4.48	24	111.3	120.0
JRCT117	4.22	7	120.7	6.922	1	115.7	4.863	3	120.8	119.1
ISR936-132	4.48	2	128.2	5.96	59	99.6	4.847	4	120.4	116.1
ISR936-144	4.4	3	125.9	6.45	21	107.8	4.548	18	113.0	115.6
ISR936-360	4.365	5	124.9	6.158	42	102.9	4.545	19	112.9	113.6
ISR936-63	3.931	20	112.5	6.573	13	109.9	4.577	17	113.7	112.0
ISR936-4	4.153	9	118.8	6.717	9	112.3	4.215	58	104.7	111.9
ISR936-389	3.928	22	112.4	6.822	5	114.0	4.37	38	108.6	111.7
ISR936-146	3.704	49	106.0	6.84	4	114.3	4.611	16	114.6	111.6
ISR936-226	3.926	23	112.3	6.346	29	106.1	4.639	13	115.3	111.2
ISR936-263	4.288	6	122.7	6.025	53	100.7	4.421	34	109.8	111.1
Berkshire	3.773	41	108.0	6.059	50	101.3	4.941	1	122.8	110.7
ISR936-262	3.929	21	112.4	6.659	10	111.3	4.338	44	107.8	110.5
ISR936-158	3.582	61	102.5	6.388	26	106.8	4.907	2	121.9	110.4
ISR936-279	3.739	42	107.0	6.329	32	105.8	4.753	8	118.1	110.3
ISR936-255	3.899	27	111.6	6.324	34	105.7	4.533	21	112.6	110.0
ISR936-390	3.976	15	113.8	6.438	22	107.6	4.354	39	108.2	109.8
ISR936-281	3.813	37	109.1	6.59	12	110.1	4.428	31	110.0	109.8
ISR936-345	4.191	8	119.9	5.624	79	94.0	4.641	12	115.3	109.7
ISR936-185	3.873	28	110.8	6.062	49	101.3	4.712	9	117.1	109.7
ISR936-165	3.923	24	112.2	6.103	47	102.0	4.612	15	114.6	109.6
ISR936-207	3.95	19	113.0	6.246	36	104.4	4.459	27	110.8	109.4
ISR936-161	3.56	62	101.9	6.359	28	106.3	4.769	7	118.5	108.9
ISR936-395	3.666	52	104.9	6.783	6	113.4	4.35	40	108.1	108.8
ISR936-387	3.519	66	100.7	6.545	17	109.4	4.679	11	116.2	108.8
ISR936-291	3.653	53	104.5	6.906	2	115.4	4.241	57	105.4	108.4
ISR936-253	4.079	12	116.7	5.803	71	97.0	4.489	22	111.5	108.4
ISR936-359	3.632	55	103.9	6.136	46	102.6	4.778	6	118.7	108.4
Jaywick	3.979	14	113.8	6.174	39	103.2	4.34	43	107.8	108.3
Bogong	3.468	72	99.2	6.757	7	112.9	4.281	48	106.4	106.2
ISR936-367	3.719	46	106.4	6.568	14	109.8	4.116	63	102.3	106.1
ISR936-74	3.824	35	109.4	6.2	38	103.6	4.211	59	104.6	105.9
ISR936-203	3.624	57	103.7	6.435	23	107.6	4.269	52	106.1	105.8
ISR936-178	3.46	73	99.0	6.377	27	106.6	4.478	25	111.3	105.6
ISR936-16	3.475	70	99.4	5.867	67	98.1	4.798	5	119.2	105.6
Canoboals	3.917	25	112.1	5.633	78	94.2	4.446	29	110.5	105.6
ISR936-355	3.839	32	109.8	5.964	55	99.7	4.275	51	106.2	105.2
ISR936-376	3.868	29	110.7	5.666	77	94.7	4.434	30	110.2	105.2
ISR936-388	3.442	75	98.5	6.554	16	109.5	4.266	54	106.0	104.7
ISR936-68	3.739	43	107.0	5.457	86	91.2	4.621	14	114.8	104.3
ISR936-15	3.705	48	106.0	5.768	73	96.4	4.423	33	109.9	104.1
Hawkeye	3.799	39	108.7	5.562	84	93.0	4.427	32	110.0	103.9
Tahara	3.495	69	100.0	5.983	54	100.0	4.025	68	100.0	100

Table 3. AGT stage 2 triticale yield trials for New South Wales in 2012.

Name	Grenfell Yield (kg/ha)	% Hawkeye	Gerogery Yield (kg/ha)	% Hawkeye	Wagga Yield (kg/ha)	% Hawkeye	% Hawkeye all NSW sites
ENDEAVOUR	2820.6	80.1	5202.5	90.2	3254	95.4	88.6
HAWKEYE	3519.7	100.0	5769.3	100.0	3410.4	100.0	100.0
TOBRUK	2970.1	84.4	5910	102.4	3368.4	98.8	95.2
BERKSHIRE	3473	98.7	5697.9	98.8	3363.6	98.6	98.7
JAYWICK	3342.1	95.0	5593.8	97.0	3355.9	98.4	96.8
ISR936-144	3362.9	95.5	5750.8	99.7	3357.8	98.5	97.9
ISR936-263	3420.7	97.2	5744	99.6	3354.7	98.4	98.4
ISR936-269	3334.6	94.7	5721.9	99.2	3359.6	98.5	97.5
RUFUS	3173.7	90.2	5469.3	94.8	3224.2	94.5	93.2
CHOPPER	3306.9	94.0	5525.7	95.8	3300.2	96.8	95.5
BOGONG	3280.8	93.2	5947.5	103.1	3442.3	100.9	99.1

Table 4. AGT stage 2 triticale yield trials for Victoria in 2012.

Name	Elmore, Bendigo, Vic. **Yield (kg/ha)**	% Hawkeye
ENDEAVOUR	3055.3	86.0
HAWKEYE	3554.4	100.0
TOBRUK	3590.1	101.0
BERKSHIRE	3721.6	104.7
JAYWICK	3421.1	96.2
ISR936-144	3606	101.5
ISR936-263	3696.5	104.0
ISR936-269	3437.3	96.7
RUFUS	3374.3	94.9
CHOPPER	3498.6	98.4
BOGONG	3692.7	103.9

Table 5. AGT stage 2 triticale yield trials for South Australia in 2012.

Name	Angus Valley Yield (kg/ha)	% Hawkeye	Cummins Yield (kg/ha)	% Hawkeye	Pinaroo Yield (kg/ha)	% Hawkeye	Roseworthy Yield (kg/ha)	% Hawkeye	% Hawkeye all sites S.A.
ENDEAVOUR	1772.1	74.5	2818.9	92.3	1049	76.7	2787.8	74.0	79.4
HAWKEYE	2378.4	100.0	3055.3	100.0	1367.5	100.0	3765.8	100.0	100.0
TOBRUK	1775.2	74.6	2640.4	86.4	1090.1	79.7	2871.1	76.2	79.3
BERKSHIRE	2497.5	105.0	3153.2	103.2	1347.1	98.5	3568.2	94.8	100.4
JAYWICK	2471.4	103.9	2719.6	89.0	1329.2	97.2	3717.1	98.7	97.2
ISR936-144	2297.7	96.6	2921.8	95.6	1334.8	97.6	3453.1	91.7	95.4
ISR936-263	2565.8	107.9	2907.3	95.2	1374.7	100.5	3698.6	98.2	100.4
ISR936-269	2537.6	106.7	2658.6	87.0	1282.2	93.8	3600.8	95.6	95.8
RUFUS	2357	99.1	2970.1	97.2	1226.4	89.7	3296.5	87.5	93.4
CHOPPER	2778.1	116.8	2625.4	85.9	1453	106.3	4006.4	106.4	103.8
BOGONG	2428.1	102.1	3254.8	106.5	1465.5	107.2	3454	91.7	101.9

3) Feed Grain Quality of New Inbred Lines ISR809-144, ISR809-263, and ISR809-269.

The faecal digestible energy (DE) and the amount of energy are shown in Table 6, and the ileal DE in Table 7. The three new inbred lines are equivalent or better than Berkshire for faecal and ileal DE. ISR936-144 had significant higher faecal DE than Berkshire at both sites, and all three lines were significantly better than Berkshire at Gerogery. When compared to Canobolas, all three lines were not significantly different for faecal DE except ISR809-269 at Temora which had a lower DE. Ileal DE for the three lines when compared to Canobolas were non-significant at Gerogery, but significantly lower at Temora. These three new inbred lines are at least as good as Berkshire or better for both faecal and ileal DE.

Total starch was the same for the three inbred lines at Temora when compared to Berkshire, but significantly higher at Gerogery, whereas Englyst NDF was the same at both sites, except for ISR9336-144 at Gerogery where it was significantly lower (Table 8). The insoluble non-starch polysaccharides (NSPs) were the same as Berkshire for ISR809-263 and ISR809-269, but significantly less at both sites for ISR809-144, whereas there was no difference for soluble NSPs (Table 9). The chemical grain quality characteristics are the same or better for the three lines when compared to Berkshire.

Table 6. Yield, faecal digestible energy and energy/ha of the selected triticale inbred lines compared to triticale varieties.

Line	TFA11TEMA Yield (t/ha)	TFA11GERO Yield (t/ha)	TFA11TEMA Faecal DE (af) (MJ/kg)	TFA11GERO Faecal DE (af) (MJ/kg)	Average	TFA11TEMA Energy (GJ/ha)	TFA11GERO Energy (GJ/ha)
Berkshire	6.06	4.94	13.74	13.26	13.50	83241	65500
Bogong	6.76	4.28	13.79	13.44*[1]	13.61	93170	57525
Canoboals	5.63	4.45	13.87	13.36*	13.61	78103	59416
Hawkeye	5.56	4.43	13.60	13.19	13.40	75662	58389
ISR936-144	6.45	4.55	13.96*	13.36*	13.66	90056	60768
ISR936-263	6.03	4.42	13.81	13.38*	13.60	83200	59158
ISR936-269	6.62	4.48	13.72	13.39*	13.56	90824	59992
Jaywick	6.17	4.34	13.65	13.32	13.48	84245	57812
Tahara	5.98	4.03	13.72	13.26	13.49	82109	53361
lsd (0.05)			0.13	0.09			

1- * indicates significantly different at 5% level of significance to Berkshire

Table 7. Ileal digestible energy of the selected triticale inbred lines compared to triticale varieties.

Line	TFA11TEMA Ileal DE (af) (MJ/kg)	TFA11GERO Ileal DE (af) (MJ/kg)	Average
Berkshire	12.02	11.67	11.85
Bogong	11.91	12.24	12.08
Canoboals	12.23*[1]	11.75	11.99
Hawkeye	11.79	11.52	11.65
ISR936-144	12.10	11.68	11.89
ISR936-263	12.04	11.84	11.94
ISR936-269	11.86	11.73	11.79
Jaywick	11.91	11.81	11.86
Tahara	12.08	11.81	11.94
lsd (0.05)	0.15	0.18	

1- * indicates significantly different at 5% level of significance to Berkshire

Table 8. Total starch and Englyst neutral detergent fibre of the selected triticale inbred lines compared to triticale varieties.

Line	TFA11TEMA Total Starch (%dm)	TFA11GERO Total Starch (%dm)	Average	TFA11TEMA Englyst NDF (%dm)	TFA11GERO Englyst NDF (%dm)	Average
Berkshire	60.00	63.62	61.81	16.31	16.88	16.59
Bogong	58.97	67.50*	63.24	16.77	16.23*	16.50
Canoboals	59.38	63.30	61.34	15.32*	17.24	16.28
Hawkeye	60.72	63.84	62.28	16.82	17.79	17.31
ISR936-144	61.94	67.57*	64.76	15.63	15.77*	15.70
ISR936-263	59.47	67.40*	63.44	16.08	16.55	16.32
ISR936-269	61.69	67.06*	64.38	16.30	16.63	16.46
Jaywick	62.92*[1]	66.73*	64.83	17.56*	16.93	17.25
Tahara	61.24	66.37*	63.80	16.20	16.56	16.38
lsd (0.05)	2.48	1.43		0.72	0.44	

1- * indicates significantly different at 5% level of significance to Berkshire

Table 9. Insoluble and soluble non-starch polysaccarides (NSP) of the selected triticale inbred lines compared to triticale varieties.

Line	TFA11TEMA Insoluble NSP (%dm)	TFA11GERO Insoluble NSP (%dm)	Average	TFA11TEMA Soluble NSP (%dm)	TFA11GERO Soluble NSP (%dm)	Average
Berkshire	8.12	8.34	8.23	1.99	1.86	1.92
Bogong	7.46	7.77	7.62	2.05	2.00	2.03
Canoboals	8.18	8.05	8.12	1.59*	1.98	1.78
Hawkeye	7.99	8.38	8.19	2.32*	2.28	2.30
ISR936-144	5.93*[1]	7.22*	6.57	2.21	2.16	2.18
ISR936-263	8.01	8.09	8.05	1.86	2.08	1.97
ISR936-269	7.89	8.23	8.06	2.09	1.95	2.02
Jaywick	7.81	7.28*	7.55	2.45*	2.23	2.34
Tahara	8.04	8.76	8.40	2.08	2.14	2.11
lsd (0.05)	1.00	0.88		0.28	0.25	

1- * indicates significantly different at 5% level of significance to Berkshire

4. Application of Research

Application of the research findings in the commercial world

The line ISR936-263 will be available for commercial release in 2015. This will depend upon;

1) A successful increase in 2013. As it is sown under irrigation, only an adverse weather event (hail, rain at harvest) will hold up production.
2) Additional yield results from the NVT trials and AGT trials that show the line is competitive with other spring triticales.

Commercialization/Adoption Strategies

- **Potential benefits to cost of production**

The line ISR936-263 is a high yielding, triple rust resistant line. It is a moderately tall triticale with good lodging resistance (it doesn't fall over under high yields). These traits will improve grain productivity and hence grain producer profits. Rust resistance, especially for stripe rust, will eliminate the need for fungicide application. The grain quality characteristics for digestible energy strongly suggest that this line is the same or slightly better than Berkshire.

The improved productivity for grain producers will benefit pig producers, as there will be a more reliable supply of triticale grain with high levels of digestible energy. This will help maintain grain prices at sustainable levels and improve productivity.

- Ease of adoption by producers

Adoption will be determined by the grain growers and pig producers. The adoption by grain growers will be determined by the crop productivity and price received. The production of triticale is influence by the price of feed grains, as well as the price of wheat and malting barley. Growers will grow the crop that will give them the best gross margin. The high yield and rust resistance, combined with the high digestible energy of the line, could help create supply from grain producers, and demand from pig producers.

The adoption by pig producers will be determined by the relative value of the grain to the production of pigs and ease of access to supply.

- Impact of the research

A new spring triticale variety, with high yield and resistance to the rusts, especially stripe rust, will ensure grain grower access to another highly productive triticale in the market. Pig producers will benefit from the increased supply of high value energy grain for feeding.

5. Conclusion

The heterosis present in triticale is below the level needed to commercially develop hybrids. When compared to the highest yielding inbred varieties, there is no real difference between the hybrids and inbred varieties over years. In some cases, the hydrid had equivalent yield to the male restorer line. The solution lies in the development of distinct heterotic gene pools; similar to the strategy used by maize breeders. However, the establishment of heterotic pools is time consuming and expensive and would take at least 10-years or more. Nevertheless, if these heterotic pools could be developed then hybrid yields greater than 15% compared to the best inbred lines could be realized.

The spring inbred line ISR936-263 was identified for potential release. It has yield equivalent to the variety Hawkeye, and has resistance to stem, leaf, and stripe rust; the resistance to stripe rust being particularly significant. It also has high levels of digestible energy that are equivalent or better than Berkshire.

6. Limitations/Risks

There are two risks associated with advancing the release of ISR936-263, these are:

1) The appearance of a new pathotype of rust, especially stripe rust, that overcomes the resistance before the variety is widely adopted by grain producers thus limiting supply to pig producers
2) Another triticale variety that is significantly higher yielding is released or introduced to Australia.

7. Recommendations

As a result of the outcomes in this study the following recommendations are made:

1. The decision on the final seed increase and subsequent release of line ISR936-263 should be based on yield, disease resistance and pig faecal DE results obtained from the 2013 triticale NVT trials. These results will be available from February 2014 from the NVT website.
2. Hybrid triticale breeding should be discontinued until sufficient resources are made available to develop the heterotic gene pools required to produce commercially viable levels of heterosis
3. If triticale is to be used routinely by pig producers as an industry staple feed, then continued access to new rust resistant cultivars will be essential as virulence patterns in the rust fungi constantly change.