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GRDC IMPACT ASSESSMENT REPORT SERIES

APR 08

An Economic Analysis of Investment in Breeding of Durum, Triticale and Oats (Other Cereals)

GRDC Impact Assessment Report Series:
Title: **An Economic Analysis of Investment in Breeding of Durum, Triticale and Oats (Other Cereals)**
April 2008
GRDC Project Code: ATR00002
This report was commissioned and published by the GRDC.

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ISBN No. 978-1-921779-03-9

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An Economic Analysis of Investment in Breeding of 'Other' Cereal Crops

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1 Executive Summary

Part of the GRDC plant breeding program, the 'Other Cereals' Cluster, has been evaluated to determine the likely economic benefits from the investment approaching $6 million over the five year period to 2008. The major outputs of the Cluster were new varieties of three winter cereal crops, durum wheat, oats and triticale. The three crops, part of the GRDC portfolio of 25 crops, contribute five percent to the gross value of grain production.

Cereal breeding projects are usually part of a longer ongoing cycle producing new and superior varieties to maintain industry competitiveness by continuously improving yield and quality to meet the changing needs of farmers and consumers. The projects in the 'Other Cereals' Cluster had additional significant features. They had a strengthened national coordination component aiming to more effectively bring together and commercialise long-established breeding programs by bringing in commercial partners. This approach built on opportunities available to develop a more responsive market-driven approach based on Plant Breeders Rights and End Point Royalties. The crops, because of the diversity of their marketing channels, differ in the extent to which they are likely to be able to develop efficient capture mechanisms for royalties.

Each of the projects developed new varieties that are clearly superior in yield and quality. The evaluation used relatively high but justified yield increases ranging from 5 to 12%, and rates of adoption up to 60% after a decade. For the remaining fifteen years of the analysis, other factors including the uncertain but likely negative environmental and economic impacts of climate change were assumed to gradually reduce net benefits. The overall benefits were additional to what could have been achieved if GRDC had not invested in the 'Other Cereals' Cluster. The key assumption in that case was that there would have been a slower and more limited flow of new varieties.

Cost-benefit analysis undertaken in this report indicates that the funds invested in the 'Other Cereals' Cluster will generate a positive but relatively modest return. The major benefit is in the form of increased profitability for grain farmers. The five year investment of close to $6 million by GRDC together with much larger investments by the plant breeder agencies is estimated to have generated a net present value of $31 million in 2006/07 dollar terms and a benefit cost ratio of 2.72 to 1. Break even is by 2013.

The investment was only close to break even if the yield increases and the rates of adoption were reduced by one third. Given that the analysis assumed relatively rapid adoption rates, the sensitivity to these assumptions shows that the level of costs are the key factor contributing to the modest returns. As the crops in total account for only five percent of the gross value of grain production, these national breeding projects will continue to be challenged to achieve economies of scale. However, the crops do contribute to a more resilient grain industry.

2 Background

Crop breeding programs have a fundamental role to play in Australian agriculture. They maintain competitiveness by continuously improving yield and quality to meet the changing needs of farmers and consumers. The 'Other Cereals' Cluster includes the breeding of three winter cereal crops: durum, triticale and oats. The crops are part of the diverse GRDC portfolio of 25 grain crops spanning temperate and tropical cereals, oilseeds and pulses.

Plant breeding to meet the expected and diverse requirements of graingrowers and consumers is a major investment focus for GRDC. A more commercial approach has been evolving over the last decade built on the opportunities from Plant Breeders Rights (PBR) and End Point Royalties (EPR), and from new technologies that can result in more efficient breeding strategies. The breeding cycle can be over a decade from:

- identifying sources of genetic variation,
- selecting and testing plants with a balance of desirable characteristics for a wide range of environments and end uses,
- protecting intellectual property, including using PBR and EPR, to
- developing and marketing commercial quantities of seed.

A range of State Government, University and, increasingly commercial agencies, undertake breeding programs - typically an ongoing cycle with regular releases of new varieties but interspersed with specific projects to meet GRDC priorities.

The three most important shared attributes of triticale, oats and durum are:

- their potential for expansion to meet current increased domestic and export demand from a range of end uses,
- their versatility particularly for oats and triticale, as crops that can be grazed and then opportunistically harvested for hay or grain, and
- the variety of marketing channels and end uses that can result in significant market failure in terms of potential to capture royalties and monitor varietal distribution, thus limiting the potential to develop a more market-driven system.

The three crops, although significant in the economy of some regions, remain relatively minor in terms of the national grain industry. In total they account for only five percent of the gross value of grain production. Triticale (an historically recent cereal crop developed by crossing wheat with cereal rye) remains predominantly a feedgrain, often produced for local dairy and pig producers. Oats and to a lesser extent durum also contribute to feedgrain supplies. Feed wheat dominates as by far the major feedgrain used by the livestock industries. The Cluster includes two triticale projects, the national breeding program and one targeting dual purpose triticale that can be sown earlier than the spring varieties. The dual purpose cereals market is very competitive.

2.1 Feedgrain aspects

Research on the yield and quality of the three crops was given (what some end users would see as belated) higher priority following the feedgrain shortages brought about by the 2002-2003 drought. Domestic grain prices had risen by over 50 percent as the 2002-2003 drought intensified. End users perceived bias in a breeding system driven by attributes required for a minor market. Feedgrain was seen paradoxically as the major domestic grain market for grains that have been mainly bred for human consumption. As Hafi and Connell (2003) stated:
'*The issue of the reliability of feed supply arises from the fact that Australia's grain industry is largely export oriented and geared toward producing food quality grains. Consequently, the feed market is largely a residual market for the grain industry'.*

The demand for feedgrains and the sophistication of the market has increased rapidly over the last two decades. In the major widespread droughts particularly in eastern Australia, supplies of feedgrains are now more likely to be limited compared with demand. The widespread nature of droughts limits buffering from spatial diversification. (The eight major droughts as measured by impacts on wheat production have all been associated with El Niño events, typically widespread.) Demand for drought feeding of livestock compounds the reduced yields of grain crops. Lags and biosecurity conditions in importing grain, together with the then limited opportunities to purchase feedgrain held by the export-oriented statutory marketing agencies put further pressure on prices. The net effect is that feedgrain prices have now become more volatile, and will be more sensitive to increased supply.

2.2 National coordination

The four projects in the cluster account for almost $6 million dollars in GRDC funding over their six year duration. An important institutional aspect of the projects is that they have a strengthened national coordination component aiming to more effectively bring together and commercialise long-established breeding programs being run by Universities and State Government Departments, often with boundaries based, with inevitable inefficiencies on State borders.

GRDC aims to achieve faster adoption of varieties with superior yield, quality and disease resistance. The projects have been designed to capitalise on the opportunities from PBR that have been introduced to stimulate private investment in plant breeding. The GRDC Strategic Plan 2007-12 includes the following strategies the GRDC is implementing with its partners:

- improving the effectiveness of competition in driving efficiency gains through End Point Royalties (EPR), and
- enhancing the links between the breeding process and the variety commercialisation process.

The three crops differ in the extent to which revenue can be captured from royalties on seed purchases, end point transactions, and from the statutory levies for research. In 2005–06 GRDC established the National Variety Trials (NVT) to provide nationally coordinated, independent and cost-effective information to Australian graingrowers on the performance of new crop varieties. New varieties with much improved performance have the potential to underpin ongoing commercial investment in breeding programs that is more directly responsive to market signals.

Features of the three crops include oats, a long established crop in Australia and around the world, whereas triticale and durum are newer crops in Australia, only grown in significant commercial quantities over the last few decades. Therefore the crops are not 'new crops' or infant industries from a national perspective. There is an increasing understanding of their agronomy in a wide range of environments and of the quality attributes needed in a range of end uses. The main limits on their rate of expansion relate to their sustained competitiveness with alternative crops and, particularly for some export markets, achieving an economic scale.

3 The Investment

The projects are part of the GRDC Output Group 1 – Varieties, one of the four output groups through which '*Driving Innovation'*, the GRDC Five Year Research and Development Plan 2002–07 is delivered.

3.1 Objectives of the Varieties Output Group (includes the 'Other Cereals' Cluster)

The generic objectives the four projects share with numerous other projects covering the 25 crops in the major GRDC Output Group are to:

- develop and commercialise new superior crop varieties with significantly enhanced production and market performance compared to current benchmark varieties in Australia
- accelerate the rate of gain in key genetic traits of importance to the Australian grains industry
- improve the overall effectiveness and cost efficiency of GRDC-supported crop improvement programs in Australia

As an indication of the scale and complexity of a breeding program, the oats program is based on field performance of 50,000 plots in four States, backed up by many thousands of laboratory analyses of grain quality and other attributes. When a new variety is released often only one every few years, a wide range of information is available on performance relative to a current variety for a wide range of criteria. For example, an oat variety sowing guide (PIRSA, 2008) includes hay and grain yields in the main climatic environments, together with performance on 26 criteria covering grain quality, disease resistance and agronomic features.

Projects Funded by GRDC to meet objectives for the Cluster are listed in Table 1.

3.2 Investments

Funding for the four projects is shown in Table 2. Expenditure over the five year period of the projects is shown in Table 3. As shown in Tables 2 and 3, GRDC has contributed 34 percent of resources in nominal terms for the four projects. The bulk of the support is provided by the host organisations. The support is 'in kind' and demonstrates the major and ongoing commitment of host organisations in maintaining the specialised scientific and technical staff, and the laboratory and field research facilities required.

Table 1: Projects Funded by GRDC to Meet Objectives for the 'Other Cereals' Cluster

Project Code, Title and Duration	Objective
DAN00105 - Australian National Durum Wheat Improvement Program 1/7/2005 to 30/6/2007	Breeding and releasing new improved cultivars to develop a profitable, internationally competitive and ecologically sustainable Australian durum wheat industry.
CWQ00011 - Dual Purpose Triticale Improvement Program 1/7/2003 to 30/6/2008	Release and further development of dual purpose triticale varieties with improved rust resistance and quality characteristics.
AGP00005 – National Triticale Improvement Program 1/7/04 to 30/6/2008	Develop disease resistant triticale varieties with improved grain yield, adaptation and feed/hay quality to meet the expected growth in demand for feed grains.
DAS00039 - Improved Oat Varieties for milling, feed, and hay/feed end use in the Southern Region Oat Breeding Program 1/07/03 to 30/6/2008	Breeding and release of oat varieties for grain and hay with improved disease resistance, productivity and quality.

Source: Project proposals

Table 2: Total Investment in Projects in the'Other Cereals' Cluster

Project	GRDC	Other Agencies	Total
DAN00105 (Durum)	657,300	1,931,219	2,588,429
AGP0005 (Triticale)	1,641,050	785,800	2,426,850
CWQ00011 (Triticale)	569,484	1,812,570	2,382,054
DAS00039 (Oats)	2,917,181	6,581,271	9,498,452
Total	5,785,015	11,110,770	16,895,785

Source: Project proposals. Other Agencies are the host organisations

Table 3: Total Investment by GRDC and Other Agencies in 'Other Cereals' Cluster (Years ending June, nominal $)

Year	GRDC	Other Agencies	Total
2004	642,034	1,533,086	2,175,120
2005	1,018,363	1,761,920	2,780,283
2006	1,394,299	2,816,002	4,210,301
2007	1,515,887	2,918,235	4,434,122
2008	1,214,432	2,081,527	3,295,959
Total	5,785,015	11,110,770	16,895,785

Source: Project Proposals

3.3 Cluster Description

As stated in the objectives for the GRDC Varieties Output, the four projects each undertake a range of activities to develop and commercialise new superior crop varieties. Breeding cycles can be up to a decade. They need to cater for a market a decade away. Superior varieties need to have yield and quality attributes to meet forecast changes in demand by farmers and consumers. Superior varieties are needed to compete with substitute crops, export competition, and to replace current varieties

that are less competitive, for example from declining yields or poor quality. For each of the projects, there are current varieties with a range of sometimes increasing susceptibilities to diseases. These are manifest occasionally at particular locations or, more generally in seasons where conditions favour disease spread.

Three of the projects are the lead national projects for that crop. The durum project is based at Tamworth, the oats project at Adelaide. There are two triticale projects, one being the national improvement program based in Adelaide and the other being a project based at Sydney University targeting grazing and grain varieties. The Adelaide triticale project has concentrated on broad adaptation and disease resistance for a mainly feedgrain end use. The Sydney project has targeted development of improved dual purpose varieties for the higher rainfall areas in south eastern Australia.

Oats and triticale when grown for grain, generally have a complementary or alternative role in farming systems to wheat, the dominant winter cereal accounting for over one half the value of grain produced. Wheat varieties include the durum type mainly milled to make semolina flour used for manufacture of pasta, and with no major opportunities for substitution from other wheat varieties. Oats and triticale are most often grown on mixed farms supporting a range of crops and livestock enterprises in the wheat/sheep and high rainfall zones. They are dual purpose cereal crops able to be grazed and then harvested as hay, feedgrains, or for human consumption, particularly in the case of oats. Barley and wheat are also competitors as a dual purpose crop. The Australian dual-purpose cereal crop is increasing in importance because of factors such as higher-value animal industries. The wide range of dual purpose cereals covers a range of environments and sowing times, and provides alternatives when there are disease outbreaks.

Main features of the crops are presented to provide necessary context for the discussion of outputs and benefits.

Durum

Durum wheats although initially grown mainly for a domestic market are now grown increasingly for the export market. Production, based on varieties of high quality by world standards, is currently concentrated in favoured environments in northern NSW and South Australia. NSW Department of Primary Industries (NSWDPI) has been involved in durum breeding based at Tamworth for more than 60 years. There is also an Adelaide program that has only achieved a small market share. Production nationally has fluctuated with widespread droughts and price movements. Production volatility in the major export producers in northern America contributes to price volatility.

In 2005-06 Australian production was around 500,000 tonnes, less than a few percent of the national wheat crop. An increased and more stable level of production is necessary for the industry to more rapidly adopt improved varieties and achieve stable export markets. The crop has flexibility; it is also marketed as a livestock feed if quality standards are not met.

Triticale

Triticale is a widely adapted crop and likely to be competitive with wheat in wetter areas and poorer soils. As a useful rotational crop, it adds diversity and flexibility to farming systems. Production in recent non-drought years has been about 600,000 tonnes. Triticale is grown on a small scale across Australian grain regions. However the majority of the production is from the higher rainfall areas of south-eastern Australia. The crop can be grazed, and then later harvested for hay or grain. The grain is a premium feed source for some livestock. Human food applications are limited but increasing. The Pork Cooperative Research Centre also funds triticale research to develop varieties better suited to the requirements of pork producers.

Oats

Oats is also a highly versatile crop being grown for grazing, specialist hay production, and as a grain crop for human and livestock consumption Grain production is concentrated in south-eastern Australia. Grain production including recent drought years has averaged 1,350,000 tonnes. Research for the specialist hay end use is a separate project. The Rural Industries R&D Corporation has funded projects to expand export hay production based on improved varieties for that purpose. The projects are partly funded by voluntary levies on hay exports. There are also a range of agencies involved in funding and research on forage oats varieties. Farmers growing these varieties typically purchase seed every year so that there is more scope for fully commercial breeding programs for forage oats. A limited survey in NSW (Roberts, 2005) showed dual purpose oats (grazing and grain or hay) were more widely grown than grain-only oats. Overall in NSW, there is a major market for a dual purpose variety. The survey showed that most farmers grew dual purpose crops for on farm use, either as grain, hay or silage.

The Southern Region Oat Breeding Program (SROB) based in Adelaide develops new varieties for the GRDC Southern and Western Regions. The SROB manages coordination and evaluation of the major breeding programs for grain and hay varieties. Some smaller oat breeding programs have closed in recent years as part of rationalising the national effort. The SROB program has concentrated on varieties suitable for milling for human consumption and with characteristics such as improved digestibility to increase value of the grain as a livestock feed.

4 Outputs

The principal outputs for the four projects from the investments made in the period from 2003 to 2008 are primarily the improved varieties released during the projects. The projects have built on germplasm available from previous breeding projects and have also generated a capital stock of germplasm that will be the basis for further releases of improved varieties provided the programs are maintained in future. In addition the projects have contributed to more efficient national programs that provide a sounder basis for the future. Specific outputs, as planned as part of the accountability processes governing the projects, are reported in Table 4. The projects were to some extent hampered by extreme drought conditions in some regions in 2006. For example some trials could not be planted. In others, data on relative performance of new varieties under drought conditions would have had some value.

Table 4: Major Outputs of the Four Projects in the 'Other Cereals' Cluster

Project	Outputs Achieved

DAN00105 - Australian National Durum Wheat Improvement Program	1. Release of TD97E as a quick maturing, high yielding, disease resistant, high quality cultivar 2. Release of a high yielding, mid season maturing cultivar, with improved processing quality 3. Publicly funded investment consolidated
CWQ00011 - Dual Purpose Triticale Improvement Program	1. Release of AT 519 and AT 528 2. Identification of improved germplasm 3. Identification and integration of new rust resistances
AGP00005 – National Triticale Improvement Program	1. Previous projects assessed. 2. Implementation of a more effective national program 3. Superior germplasm identified
DAS00039 - Improved Oat Varieties in the Southern Region Oat Breeding Program	1. Released a superior variety to Possum 2. Released a superior replacement for Euro 3. Advanced breeding lines developed

Source: Project Proposals

5 Outcomes

The principal immediate outcome of the investment is the increased profitability for grain farmers. New varieties of grain crops as they are more widely adopted, will increase yield and quality compared with varieties they are already beginning to replace.

The rate at which the outcome is achieved depends on how rapidly farmers purchase seed and build up seed stocks to grow the new varieties. For all the crops in the Cluster most seed sown is farmer seed saved from the previous crop. Farmer perceptions of the advantages and riskiness of a new variety will often be formed over several years, even though farmers have ready access to a wide range of reliable information on relative performance. But varieties with clear demonstrated advantages in more discerning markets will be adopted rapidly.

6 Benefits

6.1 Productivity and profitability

The Australian grains industry will benefit from the investment through more efficient production of grain. Higher yielding varieties reduce production costs per tonne of grain produced. Farmers who are the early adopters of new varieties will capture more of the benefits than the later adopters; for the later adopters an increased share is likely to flow to consumers. Quality improvements also result in further flow-on benefits along the supply chain.

For triticale and oats the major immediate market is a small extra contribution to feedgrains for the livestock industries, industries that overall are more heavily dependent on purchases of other feedgrains. The products from the livestock industries are for consumers in domestic and export markets. For durum, the main flow-on benefits are to millers and consumers of products in both domestic and export markets. Australian exports of durum are relatively small compared with Canada, the major exporter.

In the case of triticale there is a small benefit to the wheat industry by releasing varieties of triticale more resistant to some types of wheat rust. Early sown triticale can allow disease buildup to threaten later triticale and wheat crops.

6.2 Impact on the environment

Improved dual purpose varieties of oats and triticale have an important role in maintaining sustainable grazing systems. The new dual purpose triticale varieties can be sown in autumn to provide valuable winter grazing, as well as a grain yield similar to grain-only crops. This versatility helps farmers to take pressure off pastures and improves winter feed supply. The versatility can also be important in providing grain for drought feeding in other regions after pastures have been affected by drought.

6.3 Social impacts

The crops reduce risk and contribute to the resilience of rural and regional communities dependent on grain and grazing enterprises. The release of competitive new varieties maintains a more diverse range of enterprise choices. Dual purpose grain and grazing crops can cushion farm incomes against volatility in prices and production of the major wheat and wool enterprises.

A summary of the principal types of benefits and related costs associated with the outcomes of the project is shown in Table 5.

Table 5: Categories of Benefits from the Investment in 'Other Cereals' Cluster.

Benefits
Productivity and Profitability Improved yield and quality of varieties that maintain competitiveness and profitability for growers of durum, oats and triticale.
Environmental More sustainable pastures by reducing grazing pressure on winter pastures.
Social Reducing risk and increasing resilience by maintaining more diverse cropping and grazing, and buffering farmers and regions against production and price volatility.

6.4 Public versus Private Benefits

The benefits identified from the investment are predominantly private economic benefits. Improved yields result in reduced production costs per tonne. The benefits will to some extent eventually be passed along supply chain to grain processors and other users of grain including consumers.

There are also insurance and risk reduction benefits that are of some relevance in terms of public benefits. The three crops are relatively minor compared to the major grains such as wheat and barley. The crops have lacked the industry structure, organisation and funding to sustain efficient national breeding programs. There are benefits to the broader grain industry and to regions from maintaining a diverse suite of crop choices that can be called on as circumstances change. For example much of the early interest in triticale was a response to wheat quotas. A wide range of adaptable crops and an even wider range of varieties help to stabilise the industry against disease outbreaks, price volatility and climate change.

Oats and triticale are examples of extreme market failure because royalties with current capture mechanisms seem unlikely to be sufficient to fund the breeding programs as they are currently resourced. Thus, although the benefits are mainly private, they can be necessary and sufficient to be a public good justification for some type of public or cross-industry funding. The three main contributing factors are:

- the reliance of production on farmers seed,
- the benefits as a break crop for disease control that an oat or triticale crop confers in a rotation with other crops, and
- the diverse range of industries that benefit in the supply chain.

For oats, a substantial proportion is used on farm. Off farm use includes diverse domestic and export markets for grain for human and animal consumption. Hay is a major commodity also produced, often opportunistically, for domestic and export markets. Therefore there are major difficulties involved in developing a competitive and equitable system to fund breeding programs.

The durum industry provides another example where market failure can constrain industry growth. Expansion was seen to be clearly profitable provided adapted varieties were available to meet expanding demand and market requirements. Current production concentrated in two regions has not always been stable enough to underpin

a sustainable export market. The royalty and research funding collected from the current industry is a significant sum but would not support a more extensive and much more expensive breeding program. Such a program is essential to underpin expansion of the industry into new areas and reduce volatility in production. Attempts by commercial interests to use imported varieties have not been successful. They were poorly adapted. New varieties need to be broadly adapted and be able to produce superior quality end products in highly discerning global markets. Unlike the wheat industry, small industries cannot afford a large number of acceptable varieties. The grain receival system has an obvious constraint on the number of varietal segregations that can be provided economically. A new expanded national program was seen to be essential to support expansion beyond parochial interests.

If GRDC did not receive funding (or received less funding) from the Commonwealth, the projects probably still would have been funded but at some reduced level. The key issue is the degree of market failure in collecting levies and royalties. The free rider problem from the large proportion of the crops not contributing to grain industry research would inevitably result in under-funding unless there was an explicit policy of cross-subsidising. Some degree of grain industry cross-subsidisation would be efficient because farmers typically grow a range of crops. Some crops are of value in a rotation because of the benefits they confer to subsequent crops.

Overall, it is postulated that the investment in new varieties for 'Other Cereals' would probably not have remained as high a priority for GRDC and that the level of funding would have been reduced in the event of a Commonwealth Government reduction in funding to GRDC. If the government contribution was removed altogether, there probably would have been a significant reduction in funding to the program. One consequence, particularly from the reduced attractiveness of oats and triticale production would be intensive livestock industries subject to somewhat higher input prices, particularly during major droughts. The flow on impacts to domestic food prices would be increased.

6.5 Match with National Priorities

The Australian Government's national and rural R&D priorities are reproduced in Table 6.

The program makes its major contribution to Rural Research Priority 1 through higher cereal yields and lowered costs of production. The program by reducing market failure in the funding of feedgrains contributes to more efficient operation and reduced volatility in intensive livestock industries (Rural Research Priority 2).

Table 6: National and Rural R&D Research Priorities 2007-08

Australian Government	
National Research Priorities	**Rural Research Priorities**
1. An environmentally sustainable Australia 2. Promoting and maintaining good health 3. Frontier technologies for building and transforming Australian industries 4. Safeguarding Australia	1. Productivity and adding value 2. Supply chain and markets 3. Natural resource management 4. Climate variability and climate change 5. Biosecurity *Supporting the priorities:* 1. Innovation skills 2. Technology

The program makes a small contribution to National Research Priority 1 and Rural Research Priorities 3 and 4 by reducing grazing pressure on winter pastures, particularly during droughts. Reduced winter grazing can help maintain more productive pastures and reduce degradation of soil and water resources Both oats and triticale are hardy crops adapted to a wide range of environments and to the increased climate risks likely to result from further climate change. Biosecurity will be improved by reduced feedgrain imports (Rural Research Priority 5).

The investment has demonstrated innovation skills and new technologies (National Research Priority 3) and Supporting Rural Research priorities. The projects reflect a more sustainable and innovative strategy for breeding new varieties compounded on two major drivers:

- Improved commercialisation processes so that breeding programs could be more directly responsive to market signals, and
- The increased demand for durum, triticale and oats, which was a catalyst to expand and better coordinate national programs to drive efficiency gains and reduce market failure.

The assessment of the relative contributions to the five Rural Research Priorities are:

Rural Research Priority 1: 65%
Rural Research Priority 2: 15%
Rural Research Priority 3: 5%
Rural Research Priority 4: 10%
Rural Research Priority 5: 5%

7 Quantification of Benefits

The major outcome is the increased profitability for farmers growing the new higher yielding varieties released by the 'Other Cereals' cluster. The increased profitability will be determined by the changes in demand and supply for grain from the three crops – durum wheat, oats, and triticale.

The likely benefits flowing from each of the four investments in the 'Other Cereals' Cluster are outlined in the following. The emphasis is initially on their adoption prospects in the early years of the evaluation. Common issues are then considered to ensure consistency before the specific assumptions are developed. A summary of the major assumptions concludes this section.

Durum

Benefits in the evaluation are based on new varieties with world class quality, widely adapted, and with a yield advantage over current varieties. '*Australian durum is now regarded by Italian millers as number one or two in the world*' (NSW DPI 2005). Jandaroi is one recent durum release with a clear yield advantage in some areas and expected to be widely adopted. A previous release, Bellaroi, accounted for a 40 per cent market share in just a few years. A growing world market is likely to stimulate industry expansion and attract new growers. The transition can be relatively straight forward for bread wheat growers. They would be attracted by the premium if it were sufficient to overcome what they perceive as the risks. This analysis takes a conservative approach and assumes adoption of 40 percent of the current level of production over the next decade. No increase is assumed beyond then. New varieties could be expected to displace the current varieties. The possible impacts of climate change also warrant a conservative approach.

Triticale (AGT project)

Benefits are based on two varieties (Jaywick and Hawkeye) being released commercially in 2008. They are significantly higher yielding in many regions and have improved disease resistance. Some current varieties likely to be replaced were released up to two decades ago. This reflects the limited resources available to triticale breeding up until this project, which is based on a more effective national approach. Adoption is assumed to be rapid initially.

Triticale (dual purpose)

Benefits are based on two new varieties (Tobruk and Endeavour) suited for higher rainfall regions in NSW and with yield and disease-resistance advantages over current varieties. An important advantage results from the potential for early sowing to provide autumn feed. The new varieties are likely to rapidly replace current varieties susceptible to a new strain of stripe rust.

Oats
Benefits are based on the new releases Mitika and Yallara. Mitika is preferred by millers because of its high mill yield and other qualities, and is also a preferred variety for grain for livestock. As a dwarf variety, it is not suited for use for both grazing and grain. Yallara has improved resistance to some forms of rust, and is also an attractive feed for the horse industry. As end users become more discerning on quality, they will have an important role in stimulating adoption of these new varieties. Research reported in Nicol (2003) showed there was a surprisingly high range in quality of oats used as feedgrains. The best quality varieties were most often from programs that specialised in grain end use. The capacity of the livestock markets to assess quality and buy by variety has been improving rapidly in recent years.

7.1 The Approach to Estimating Consistent Benefits for the Four Projects

Supply/demand aspects
Oats and triticale as grain crops, are mainly grown for use on farm or for domestic feedgrain markets. They are used in feeding of poultry, pigs, dairy and beef cattle. The markets are dominated by feed wheat so that in other than drought years prices are mainly determined on the basis of export wheat prices. In addition, there is typically a high degree of substitution between alternative feedgrains so that changes in supply of a source other than wheat are unlikely to impact on prices for particular feedgrains.

Historical statistics on area and production are readily available for oats and triticale grown for grain (ABARE, 2006), but not for durum as it is a wheat variety and production is included with wheat. Comparing the most recent decade with the previous one, the area of oats for grain has declined by about one quarter whereas triticale has expanded rapidly. Despite recent droughts, the grain industry has expanded rapidly over the last two decades with increased demand for bread wheat and feedgrains. The area of wheat planted has increased by one third comparing the most recent decade with the previous. However, the total area of triticale and oats as a proportion of wheat area has declined from 14 percent to 10 percent. These historical trends suggest better market prospects for triticale than for oats. Oats is mainly a feedgrain. The milling market is about 15 percent of the total and is a premium market with increased demand for oats for human consumption.

The demand for feedgrains and the sophistication of the market has increased rapidly over the last two decades. In the major widespread droughts particularly in eastern Australia, supplies of feedgrains are now more likely to be limited compared with demand. The widespread nature of the major El Niño droughts limits buffering from spatial diversification. Demand for drought feeding of livestock compounds the reduced yields of grain crops. Lags and biosecurity conditions in importing grain have put further pressure on prices. The net effect is that feedgrain prices have become more volatile, and will be more sensitive to increased supply in drought years.

The evaluation of benefits needs to reflect the implications of the trends on profitability that are likely to be more evident in the latter part of the period in the analysis. In addition because of the uncertainties a conservative approach is

warranted. The framework for estimating benefits also needs to recognise likely shifts in supply and demand as a result of the new varieties. A simple approach to increasing benefits based on increased profits to grainfarmers is likely to overestimate benefits. Benefit estimation based on a cost reduction approach is a preferred and more conservative approach to estimating benefits and is used for the three crops (GRDC 1992).

The stream of benefits over the 25 years of the analysis is largely based on the benefit per tonne from improved new varieties. The benefit per tonne is determined by the reduced unit production cost of the higher yielding variety compared with the old varieties displaced. The production pattern over time of the new variety is estimated indirectly by using a likely rate of adoption percentage of the total production base. Estimates of the two key components of benefits per tonne and the adoption rate are determined below for the period of the analysis. They are also the two estimates to be varied in a sensitivity analysis.

Base Production

The tonnage for the 25 year period of analysis is based on the average for the six year period to 2006/07. Relevant factors include:

- Medium term projections of overall grain supply and demand do not assume any significant expansion (Lawrance et al, 2007).
- Expansion prospects for oats and triticale are constrained by the extent to which they have substitutes; they are mainly minor crops in highly competitive feed grain markets dominated by wheat.
- The six year base period includes two major droughts, higher than historic drought incidence, but possibly realistic for the next 25 years given projections of up to 20 per cent more drought months over most of Australia by 2030. (CSIRO and the Bureau of Meteorology 2007).
- One forecast (assuming no adaptation) is of a 9.2% decline (from the reference case of no climate change impacts) in Australian grain production by 2030 (Gunasekera et al, 2007).

Yield Increases

The new varieties have been subjected to extensive testing in the National Variety Trials over a number of sites and usually at least two seasons. Their yield advantage compared with a control variety is documented in varietal guides and factsheets for example AGT (2008) and Waratah (2008). The advantage varies and is dependent on factors such as location, disease incidence and end use. The average yield increase used in the evaluation needs to be in comparison to varieties likely to be displaced. Yield assumptions for both triticales were reduced from the large increases reported. For example Hawkeye showed large increases over Tahara in 2006, but that was an unusual type of drought year. Other data from trials in South Australia showed advantages that other varieties had over Tahara in 2006 were atypical compared with comparisons over the previous seven years (Saunders, 2007). Increases were not changed to reflect that yields in trials may be greater than those achieved on farm. Relative yield increases can usually be assumed the same as in the trials.

Benefit/tonne

The benefit per tonne is based on the cost reduction resulting from the increased yield of the new variety. Estimates of yields and costs were taken from the gross margins

available for the four crops involved (NSW DPI, 2007). Data are for New South Wales regions. The North East region was used for durum. For oats and triticale the South East Region was used as representative of the major production areas for oats, and triticale for grain, and as a dual purpose crop. For dual purpose triticale, grazing yield was not included. Trial data indicated only a small grazing advantage for the new variety (Waratah, 2008).

Benefits/tonne for oats and triticale are assumed to remain constant for the first decade and then decline. The reduction is in recognition of the possibility of unfavourable trends in grain industry profitability related particularly to bio-physical and economic impacts from climate change. For example, fertiliser can account for up to half of variable costs of production. No reduction is assumed for durum given the strong demand, less competition, and because it is used more directly for human consumption compared with feedgrains.

Adoption (% of base)

The likely rates of adoption were based on the yield increase and on experience with similar varieties. Adoption patterns are well documented for wheat (Brennan and Bialowas, 2001) using data from grain receivals into the NSW storage and handling system. For the NSW data analysed, new varieties superior in some respects were released at the rate of one or two annually. On average a peak rate of adoption was reached after five years followed by a decline to zero over 17 years. Typical annual yield increases were only of the order of one or two percent. The pattern will be broadly similar for the new releases in the 'Other Cereals' Cluster. But differences will arise from the more infrequent releases for these programs and their larger yield increases reflecting the expanded breeding effort in recent years. A common feature is the eventual displacement of a variety by a superior variety. In that case, the level of adoption and the benefits being achieved provide the ongoing base against which a new variety is evaluated. The benefits achieved by the variety displaced continue to be attributed to the original investment. For this evaluation, rapid adoption is assumed for the first decade. Thereafter displacement is assumed to occur, but the benefits continue.

Higher rates of adoption are assumed for durum and for triticale than for oats. New high quality durum varieties have been adopted quickly. There is less data for triticale but given the large increases in yield, adoption should also be rapid, and is assumed proportionate to the yield advantage. The new oats varieties are also likely to have rapid adoption but only where they can displace current milling varieties. The milling market is small compared with oats for feedgrain and oats grown for grazing and then harvested for grain. The new variety Mitika is not suited for grazing. Oats is grown in a more diverse range of environments and for more varied markets than durum and triticale. Therefore any one variety is unlikely to be well enough adapted to be adopted rapidly and widely. A GRDC survey showed that less than a quarter of growers had adopted a new oat variety in the previous five years (GRDC, 2005).

7.2 The Counterfactual (Outcomes without the GRDC Investment)

This evaluation is based on a comparison of benefits arising as an outcome from the GRDC investment in the four projects compared with the outcome if there had been no GRDC investment. The comparison needs to take account of how funding for breeding programs is evolving since the first of the projects began in 2003. The

projects aimed to more effectively bring together for each crop the long-established breeding programs previously being run by Universities and State Government Departments. The projects have a strengthened national coordination component. The two related key drivers were the introduction of Plant Breeders Rights and the decline in funds from the host organisations, related for example to the State's responses to National Competition Policy. GRDC had traditionally supported investment in the host organisation programs but on a more ad hoc or even supply-driven basis, and with only limited national coordination or rationalisation. PBR provided opportunities for a more commercial approach provided that royalties could be captured.

Capture of EPR is likely to be most effective for durum because the majority of the crop has been marketed through the Australian Wheat Board. Even with continuing deregulation, EPR capture will remain high because the majority of the crop is for export and enters grain receival systems. In contrast, triticale and oats are marketed through a very diverse range of channels, or else used on farm. There is a Pork Australia breeding program for triticale funded to produce varieties tailored to pork production. These varieties are unlikely to be as widely adapted as varieties bred by the GRDC program. However, newer varieties would be more widely adopted as older triticale varieties with reduced resistance to disease declined in yield. Similarly with oats there are other breeding programs operating on a near commercial basis, for example targeting varieties for hay and forage production.

In the absence of the GRDC investment, breeding programs would have been much more modest. Public sector agencies could have been expected to scale back, sell off or even terminate their programs. Commercial interests may have purchased rights to existing germplasm and been able to fund limited ongoing programs where there is a capture mechanism for a particular end use. Imported varieties have not been a low-risk viable alternative without a major investment to develop adapted varieties. They are unlikely to generally substitute for breeding programs geared to producing varieties adapted to the wide range of difficult Australian environments.

The key assumption in the absence of the GRDC investment is that it would have taken a decade before alternative arrangements released a limited range of new varieties. On that basis, the additional benefits due to the GRDC investment (the 'with minus without' situation) are reduced after a decade has elapsed since the start of the investment in 2003. The reduction allows for the likelihood of some limited and opportunistic release of new varieties in the absence of the GRDC investment in the 'Other Cereals' Cluster. The reduction recognises that varieties from smaller targeted programs are not likely to be as high yielding or as widely adapted.

In summary, in the absence of the GRDC investment in the 'Other Cereals' Cluster, the assumption is made that there would be some release of new varieties but not until 2012. These varieties are assumed to be a gradually increasing proportion of the benefits achieved by the releases from the Cluster program. Over the period from 2012 to 2032 the proportion is increased from zero to one-third except for durum where the increase is to one half. Durum is more likely to eventually develop some capacity in the absence of GRDC investment because of the better opportunity to capture end point royalties.

7.3 Period of Investment and Associated Benefits - the Investment Model

Investment in breeding new varieties is generally a continuum. Therefore a project-based investment model needs to consider the value of the capital stock at the beginning and end of the project period. The varieties released during the course of the four projects are a result of investments made during the project and over the decade or more prior to the project in some cases. At the end of the projects a capital stock is available as a basis for further investment and release of new varieties. If the evaluation was to show the benefits from a short and discrete project within a longer term breeding program, then the initial capital might also be considered. If the decision was to invest or not, then the initial capital as at 2003 is a sunk cost. The initial and final capital values would tend on average to be similar in a steady state model.

The breeding programs in this cluster have been increased to some extent compared with previous projects. With significant further investment the projects could capitalise on the germplasm built up and develop benefits and royalty income from new releases. Thus, the investment decision in 2009 would simply be a repeat of this investment from 2003. Given the complexity of estimating the residual value in the form of potential intellectual property at the end of the project, the preferred approach is inclusion of the change in capital value of the stock of germplasm as an unquantified benefit.

The analysis excludes royalties as they are a transfer payment and not therefore included in an economic evaluation. The costs of promoting new varieties are partly met by extension agencies and have not been included on the basis they are minor and in any case they do not change if a new variety displaces an old variety.

7.4 Summary of Assumptions on Benefits from the four projects

A summary of the key assumptions made is shown in Table 7.

Table 7: Summary of Assumptions for Estimating Impact of Investment in the Breeding Programs for Oats, Triticale and Durum Wheat

Item	**Durum**	**Oats**	**Triticale (national)**	**Triticale (dual purpose)**
With the GRDC investment				
Base production (all years, ,'000 tonnes per annum)	600	1,350	450	150
Yield Increase (%)	5	5	8	12
Cost Reduction ($/t)	7.9	4.5	7.2	10.4
Benefit ($/tonne)				
2007	7.9	4.5	7.2	10.4
2017	7.9	4.5	7.2	10.4
2033	7.9	3.0	4.8	6.9
Adoption (% of base)				
2007	0	0	0	0
2017	40	30	40	60
2033	40	30	40	60
Without the GRDC investment				
Benefits as a % of the with GRDC investment				
2012	0	0	0	0
2033	50	33	33	33

Note: Years are financial years, for example 2007 is for the estimate at the end of 2006/07. Estimates for intermediate years to those tabled are interpolated using linear trends.

8 Results

All past costs and benefits were expressed in 2006/07 dollar terms using the CPI. All benefits after 2006/07 were expressed in 2006/07 dollar terms. All costs and benefits were discounted to 2006/07 using a discount rate of 5%. The base run used the best estimates of each variable, notwithstanding a high level of uncertainty for many of the estimates. All analyses ran for the length of the investment period plus 25 years from the last year of investment (2007/08 to 2032/33, the final year of benefits assumed).

Investment criteria were estimated for both total investment and for the GRDC investment alone. Each set of investment criteria were estimated for different periods of benefits. The investment criteria were all positive for the ten year period and above as reported in Tables 8 and 9.

8.1.1.1.1.1.1 Table 8: Investment Criteria for Total Investment (discount rate 5%)

Criterion	0 years	5 years	10 years	15 years	20 years	25 years
Present value of benefits (m$)	0.57	10.09	25.40	36.74	44.10	48.77
Present value of costs (m$)	17.91	17.91	17.91	17.91	17.91	17.91
Net present value (m$)	-17.35	-7.82	7.49	18.83	26.19	30.86
Benefit cost ratio	0.03	0.56	1.42	2.05	2.46	2.72
Internal rate of return (%)	negative	negative	9.8	13.2	14.2	14.6

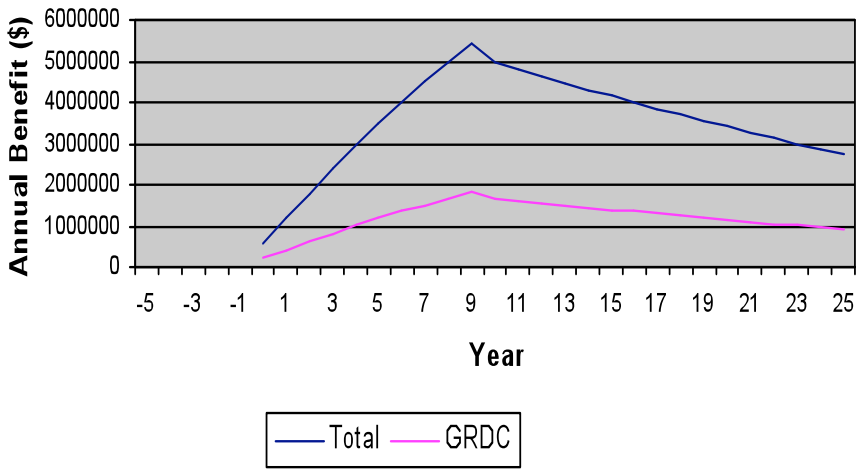
8.1.1.1.1.1.2 Table 9: Investment Criteria for the GRDC Investment (discount rate 5%)

Criterion	0 years	5 years	10 years	15 years	20 years	25 years
Present value of benefits (m$)	0.19	3.40	8.55	12.36	14.84	16.41
Present value of costs (m$)	6.00	6.00	6.00	6.00	6.00	6.00
Net present value (m$)	-5.81	-2.61	2.54	6.36	8.83	10.40
Benefit cost ratio	0.03	0.57	1.42	2.06	2.47	2.73
Internal rate of return (%)	negative	negative	9.9	13.3	14.4	14.7

In terms of the quantified benefits, 100% could be attributed to the productivity and adding value component of the rural research priorities.

The cash flow of benefits is shown in Figure 1 for both the total investment and for the GRDC investment.

Figure 1: Annual Benefit Cash Flow



Sensitivity Analyses

Sensitivity analyses were carried out on a range of variables and results are reported in Tables 10 to 12. All sensitivity analyses were performed using a 5% discount rate with benefits taken over the life of the investment plus 25 years from the year of last investment. All other parameters were held at their base values in Tables 10 and 11 while two variables were changed at the same time in Table 12.

The key assumptions identified for the sensitivity analysis were the yield increase achieved by the new varieties and their rate of adoption. Three sensitivity analyses are presented covering yield increase, rate of adoption, and one when both are varied together. A positive relationship could be expected between yield increase and adoption rate.

Table 10 shows results for the investment criteria when the yield improvement due to the breeding program change is varied.

Table 10: Sensitivity to Assumption Regarding Yield Improvements due to the Breeding Program Investments
(GRDC investment, 5% discount rate; 25 years)

Criterion	**All yield improvements**		
	Reduced by one third	**Base levels**	**Increased by one third**
Present value of benefits (m$)	10.89	16.41	22.23
Present value of costs (m$)	6.00	6.00	6.00
Net present value (m$)	4.89	10.40	16.22
Benefit cost ratio	1.81	2.73	3.70
Internal rate of return (%)	10.4	14.7	20.1

Table 11 shows the results for the investment criteria when the adoption levels change.

Table 11: Sensitivity to Adoption Levels Assumed
(GRDC investment, 5% discount rate; 25 years)

Criterion	Adoption Levels in 2017 and 2033		
	Decreased by One Third	**Base Levels**	**Increased by One Third**
Present value of benefits (m$)	10.99	16.41	21.82
Present value of costs (m$)	6.00	6.00	6.00
Net present value (m$)	4.99	10.40	15.82
Benefit cost ratio	1.83	2.73	3.64
Internal rate of return (%)	10.5	14.7	18.2

Table 12 provides the results for the analysis when both the adoption levels and yield improvements are varied together.

Table 13 presents the net present value (NPV) for low, expected and high adoption assumptions for each of the 0, 5, 10, 15, 20 and 25 year timeframes (for all investment).

Table 12: Sensitivity to Both Adoption Levels and Yield Improvements
(GRDC investment, 5% discount rate; 25 years)

Criterion	Adoption Level and Yield Improvement		
	Both Decreased by One Third	**Base Level**	**Both Increased by One Third**
Present value of benefits (m$)	7.30	16.41	29.56
Present value of costs (m$)	6.00	6.00	6.00
Net present value (m$)	1.29	10.40	23.56
Benefit cost ratio	1.22	2.73	4.93
Internal rate of return (%)	6.6	14.7	24.5

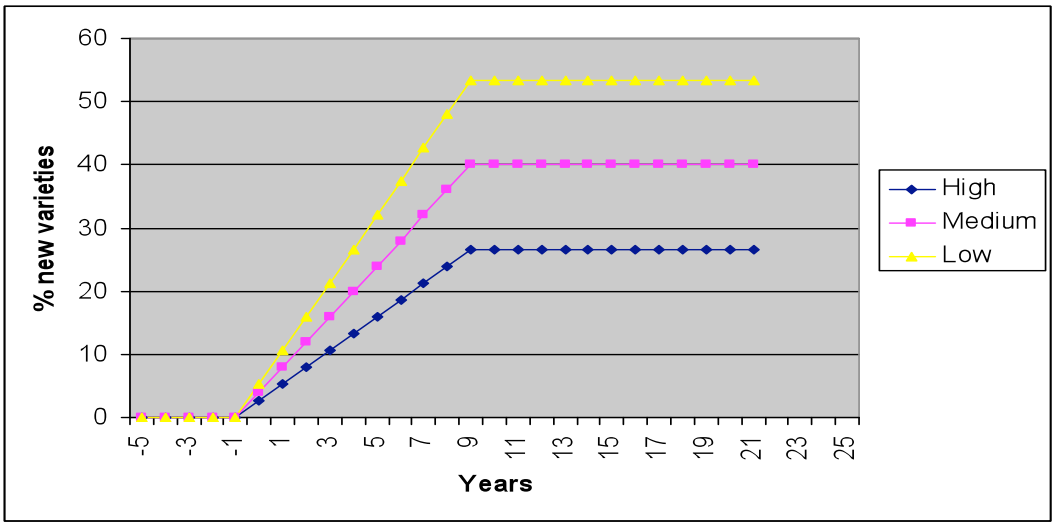
Table 13: Net Present Value Sensitivity to Adoption
(all investment; 5% discount rate; $m)

NPV	Project Horizon (years)					
	0	5	10	15	20	25
Low	-17.53	-11.15	-0.89	6.71	11.63	14.76
Base	-17.35	-7.82	7.49	18.83	26.19	30.86
High	-17.16	-4.49	15.87	30.95	40.74	46.95

Note: 'Low' is based reduced by one third; 'High' is base increased by one third

Figure 2 shows the low, expected and high adoption profile for Durum wheat expressed as a percentage of all varieties grown.

Figure 2: Low, Expected and High Adoption for New Durum Wheat Varieties



9 Conclusions

Cost-benefit analysis undertaken in this report indicates that the funds invested in the 'Other Cereals' Cluster will generate a positive but relatively modest return. The five year investment of close to $6 million by GRDC and $11 million by host organisations over the five year period from 2003/04 is estimated to have generated a net present value of $31 million in 2006/07 dollar terms, a benefit cost ratio of 2.72 to 1 and an internal rate of return of 14.6 percent over 25 years.

The benefit cash flow as was shown in Fig 1 is the typical expected pattern for a breeding project based on increasing adoption of a new variety up to a peak and then a decline a decade after release of the variety. The major part of the decline reflects that the benefits are only those additional to what would have happened in the absence of the GRDC investment. In that case, other breeding programs were assumed to develop much more slowly. The net present value of the total investment as determined by the benefit cash flow in relation to the present value of the investment achieves a break even level by 2013.

The returns identified by this analysis are in accord with what might be considered the expectation for typical projects as part of ongoing breeding programs with often long lead times. Breeding projects do occasionally have breakthroughs and exceptional benefits, but in most cases the gains are gradual. Oborne and Jervois (1993) reported an exceptional prospective return to a SARDI oats breeding program, but that was based on releasing a breakthrough variety with improved resistance to a major disease problem in southern Australia.

These projects did however have features that distinguished them from their predecessors. They were expanded efforts to achieve better coordinated national efforts to meet GRDC aims of achieving faster adoption of superior varieties. The projects were designed to capitalise on the opportunities from Plant Breeders Rights that have been introduced to stimulate private investment in plant breeding, and provide better feedback on performance.

Durum, oats, and triticale, the crops included in 'Other Cereals' Cluster are not major crops from a national perspective but they have an important role to play in many regions. Durum has excellent prospects for expansion to meet increased demand for pasta products. Oats and triticale are versatile crops producing grain in markets that have been expanding.

The evaluation was based on rapid adoption by superior varieties. The evaluation did not include the residual value of the projects, or the initial resources available from predecessor projects. The projects have resources available, and an increasing capacity to continue to develop further superior varieties, but that would clearly require ongoing investment. The analysis did not evaluate benefits from improved quality, or from grazing for varieties that are usually grazed, or from benefits to other crops in rotations. The oats breeding program may include some limited cross-subsidisation of oaten hay research. Overall the additional unquantified benefits and costs are unlikely to substantially alter the results.

The results were sensitive to the key assumptions relating to the yield and benefit increase, and to the rate of adoption. A feasible one third decrease in both the benefit and the rate of adoption was sufficient to lower returns close to a break even level. Given that the analysis assumed relatively rapid adoption rates, and some major yield increases, the sensitivity to these assumptions shows that the level of costs are the key factor contributing to the modest returns. The costs attributed to the host organisation for the oats project were the largest cost component in the 'Other Cereals' Cluster.

The crops in total account for only five percent of the gross value of grain production. Their breeding programs will continue to be challenged to achieve economies of scale necessary for an efficient national breeding program with varieties adapted to diverse environments and markets. However the 'Other Cereals' Cluster also has an important role in ensuring a more resilient grain industry with a range of well adapted and versatile crops in its portfolio. That role will be increasingly important in a more uncertain future.

10 Acknowledgments

Vince Fernandes, Business Analyst, Grains Research and Development Corporation
Ray Hare, Plant Breeder (Durum) NSW Department of Primary Industries
Sara Hely, Project Manager-Plant Breeding, Grains Research and Development Corporation
Peter McCormack, Manager, Interstate Trial Coordination, PIRSA (Department of Primary Industries and Resources of South Australia)
Robert Park, Plant Breeding Institute, University of Sydney
Jason Reinheimer, Plant Breeder (Triticale), Australian Grain Technologies
Jeremy Roake, Plant Breeder (Triticale), University of Sydney
Colin Wellings, Plant Breeding Institute, University of Sydney
Pamela Zwer, Plant Breeder (Oats), SARDI (South Australian Research and Development Institute)

11 References

ABARE (2006). "Australian Commodity Statistics 2007", Canberra.

AGT (2008) "Hawkeye – Triticale". Factsheet, Australian Grain Technologies, Adelaide.

Brennan, J.P. and Bialowas, A. (2001) "Changes in Characteristics of NSW Wheat Varieties", 1965-1997, Economic Research Report No. 8, NSW Agriculture, Wagga Wagga.

Brown A., Lawrance L., and O'Donnell V. (2007) "Grains – Outlook for Wheat, Coarse Grains and Oilseeds to 2011-12", Australian Commodities, Vol 14 No 1, pp.27-41.

CSIRO and Bureau of Meteorology (2007). "Climate Change in Australia": Technical Report 2007, CSIRO, Melbourne.

GRDC (1992) "Gains for Grains – Overview".Vol 1, GRDC Canberra.

GRDC (2005) "Annual Report, 2004-05." GRDC Canberra.

Gunasekera, D., Yeon Kim, Tulloh. C., Ford, M. (2007) "Climate Change -Impacts On Australian Agriculture" Australian Commodities Vol. 14 No. 4, December Quarter 2007.

Hafi , A. and Connell, P. (2003) "Feed Grains: Future Supply and Demand in Australia", ABARE

Nicol A (2003) "The great feedgrain mystery starts to give up its secrets". Australian Grain , 13:4 , p6.

NSW DPI (2005) "Development Officer to help boost durum industry" http://www.dpi.nsw.gov.au/archive/news-releases/agriculture/2005/development_officer

NSW DPI (2007). Farm Enterprise Budget Series, New South Wales Department of Primary Industries.

Oborne, G. and Jervois, K (1993). "Breeding special purpose oat cultivars with resistance and tolerance to cereal cyst nematode". In Gains for Grains Vol 2 Case Studies, p49-53. GRDC, Canberra.

PIRSA (2008) "Oat Variety Sowing Guide", Fact Sheet 9/86/08. Department of Primary Industries and Resources of South Australia

Roberts G. (2005) "Situation Analysis – Nature of Dual Purpose Oats Industry", Temora Agriculture and Research Station Report, NSW DPI.

Saunders, R.(2007) "Speedee races home on a dry track", SARDI.

Waratah (2008). “Endeavour – Dual Purpose Triticale”. Factsheet, Waratah Seed Company (based on data supplied by NSW Department of Primary Industries).