Improved Triticale Production through breeding and agronomy

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Report prepared for the Co-operative Research Centre for an Internationally Competitive Pork Industry

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Executive Summary

Triticale has become an important feed grain for pig diets. This project aimed to increase the value and supply of triticale to the pork industry through plant breeding and improved agronomy.

Plant breeding offers the opportunity to select for improved grain yield and exploit the genetic variability of feed grain quality to increase the digestible energy (DE) of the grain. Both conventional inbred breeding techniques and the development of triticale hybrids were used to increase grain yield and quality.

Grain growers of triticale often achieve below par yields, despite evidence that triticale can achieve yields equivalent or better than that of wheat, particularly in hostile soils (e.g. acid soils). The agronomic requirement of triticale has been addressed through the preparation of a management booklet informing growers of ways to optimize grain production. This information is based upon a review of the literature, a survey of triticale growers and anecdotal information from growers, agronomists and researchers

A new triticale variety, *Berkshire*, was released in 2009. In National Variety Yield Trials for NSW and northern Victoria in 2007 and 2008, *Berkshire* was 16% higher yielding than the standard variety *Tahara*. Compared to benchmark triticale varieties, the ileal DE and faecal DE of *Berkshire* was 0.71 MJ/kg and 0.25 MJ/kg greater, respectively.

For the development of hybrid triticale, a high yielding maintainer line (female line) was identified, being the variety *Berkshire*. In subsequent projects, this will be used to cross to restorers (the male line) to produce hybrids for yield testing to find combinations with heterosis (higher yield) compared to current varieties.

The main recommendation from the agronomy package is that grain growers should optimize the fertilizer requirements for triticale, especially nitrogen to achieve satisfactory yields. Grain growers should aim for 11.5% grain protein, to ensure optimum yields are being achieved. This would increase the gross margins, and help increase triticale production. This will be communicated to growers and agronomists through the release of a small booklet on the agronomy for triticale.

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1. Introduction

Triticale, being a relatively young crop, has great potential for increasing yield and quality through plant breeding and agronomy. There is great potential to find quality traits specific to pork production, and to significantly increase yields through the development of hybrid triticale. Triticale grain use for pork production has expanded in recent years, but grain producer knowledge of how to regularly grow high yielding uniform protein grain is poorly developed. Whilst new varieties have been introduced in the last five years, there is a need to develop a production package which provides growers with decision support information concerning management options for time of sowing, fertiliser usage and plant protection.

The key aims of this program are to:

1) Deliver new high yielding rust resistant cultivars which meet the quality needs of the pork industry using rapid breeding methodologies

2) To produce a technical booklet covering all issues of triticale growth and management to yield grain which optimizes pork production

2. Methodology

1) Release of Improved Inbred Lines

Inbred spring triticale lines were yield tested over multiple sites over years, and also screened for resistance to stem, leaf and stripe rust. These lines were also screened for the quality traits for pigs using the NIR calibrations that were developed by the Premium Grains for Livestock Program

2) Development of Hybrid Triticale

Selected spring triticale lines that were high yielding (in normal wheat (*Triticum aestivum)* cytoplasm) were crossed to a male sterile triticale (in *T. timophevvi* cytoplasm). The F1 hybrids were yield tested at Cowra and assessed for their ability to restore fertility or were male sterile.

Lines that were high yielding and male sterile were backcrossed 4 times to the male sterile line to start producing the male sterile near isogenic line.

F 1 lines were produced to create new maintainers by double haploid using microspore culture, as means to rapid identification of maintainers from resulting progeny

3) Improved Agronomy

a) Initially, yield trials conducted by NSW Department of Industry and Investment were collected on current varieties to determine the best varieties to examine in field trials. In addition there were discussions with end users (such as Rivalea) and grain nutrition experts to ascertain their main issues which need changes for a better pork production grain

b) The best varieties were tested at representative growing sites for triticale with emphasis on their yield response to applied nitrogen, sowing rate, and time of sowing

c) Using all available data from other sources, the above experiments, together with a survey to farmers, a detailed publication has been produced for growers of triticale and their agronomy advisors to improve its production for pork producers (Appendix 1).

3. Outcomes

1) Release of Improved Varieties

The lines JRCT74 and *JRCT101* (now renamed *JRCT400*) were identified as having high yield, acceptable rust resistance, and high energy for pigs. JRCT74 was released as the commercial variety *Berkshire* in 2009 and the further improved line, *JRCT101*, is likely to be commercialised in 2011.

Berkshire was 16% higher yielding than *Tahara* in 10 National Variety Trials in 2007 and 2008 in southern NSW and northern Victoria. The faecal DE was 14.3 and 14.2 MJ/kg compared to *Tahara*'s value of 14.1 and 13.9 MJ/kg at Cowra in 2005 and 2006, respectively and the ileal DE was 12.7 MJ/kg compared to that of *Tahara*, being 12.0 at Cowra 2006 (see Tables 1 and 2). The starch content is 1% higher than *Tahara*, and all the fibre figures are lower.

JRCT101 was 20% higher yielding than *Tahara* in the 2 trials. In addition, *JRCT101* had the 2nd highest faecal DE in these two trials, being 14.6 and 14.4 MJ/kg, respectively, and the highest ileal DE of 13.08 MJ/kg, being higher than *Tahara* and, to a lesser extent, *Berkshire* (Tables 1 and 2). *JRCT101* had the highest starch content, and the lowest fibre content of the lines tested (Table 2).

Table 1. Cowra 2005 – Feed Quality Data from NIR

VARIETY	*Pig FDE (MJ/kg as fed)*	*Rnk*	*Pig I/F DE ratio*	*Rnk*	*Crude Protein %DM*	*Rnk*
JRCT-101	14.55	2	0.875	1	12.2	47
BERKSHIRE	14.25	8	0.852	28	12.2	43
TAHARA	14.12	17	0.856	17	12.7	28
KOSCIUSKO	13.81	47	0.852	26	12.4	36

Table 2. Cowra 2006 – Feed Quality Data from NIR

	Pig FDE (MJ/kg as fed)	*Rank*	*Pig Ileal DE*	*Rnk*	*Starch_DM[1]*	*Rnk*	*CF[2]*	
JRCT101	14.45	2	13.08	1	63.08	2	3.31	1
BERKSHIRE	14.21	7	12.72	4	61.41	18	3.62	13
KOSCIUSKO	13.93	51	12.06	51	60.31	69	3.76	33
TAHARA	13.87	77	12.01	57	60.38	65	3.78	40

1 – Total starch dry matter
2- Average crude fibre

2) Hybrid Development

A yield trial was conducted at Cowra in 2006, with hybrids based on an old maintainer from CIMMYT, and 4l lines crossed to the maintainer. From this experiment, the lines were designated as either maintainers, restorers or segregating for maintenance and restoration, based on the seed set of the hybrid.

From the lines designated as restorers, 12 lines had heterosis levels between 9% to 52% higher than the mid-parent (add the yield of the 2 parents of the F1 hybrid divided by 2 and then divide the F1 yield value by the mid-parent value), and 4 lines had high parent heterosis levels of 17% to 52% (F1 hybrid yield divided by the highest yielding parent of the F1 hybrid). The yield of the Male sterile 'A' line was 25% lower than *Tahara*, this accounting for fewer lines having high parent heterosis. A higher yielding 'A' line should help achieve higher levels of heterosis, and yields higher than the best inbred varieties.

Seven lines were thought to be maintainers, one of which was *Berkshire* (JRCT74). The F1 of the male sterile x *Berkshire* was then tested again in the glasshouse, and found to be a maintainer line, as the F1 was male sterile. The process of creating the male sterile near isogenic line was commenced by backcrossing *Berkshire* to the male sterile F1. The BC1F1 plant was male sterile, confirming that *Berkshire* was a maintainer line, and the backcrossing was continued. By the end of the project, the backcrossing was up to BC4F1, the male sterile line being 96.875% similar to *Berkshire* on average. The line is now undergoing further backcrossing and seed increase in the new 3-year project funded by Pork CRC from July 1, 2009.

3) Improved Agronomy

The triticale agronomy package had two main aims:

(1) to complete an industry survey of growers to determine the main constraints to the expansion of triticale production and utilisation with an emphasis on the usage of triticale by the Australian pork industry
(2) to design a production package to improve the agronomic options for triticale growers and their agronomy advisors

Both these aims have been completed and enclosed as Attachments. The survey summary is enclosed as an attachment and the main findings from this survey have been incorporated into the production manual.

TRITICALE SURVEY:

Ninety-two triticale grower responses were received from 400 dispatched surveys. It was unfortunate that the majority of the respondents to the survey did not supply grain to the pork industry.

The main findings from this survey were:

* Most triticale was being used for dairy feeding (73%) with lesser amounts for cattle feedlot and pork production

* The two major reasons why the farmers grew triticale were a high level of acid soil tolerance (32%) and that it suits the farm rotation (31%)

* Most growers (69%) did not see marketing as a constraint for growing triticale

* The main production problems with the crop in the year of the survey (2007) were frost susceptibility (41%) and drought effects on grain yield (34%). Price received for the grain was also a serious constraint to overall triticale production (34%)

* The two major determinants for selecting triticale varieties to grow were yield and price. If a new variety was to be released for the pork industry the growers would assess it on the basis of comparative grain yields (46% of growers) and the price paid for the grain (42%)

TRITICALE PRODUCTION MANUAL:

The second aspect of the triticale agronomic work was to produce a production manual which would bring together work assessing the differences between the production requirements of triticale compared with other winter cereal crops (mainly wheat). Key research aspects related to the nutritional needs of triticale (mainly nitrogen and phosphorus responses), tolerance to soil aluminium levels and frost tolerances. Much of this experimental work was undertaken on a limited basis with final year honours students and research students. The main experimental results are summarised below.

* A series of nitrogen (N) fertiliser experiments were conducted at Gerogery, Narrabri and Armidale. Nitrogen responses at low/medium yield levels are similar with both wheat and triticale. At high yield levels (4t/ha plus) there was a suggestion that N requirements of triticale exceed those in bread wheats. **This suggests that growers should not reduce N fertilizer treatments in triticale compared to wheat and in fact, high yielding conditions, triticale may have a higher N requirement**

* Phosphate (P) response work has been extremely limited in Australia but the data available (Montgomery 1999) suggests that wheat and triticales show similar levels of grain yield response to applied P fertilizer

* Recent work (Alter, Murphy, Jessop and Roake, 2008) has reported screening work for aluminium (Al) tolerance in the newer Australian triticales. Whilst most varieties had improved Al tolerance compared with wheat, a range of apparent Al tolerances in flow culture were recorded with *Tobruk*, *Everest* and *Endeavour* at the lower end of the range and *Canobolas* with one of the highest apparent Al tolerances. This suggests that *Canobolas* should be considered by growers in acid soil situations

4. Application of Research

The findings of the survey, together with information in the Triticale Production Manual, provide numerous suggestions for commercial triticale growers. Key ones include selection of varieties suited to specific locations (for high yields), the use of adequate levels of fertiliser elements to allow optimum yields, avoiding frost problems by careful selection of sowing times/variety choice and selection of varieties with increased levels of digestible energy.

The high yields of triticale varieties in acid soil situations should lead to improved returns to growers. The NVT data also indicate major yield improvements of the newer varieties including *Berkshire*, compared with older varieties in grain yields. The data from the energy calibrations suggest that some varieties, particularly *Berkshire* and *JRCT101* have higher levels of DE which should improve suitability and appeal for pork production.

The variety *Berkshire* was released in 2009 to a limited number of growers. The variety has been bulked up in 2009 and more seed will become available to growers in 2010. The variety was protected by PBR and will be further commercialised by Waratah Seeds in 2010.

JRCT400, formerly *JRCT101*, was found to have a higher DE level and lower fibre than even *Berkshire*. It is currently undergoing seed increase, to be released in 2011 and again it will be protected by PBR.

These lines should reduce the cost of production and/or increase production or yield. which will be attractive to the triticale grower. In addition, the higher DE content for these released varieties should make them more attractive to the major endusers, pork producers and stockfeed mills. The new varieties will be grown as they are higher yielding, and there should be a ready market for the grain with pork producers. The research will further impact the pork industry through the release of varieties in the future with even higher DE and lower levels of fibre. The development of hybrids should help increase grain yield by 15-20% which should appeal to the triticale growers.

5. Conclusion

The main results of the research are:

1) Inbred triticale lines have been identified that have higher digestible energy and lower fibre values compared to current triticale varieities. These lines had 0.6 – 1.0 MJ/kg more ileal DE compared to *Tahara*, and 1% higher levels of starch.

2) Two of these lines were acceptable for commercial release, with *Berkshire* having a 16% higher yield than *Tahara*. The line *JRCT400* has even higher energy levels being about 1 MJ DE/kg higher than *Tahara*, and very low fibre levels, with yields being 15% better than *Tahara*.

3) *Berkshire* was found to be a maintainer, and this will assist greatly in finding high levels of heterosis when crossed to high yielding restorers.

4) The survey conducted highlighted a number of positives and negatives with triticale producers. The positives were that it fits well with the farm rotation, the acid soil tolerance of triticale, and that marketing was not a problem for most growers. Growers would grow new varieties provided that they were higher yielding. The main negative with triticale was the frost susceptibility, and drought effects on grain yield, and the price received for the grain was also a serious constraint to overall triticale production.

5) The response to increased application of nitrogen and phosphorus fertilizer is similar to wheat. It needs to be emphasised that triticale requires as much fertilizer as wheat to achieve high yields.

6. Limitations/Risks

The limitations of the research are:

1) The higher DE and lower fibre levels of selected lines by NIR need to be confirmed with *in vivo* digestibility studies with pigs and comparative feed tests to piglets

2) The high levels of heterosis need to be found in high yielding inbred lines, one a maintainer, the other a restorer. If one of the parents is low yielding, it will potentially reduce the average mid-parent heterosis of the hybrid and the high parent heterosis will be negative. i.e. the yield of the hybrid will be better than the average of the two parents, but will be less than the yield of the high yielding parent

7. Recommendations

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

- The findings of the agronomy report , especially the optimization of nitrogen, need to be advertised and promoted to growers and agronomists, as this is limiting the productivity of triticale
- The release of the new variety, *Berkshire*, will need extensive promotion to both grain growers and pork producers. The linking of the two groups also needs to be worked on to build better partnerships, so as to optimize benefits for both
- Yield trials of potential lines for the pork industry need to be trialled in South Australia and Western Australia at sites that are located close to their pork industry
- There is genetic variation in triticale for grain quality characteristics, as evidenced from this study on a limited number of lines. By further breeding, it should be possible to further increase the energy in triticale available to pigs
- The finding of the high yielding maintainer line (female line), *Berkshire*, shows there is great potential to increase the yield of triticale varieties by finding restorer (male) lines to increase yields through the exploitation of heterosis

Appendix 1 - Triticale Production Manual

TRITICALE PRODUCTION MANUAL – AN AID TO IMPROVED TRITICALE PRODUCTION AND UTILISATION.

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INTRODUCTION

While the production of triticale in Australia is relatively low compared to the major cereal grains, wheat, barley and sorghum, triticale is a small but important cereal forage and grain crop used mainly for a range of stockfeed purposes. In addition, small amounts of grain are used in human food products such as breakfast cereals and biscuit/cakes/bread products. The following key points are important for triticale production.

Triticale is a widely accepted grain and forage crop mainly grown in south eastern Australia.

The newer long season (grazing/grain types) and spring (grain only) varieties will produce higher yields than alternative forage and grain stockfeed species.

Australian triticales have high levels of adaptation to stress conditions such as acidic soils, excess moisture, and cold conditions than other available species.

The newer triticales have excellent feeding quality for both monogastric and ruminant animals.

Recent grain quality data indicates that some triticales have grain energy levels approaching those in wheat.

#There is expanding interest in the dual purpose grazing/grain varieties with feedlots using both grain and forage for silage production.

Demand for the grain continues in the dairy, pork chicken meat and layer industries. Usage is also expanding in human use for breakfast cereals and bread.

New areas of production, such as the northern coastal regions of NSW, indicate the value of the crop in diverse cropping/grazing locations.

TRITICALE DEVELOPMENT IN AUSTRALIA

Current varieties of triticale are crosses between durum wheat and rye by traditional plant breeding methods. The first triticales were made in both Scotland (9) by Wilson and by Rimpau in Germany (22) but both attempts to commercialise this new crop were limited by low fertility/sterility in the heads. In the early 1900's Farrer also experimented with wheat/rye crosses but it was not until the late 1960's that chromosome doubling using colchicine and embryo culture produced more fertile, high yielding crosses. Much of this work was undertaken at the International Centre for Maize and Wheat Improvement in Mexico (CIMMYT). In the last 40 years CIMMYT has been the main world source of spring grain only triticales whilst the longer season varieties (winter and semi-winter types) have been mainly produced at a range of European ccntres. The production of triticales is complicated compared with conventional cereals since the original wheat/rye cross is normally crossed back to triticales to obtain agronomically useful material.

The development of triticale in Australia has been centred on the three university programs at Adelaide, Sydney and UNE Armidale with limited support from the Grain Research and Development Corporation and the Rural Industries Research and Development Corporation. In more recent times industry groups such as Rivalea and the Pork Cooperative Research Centre have become heavily involved in triticale development. Long season (graze/grain) varieties have mainly been produced by the University of Sydney whilst the other two universities have released spring grain only varieties.

Triticale industry development work until very recently has been limited to varietal improvement. Variety release data now centres on the results from the National Variety Trials (NVT) which have taken over from State Department of Primary Industry trials. Advanced varieties can be submitted for a limited number of years to these trials before formal release. Most varieties are now being released by commercial seed companies in conjunction with the University groups mentioned above.

Until very recently, almost no information has been available on comparative feed value of the range of triticales currently available to growers. The Pork Cooperative Research Centre is now undertaking detailed assessment of the feeding value and results will be presented later in this report. Additionally, a recent triticale producer survey amongst about 400 growers has highlighted both the potential and problems with the production system. The main results from this survey will also be discussed later in this report and the results will be referred to throughout this report as “survey findings”.

The aim of this manual is to aid growers in optimising the production of triticale based on the production of grain suitable for the user industries, particularly the Australian pork industry. The topics to be discussed will concentrate on the grain production issues but, where relevant, grazing values will be mentioned. Topics covered will be adaptation to soil environments including waterlogging tolerance, variety selection parameters, sowing date/rate selection, frosting tolerance, weed control options, fertiliser requirements, disease susceptibility and control, insect problems, lodging tolerance, harvesting requirements (including threshability), seed storage, and factors affecting feed grain quality.

ADAPTATION TO SOIL ENVIRONMENTS.

The main reason for the popularity of triticale in specific locations has been its ability to yield well in problem soil environments. One of its parent species (rye) is grown widely on acidic soils in Europe; such soils may also have low nutrient levels and be waterlogged in winter. Triticale has inherited at least some of rye’s abilities to handle these conditions, but as for other cereals, these tolerances vary with varieties.

Acid soil tolerance.

At soil pH levels of below 5, aluminium (Al) and manganese (Mn) become available in soil solution and can damage root growth and reduce yields. Screening work in flow culture systems and field observations indicated that there was a range of tolerances in triticale to aluminium (Zhang *et al*, 2003). For example, *Tahara* is highly Al tolerant whilst Empat (an older grazing/grain type) had much poorer Al tolerance.

A range of new varieties have been released without any data on relative acid soil tolerances. The recent survey of growers indicated that acid soil production was still an important requirement for triticale. Many of the new varieties have now been screened in flow culture for Al tolerance (Table 1). In the screening system small plants are given an aluminium stress in solution and then examined for root re-growth after this stress. The presence of re-growth and its length indicate relative tolerance with greater re-growth length as a measure of increasing Al tolerance.

TABLE 1 ALUMINIUM TOLERANCE OF NEWER TRITICALES

Variety	Re-growth length (mm)	Standard error of mean
Wheat	2.4	3.7
Rye	40.6	3.7
Tobruk	21.0	3.9
JCRT 74	29.5	3.9
JCRT 75	30.8	3.9
Breakwell	36.5	3.8
Tahara	35.1	3.7
AT528	27.6	3.8
H20	27.6	3.7
H55	39.6	3.7
H116	29.5	3.9
Bogong	29.5	3.8
H128	35.4	3.8
H157	29.5	3.9
H249	32.8	3.9
Canobolas	46.1	3.9
H426	48.7	3.9

As expected the wheat variety (Janz) had poor Al tolerance, rye was good and there was a range of tolerances within the triticales with Canobolas being the most Al tolerant variety. Based on earlier work (Zhang *et al* 1998), varieties with good regrowth after Al stress in flow culture perform well on acid soils. This relative ranking in acid soil tolerance should be confirmed in field studies.

Drought tolerance

No detailed field work has been undertaken to compare yield performance of current triticales and wheat under dry conditions. The survey findings showed that 34% of growers had encountered problems with drought tolerance in triticale and 10% would like increased research on drought tolerance improvement in triticales. This probably reflects the effects of the recent dry seasons.

Laboratory work (Barary *et al* 2005) indicated that, common South Australian varieties (Tickit and Credit) were able to accumulate more carbohydrates (sugars) in their stems and to translocate them to the grain compared with New South Wales varieties such as Everest and *Kosciusko*. This improved translocation capacity may be related to improved drought tolerance. More detailed field assessment of water relations in triticales compared with wheat is needed, especially with the likelihood of drier conditions associated the current projections on climate change.

Overseas data indicates that under dry conditions triticale's biomass production falls but the biomass of wheat normally falls much further, and triticale's relative advantage is likely to become more pronounced under drought conditions (Triticale, 1989).

Waterlogging tolerance

Increased interest in triticale is occurring in coastal regions of northern New South specifically in areas where sugar cane is grown. The varieties being used include Everest, Rufus and Yukuri and these varieties have been grown close to the coast where waterlogging is a problem. Recent reports by W.Wilson, Broadwater (near Grafton), in northern New South Wales indicate that triticale has tolerance to these conditions. Rufus was completely under water for 4 to 5 days and still yielded 1.34t/ha. In addition it carried no rust and the straw was baled for sale to dairy producers.

Performance on alkaline soils.

Triticale varieties are generally well adapted to alkaline soils. Past studies overseas have indicated good performance of triticales compared to other cereals in Mexico, Spain and Portugal (Triticale 1989). NVT experiments in South Australia on alkaline soils at Pinaroo, Streaky Bay and Minnipa, have indicated good yields compared with other cereals, even in dry years. Farmer experience (Kath Cooper, pers.comm) on dry rocky soils in South Australia has shown a 25% yield advantage for triticale, compared with wheat. In these difficult conditions, the variety Rufus has proved most valuable.

VARIETAL SELECTION

Varietal selection will depend on the location and the aims of triticale production. In New South Wales many growers are producing triticale for both forage and grain (long season) usage. In other locations, growers are using spring grain only types. A clear distinction needs to be made between these two end uses.

Long season grazing/grain varieties

The most up to date information for NSW growers is contained in the NSW Winter Crop Sowing Guide. Data in this report indicates varietal differences in dry matter production from early and later grazings, suggested sowing times and grain yields.

Spring grain only varieties

The varieties in use from 2009 onwards are likely to change rapidly from the older varieties owing to stripe rust susceptibility and low yields associated with the older varieties. The data below is based on NVT data from 2006, 2007 and 2008. Only the higher yielding and currently rust resistant varieties are listed below.

Spring variety grain yields (t/ha) 2006-2008

Variety		*Gerogery*	*Boorowa*	*Temora*	*Yarrawonga*	*Streatham*
	2006	*2007*	*2007*	*2006*	*2007*	*2007*
Bogong	-----	3.85	2.22	-----	1.73	8.59
Hawkeye	1.69	3.75	2.28	6.02	2.11	-----
Jaywick	1.75	3.70	2.56	5.80	1.91	-----
Tahara	1.20	3.50	2.26	5.98	1.67	7.18
Tobruk	1.41	3.48	2.43	5.57	1.45	-----
Canobolas	-----	3.25	2.33	6.98	2.14	8.43
Berkshire	-----	3.63	2.59	-----	1.98	-----
JRCT-101	-----	3.43	2.60	-----	2.08	-----

Spring variety grain yields (t/ha) 2008/09

Variety	*Gerogery*	*Boorowa*	*Temora*	*Rutherglen*
Bogong	2.97	4.84	2.40	3.57
Hawkeye	2.87	4.39	2.52	3.96
Tahara	2.64	3.91	2.60	3.50
Tobruk	2.29	4.78	1.83	-----
Canobolas	2.86	4.98	2.05	3.85
Berkshire	2.79	4.72	2.59	3.96
JRCT -101	2.74	4.50	2.50	3.91

Individual variety decisions should be based on the best yield data available close to a grower’s location. For New South Wales much of that information is available in the Winter Crop Sowing Guide for each year.

SOWING DATE/SOWING RATE OPTIONS

The range of sowing rates varies with variety and end use. Grain size is larger than in wheat so that higher sowing rates are needed to achieve the same plant density. Sowing rates approximately 20% higher than for wheat are recommended.

Before determining seed sowing rates, seed germination levels need to be known. For purchased seed this will be stated on the bags supplied. For home grown seed percentage germination can be simply estimated by moistening the seed in blotting paper on a saucer covered by another inverted saucer. The seed should be kept warm (20 degrees C) and moist for 10 days and after that period, the percentage germination can then be recorded. Seed with approximately 90%

germination or more is suitable for sowing. Seed produced in tableland cooler environments may tend to have poorer germination levels than seed produced in warmer regions; hence the need to check the germination rate.

long season grazing/grain varieties:

In general, the long season grazing/grain varieties are sown from March through to mid April; these varieties can be sown later but they will yield less forage for grazing in winter. Grain yield recovery will also be less with later sowing. Sowing rates will commonly be between 80-120kg/ha with much lower rates (20-50kg/ha) for undersown pastures (NSW Winter Crop Sowing Guide 2008).

spring grain only varieties:

For the spring grain only varieties, later sowing from mid May through to later June is ideal. Since triticale has a reputation for suffering from frost damage (a major finding in the industry survey), sowing up to 10 days later than wheat (see also comments below) can reduce frost damage. Sowing rates will vary from 40-50kg/ha in the drier areas and up to 120kg/ha in the wetter regions or under irrigation, with higher rates being used with later sowing. In southern New South Wales rates of 80 to 90 kg/ha are commonly used (Evan Moll, pers comm.).

FROST TOLERANCE

Lack of spring frost tolerance was rated as the most serious problem encountered by triticale producers in the grower survey and was mentioned by 41% of respondents. No research data is yet available which assesses relative frost tolerance across a range of varieties. Research work is currently underway in 2009 at UNE Armidale to assess comparative frost tolerance in newer triticale varieties with those in wheat and rye. Field assessment of frost tolerance is difficult since it is heavily dependent on small differences in development stage at the time of frosting. It is the occurrence of late frosts close to, or after, ear emergence which causes possible severe problems.

Grower evidence suggests some varietal differences in frost tolerance which are probably related to differences in varietal development patterns. In a report from Yarrawonga, (Adam Inchbold, pers.comm.) it is suggested that the older variety Abacus was regarded as more frost susceptible than other spring varieties and this may be related to a longer flowering stage than some other grain types. It may also be that Abacus was the main variety sown in areas prone to frost problems.

Some direct quotes have been received from Adam Inchbold (Yarrawonga) and Dale Grey (DPI TopCrop agronomist, Cobram) and they are listed in full below. It should be remembered that these relate to northern Victoria/southern New South Wales.

"Significant frost damage has occurred several times in triticale crops in recent years in the eastern cropping regions of northeast Victoria and southern New South Wales. The risk of frosting, particularly in low lying paddocks, can be reduced by not planting too early: however, heat stress during grain fill will potentially become more of a factor as sowing date is delayed.

It is recommended that main season varieties of triticale not be sown before the end of the first week in May in this area.

Newer varieties, with some winter habit, combined with the ability to cope with drier seasons represent to growers a significant improvement in variety choice."

In regions other than those listed above, and where spring frosts are a likely problem, a delay 7-10 days in sowing compared with main season wheat varieties should reduce potential frost effects. The avoidance of frost prone areas (low lying paddocks and creek areas) will also reduce possible frosting effects.

Once heads and grain have been frosted, small discoloured grain may be produced. Depending on the degree of damage the grain can still be very valuable stock feed (Richardson, Kaiser and Piltz 2001). These authors showed that severely frosted wheat grain had approximately 1MJ/kg lower estimated metabolisable energy (ME) than unfrosted wheat. Provided allowance is made for this decrease in energy value, the grain is still very valuable in a feed ration. It can be assumed that wheat and triticale would perform similarly in this respect.

WEED CONTROL OPTIONS

Triticale has large seeds which lead to rapid early growth and the capacity to suppress weeds via good competitive ability (Lemerle and Cooper 1996). In experimental work examining the suppression of annual ryegrass, triticale and rye were superior to wheat. This work was based on older varieties and needs to be repeated with current lines.

Chemical weed control options in triticale varieties are in general similar to those for wheat, although some differences in tolerances are important. In all states the DPI or its equivalent produce a recommended herbicide usage publication which should be consulted before using herbicides with triticale. In New South Wales the publication is Weed Control in Winter Crops and it can also be found on the NSW DPI web site at www.dpi.nsw.gov.au/agriculture/field/field-crops/winter-cereals/pests-diseases.

It is important that care is taken to ensure crop and weed tolerances based on the label recommendations are adhered to. Additionally, weather conditions, herbicide rates, water dilution rates, and adjoining crops status need to be assessed and managed correctly.

Tony Cook (NSW DPI, Tamworth) has recently complied a short note on comparisons of weed control chemical options in wheat and triticale. This is available directly from Tony (email address tony.cook@dpi.nsw.gov.au) but in summary he indicates that whilst a range of chemical are registered for use in both wheat and triticale, some herbicides are only legal for use in wheat. Additionally, some herbicides are only legal to use at specific crop stages in triticale.

FERTILISER REQUIREMENTS

High yields in any crop are strongly dependent on adequate nutrients being available during growth. Evidence from Mexico (Sayre, Pfeiffer and Mergoum (1996) comparing bread wheat responses to nitrogen fertiliser with those of the newer triticale varieties indicate at least equal response compared with wheat and in some cases higher levels of grain yield response.

As a result of this Mexican work, nitrogen response experiments were established at Armidale, Gerogery and Narrabri. Three experiments were attempted at Armidale in 2002, 2003 and 2004 but owing to adverse seasonal conditions the 2003 experiment was abandoned.

Soil tests for the remaining experiments indicated marked differences between the years in nitrogen (N) and phosphorus (P) status. In 2002 the site had a very low soil N level (2ug/g nitrate) and a low/medium level of P (16ug/g available P). The data from the 2004 site indicated much higher levels of nutrients, being 64ug/g nitrate and 46ug/g phosphorus.

The response of Triticale (tonne/ha) to nitrogen fertiliser at Armidale, 2004

Variety	*0 N*	*50kg/ha N*	*100kg/ha N*	*Response 100kg/ha N*
Everest	6.85	7.96	7.98	1.13
Kosciusko	7.37	7.48	8.34	0.97
Tahara	7.96	8.22	8.52	0.56
Janz wheat	6.73	6.99	7.00	0.27

Although this experiment in 2004 used varieties that have now been largely superseded, the major findings from these experiments were that in a high rainfall region with yield potential levels above average the yield responses to N fertiliser of a range of triticale varieties was at least equal to those for wheat. With high yield potential (up to 8t/ha) triticale varieties showed up to 4 times the yield response of the wheat variety Janz. At lower yields levels (2t/ha) there were no differences in response between wheat and triticale varieties (Gerogery 2006). Similar data to that at Gerogery were produced at Narrabri in 2007.

These results indicated that, with low/medium yield expectations, wheat and triticale appear to show similar responses to additional N fertiliser. In locations with increased yield potential there is a suggestion that N requirements of triticale varieties exceed those of bread wheat varieties. The exact amounts of additional N fertiliser applied will depend on expected grain yields, soil N status, crop water availability and the current ratio of N fertiliser prices and crop returns.

In data presented at the triticale afternoon by the Pork CRC (9/2/2009) at Wagga Wagga, John Sykes emphasised that growers need to aim for sufficient soil N to obtain 11.5% protein in triticale as below this level both grain yield and protein will be reduced. This aspect of triticale has been overlooked in the past and often triticale yields have been severely reduced compared with those in wheat as a result of inadequate N fertiliser application.

There is no published Australian field experimental work comparing yield responses of current varieties of wheat and triticale varieties to other nutrients such as phosphorus and sulphur. Data from Western Australia (Osborne and Rengel 2002) for plants grown in nutrient solution indicates that, compared with bread wheats, rye and triticale were more efficient in using P at low levels of P supply.

Overseas evidence (CIMMYT, Mexico) suggests that P rates at least equivalent to those used for wheat should be supplied to triticale to maintain high yields.

DISEASE CONTROL OPTIONS

In the early development stages of triticale in Australia, the crop was relatively free of disease compared with other winter cereals. As the crop expanded in the 1980's, a range of fungal and other diseases became more important and required management. The main diseases have been the three rusts (leaf, stem and stripe rust), crown rot, barley yellow dwarf virus (BYDV), and nematodes.

The likely arrival of stem rust Ug99 plus new races of stem rust has major implications for triticale production since the genetics of rust resistance is less well documented in triticale compared with wheat.

Rusts

-Leaf rust. The current commercial triticale varieties have good resistance to leaf rust and newer varieties should maintain this attribute.

-Stem rust. All the present commercial varieties have been screened for the current races of stem rust and they have adequate levels of resistance. The possible arrival of newer races of stem rust requires further screening for these races. The levels of resistance to these new races are unknown.

-Stripe rust. This disease (known outside Australia as yellow rust) has become more important in recent years owing to new races arriving in eastern Australia. The range of resistances to stripe for commercial triticale varieties is shown in the NSW Winter Crop Variety Sowing Guide. Newer varieties generally have improved stripe rust resistance. Varieties with at least an MR/MS (moderately resistant/moderately susceptible) should be used. For New South Wales the best source of information on current rust resistance in triticale varieties is in the DPI Winter Crop Variety Sowing Guide (www.dpi.gov.au).

Crown rot

Information concerning the resistances of triticale varieties to these diseases is very limited. For crown rot (*Fusarium psuedograminearum*) most work has been completed in wheat but data from 2007 by Daniel and Simpfendorfer (GRDC Termination Report) included one triticale (Everest). Inoculation with the crown rot fungus caused the greatest reduction in yield in durum wheat (average of 58%) with less but similar reduction in 5 wheat varieties (25%) and one triticale (23%). Within the wheat varieties the reductions were in a 10% range and it is likely that a similar position would occur within triticale varieties. This emphasises the importance of crop rotational strategy (use of disease break crops such as canola/mustard) within the cropping system.

Data from David Backhouse (pers.comm.) from work at Armidale in 2005/2006 in a mild finishing environment indicated no effect of crown rot on yield. There was no late season moisture stress. There was however a strong increase in crown rot with added nitrogen fertiliser. Take-all levels in triticale have not been reported to be a major problem in southern New South Wales (J.Sykes, pers.comm.)

Barley Yellow Dwarf Virus (BYDV)

The incidence of BYDV varies strongly with season and with time of sowing. The long season varieties indicate varying levels of BYDV in seasons with higher than normal aphid levels observations. This disease does appear to be more prevalent with the grazing varieties but no data is available for varietal screening of BYDV.

Nematodes

Cereal cyst (*Heterodera avenae*) and root-lesion nematode (*Practylenchus* spp.) can cause major yield losses in cereals in south eastern Australia. In locations where nematodes are known to cause problems, resistant varieties need to be used.

Cereal cyst nematode (CCN)

Triticale varieties have a range of resistances to CCN. In regions where it is a known problem, the varieties *Tahara*, Tickit, Hawkeye, Jaywick and Rufus should be considered as they have high levels of resistance (Kath Cooper, pers.comm) and Richard Saunders (2007).

Root-lesion nematode (RLN)

Whilst other nematode species have been identified, two species of root-lesion nematode are important in Australia. These are *Pratylenchus thornei* and *P. neglectus*. and are the most common ones affecting winter cereals (Vanstone *et al* 2008). The older varieties of triticale had markedly different effects on the levels of *P.thornei* in soil in pots (V.Vanstone, pers.com). Credit and Everest resulted in low levels whilst Muir and *Tahara* showed the reverse effect. Dr Vivian Vanstone has indicated that all triticales she has tested were resistant and tolerant to the RLN *P. neglectus*. Furthermore data from South Australia (Saunders 2007) indicates that *Tahara* and Abacus have the ability to reduce RLN numbers.

Insect Problems with triticale

Triticale has the same insect predators during growth as other cereals but in general fewer insect control measures are required with the exception of grain storage insects. This was quoted as a serious concern for growers. In the grower survey 24% of respondents rated problems in grain storage as a limitation to the amount of triticale they produce.

Earthmites (red-legged and blue oat mites) can be problem in early growth and chemical control may be necessary depending on insect numbers/damage. Aphids may occur in late winter/spring and whilst usually not causing major damage themselves they do transmit BYDV and this may warrant control in severe infestations.

Aphids have not been a problem in southern NSW (J. Sykes, pers.comm). From flowering onwards (especially in tableland regions) caterpillars (*Helicoverpa* spp.) frequently cause damage and require control. Otherwise, severe losses may occur without treatment. State DPI publications such as “Insect and Mite Control in Field Crops” should be consulted for detailed information on control measures and threshold levels.

LODGING PROBLEMS IN TRITICALE

The main commercial triticale varieties are relatively tall compared with newer wheat varieties. However in most of the newer varieties lodging is not considered a problem. However, whilst these newer varieties have been selected for adequate straw strength a recent assessment of the NVT site at Tamworth after storms indicated a range of straw strength levels. The likelihood of lodging is increased by high rates of nitrogen fertiliser and under irrigated conditions.

Lodging Scores in NVT Tamworth, 4/11/2008

Variety	Score
Bogong	0/5
Jaywick	3/5
Tahara	3/5
Tobruk	0/5
Canobolas	0/5
Berkshire	1/5
JRCT 101	0/5
Yukuri	5/5
Rufus	5/5

Where a score of 0 means no lodging while 5 means that the variety is prone to heavy lodging.

HARVESTING AND STORAGE

Triticale varieties vary strongly in thresh-ability. Some varieties are difficult to thresh cleanly without either leaving intact head sections in the grain sample or causing grain cracking through tight concave settings. Conversely, some varieties are prone to shedding under windy conditions. Most triticale varieties have inverted heads at maturity which shed rain and therefore make the crop less liable to sprouting at maturity. This can be especially important in regions where storms can delay harvesting.

The level of carryover (hard seed) self sown plants which occurs after a triticale crop appears to be higher than with other winter cereals (Craig John, ABB Seeds, pers.comm). No data exists concerning any varietal differences in hard seed levels but especially where some seed shedding has occurred this will need careful management.

As mentioned earlier, insect attack during seed storage remains a serious problem with triticale. In the grower survey, storage problems were listed by 24% of growers as a reason for limiting the amount of triticale they grow. In general, this is worst with the softer grain types (e.g. *Tahara* and other older types). Newer varieties are generally of a harder seed type but they still require careful grain protection during storage. Many growers have reported the need to carefully monitor insect levels and apply effective control systems.

Maximum moisture content for triticale grain storage is 12% and aeration cooling is one way to reduce insect problems. Chemical protectants are also usually needed in triticale storage of triticale. Recommendations about the storage management of triticale are well described in the article by Joanne Holloway in the NSW DPI 2009 Winter Crop Variety Sowing Guide.

GRAIN QUALITY

Triticale and other cereal grains are predominantly an energy source for monogastric feed purposes. As a result of valuable work within the Pork CRC, a range of grain quality assessments for pork production have been undertaken for grain from the NVT trials in 2006, 2007 and 2008. The key measurements are related to grain energy values and the data for the first two years is now available. In 2006, the measurements were completed on grain from sites at Tomingley, Temora, Gerogery and Boorowa. At these sites the mean pig faecal digestible energy of the triticale varieties was 13.8MJ/kg with one variety (Canobolas) having 0.5 MJ/kg more energy at both sites. The newly released variety, *Berkshire* also has consistently higher energy values compared to the average energy content of triticale. Similar trends were shown in pig ileal digestible energy. More detailed agronomic studies at Gerogery indicated no effects of either nitrogen fertiliser or fungicide treatment on energy levels.

In 2007, quality results were measured in grain samples from NVT sites at Boorowa, Gerogery, Cowra, Tomingley, and Jerilderie. The mean pig faecal digestible energy of the triticale varieties was 13.6MJ/kg and again Canobolas and *Berkshire* had a higher energy value than the other triticale varieties. In detailed agronomic studies there were again no effects of nitrogen or fungicide on grain energy levels. Based on this data it appears that whilst wheat generally has a higher energy level than the triticales, selection within triticales can raise energy levels.

TRITICALE MARKETING

Triticale is still predominantly a stock feed grain but increasing interest is being shown in the use of the grain in human use end products such as breakfast cereals. Some growers in a number of locations have contracts for usage in this expanding human use market. These contracts are usually for a variety well suited to a specific end-use. A good example, quoted by Doug Godwin, a grower near Dubbo, is that Ben Furney Flour Mills (Dubbo) have developed a section of their mill exclusively for processing triticale for human use.

The bulk of the grain crop is used in dairy, pig and chicken production. Approximately 29% of growers in the producer survey rated marketing problems as an issue which limited the area of triticale they grow. The bulk of triticale grown on individual properties is used on farm with excess being sold off-farm. Regular triticale growers carefully assess markets/prices before commencing production. Adequate grain storage is a key factor in obtaining the best prices as the lowest prices are usually received at harvest. Whilst most triticale growers responding to the survey reported that marketing was not a problem, those who said it was a problem listed low price (24%) and lack of regular end-users (17%) as causes of marketing concerns.

Owen Croft (Uralla, northern NSW) has indicated that all new growers should secure a market before large scale production. Additionally, he suggests that a group marketing operation to supply larger amounts of grain and to guarantee delivery at nominated times should be considered.

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Appendix 2 - Triticale Production Survey 2007 - Summary of Results

Background Survey Aims and Methodology

Triticale (x *Triticosecale* Wittmack) is a small winter cereal grain crop used mostly for animal feeding purposes in Australia. The total crop covers approximately 350,000ha (ABARE Australian Crop Report June 2009) and both spring grain only and longer season grazing/grain varieties are grown. The majority of the crop is grown in New South Wales with smaller areas of production in all other states except the Northern Territory. The crop is used mainly in regions where soil constraints limit the yields of wheat and other cereals. These constraints include acid and alkaline soils, dry sandy soils, soils with specific nutrient deficiencies, coastal locations and in high altitude tableland regions. Triticale is also produced under fully irrigated situations where high yields are possible.

The grain is fed to all classes of animals including pigs, poultry, cattle, sheep and horses and it is strongly sought after by dairy producers.

The triticale industry has no formal industry group which represents the interests of it's producers. Production tends to be in small volumes where the attributes of the crop suit individual growers. The Pork Cooperative Research Centre (CRC), as part of the triticale improvement program, requested the preparation of a production survey to assess the potential of, and major limitations to, an expanded production and utilisation of triticale in eastern Australia. This was the first attempt in 30 years to gather information on how producers view the industry and what were the main constraints to expanded utilisation of the crop. The data will be used by the CRC to assess research directions and to indicate how receptive the industry would be to new varieties specific designed for the pork production industry.

The survey was forwarded to over **400** triticale producers in New South Wales, Victoria and South Australia. It consisted of 12 questions and for most people it took approximately 15 minutes to complete. A reply-paid envelope was provided for the return information and **92** replies were received.

Major Results

Question 1. Location:

most replies were from central/southern New South Wales postcode regions with only 20 replies from a mixture South Australian/Victorian areas.

Question 2. Average triticale production area:

this was 212ha but the spread of area was from 5ha to 1000ha.

Question 3. What factors limit the area of triticale you grow?

Four main limitations were reported
1) storage problems (either capacity or insect concerns) (24.4%)

2) price (34.4%)

3) marketing problems (28.9%)

4) amount of available land (28.9%).

Question 4. Why do you grow triticale in preference to other crops?

There was a range of answers to this question but the main ones were;

1) High level of acid soil tolerance (32.2%)
2) It suits my rotation (31.1%)
3) Good disease tolerance (23.3%)
4) Grazing value (18.9%)
5) Dollar returns (17.8%)
6) Undersowing capacity (16.7%)

Question 5. What type of triticale do you mainly grow (dual purpose/grain only)?

1) 47.8% grew grain only varieties
2) 23.3% grew dual purpose types only
3) 27.8% grew both types.

The response above would be highly dependent on the main locations of the responses. For instance, tableland growers in New South Wales would be almost totally dual purpose growers.

Question 6. What do you like about the triticale grown on your farm?

(1) High yields (41.1%)

(2) Grazing value (24.4%)

(3) Disease tolerance (15.6%)

Question 7. What happens to the triticale grown on your farm?

(1) It used both on-farm and sold (61.1%)

(2) It is sold off-farm (25.6%)

(3) It is used on-farm (8.9%)

(4) It used for dairy (14.1%)

(5) It is used for feedlots (7.8%)

(6) It is used for pork production (4.4%)

Question 8. Is triticale marketing a problem?

No (68.9%); yes (27.8%).

If the answer here was yes what are the main causes of the marketing concern?

(1) Low price (24.4%)

(2) Lack of regular end-users (16.7%)

(3) Variable grain quality (6.7%)

Question 9. Do you think there is potential to sell more triticale into the following industries? The following industries were nominated:

(1) Dairy (73.3%)

(2) Feedlot (65.6%)

(3) Pork (60.0%)

Question 10. If a new variety was developed for the pork industry, what would be needed for you to grow this variety?

(1) High yields (45.6%)

(2) Price paid (42.2%)

(3) Adequate markets (28.9%)

Question 11. What problems have you encountered with triticale?

There were many answers here but the main ones are listed below.

(1)Frost effects (41.1%)

(2) Drought effects (34.4%)

(3) Height-too tall (18.9%)

(4) Lodging (17.8%)

(5) Flowering period (too late/too long) (12.2%)

(6) Inadequate crop nutrition; insufficient N used (10.0%)

Question 12. Can you nominate the research problems you would like addressed in order of priority.

(1) Grain yields (30%)

(2) Disease tolerance (21.1%)

(3) Frosting tolerance (17.8%)

(4) Lodging resistance (17.8%)

(5) Better dual purpose lines (11.1%)

(6) Improved drought tolerance (10.0%)

(7) Threshability (7.8%)

(8) Markets (6.7%)

(9) Better acid soil tolerance (4.4%).

Conclusions

A number of conclusions can be drawn from the survey

1) Price ($/t) returns to growers were an important constraint to overall production of triticale (33.7% of returns).
2) Most growers (66%) considered there was major potential to expand triticale sales into a range of animal production systems. The highest potential was considered to be the dairy industry.
3) In comparison with other crops, triticale was chosen owing to its acid soil tolerance (32%) and its suitability to the farming system (31%).
4) Yield was the prime reason for using a new variety (46%).
5) The main problems encountered with triticale were frost (41%) and drought effects (34%). Varietal differences in frost tolerance are currently being assessed (August 2009) and compared to those in other winter cereal species.

A deficiency in the survey was the small number of responses from growers who supply grain to the pork industry. In part, this may be the result of the current financial constraints within the pork industry.