An Economic Analysis of GRDC Investment in a Functional Genomics Program

Executive Summary

The interest in gene manipulation for grains has been increasing over the past decade. Investment in cereal genomics had been growing in the early 2000s in both the public and private sectors. Access to and control of gene sequences and the associated intellectual property were seen as key factors in maintaining a competitive plant improvement program and the maintenance of control over improved cereal varieties.

The GRDC supported projects (UA523 to 529) identified and cloned a large number of genes and/or proteins with putative function. The overall investment produced a number of patent applications in which GRDC has an intellectual property interest.

Of the patent applications two technologies and their related patent applications were licensed to the Australian Centre for Plant Functional Genomics (ACPFG):

- Polysaccharide Synthase (IP status - a PCT application)
- Tissue Specific Expression (IP status – provisional)

These are the only technologies developed by the GRDC investment that are likely to be commercialised in the medium term future. The long-term benefits are likely to be prospective new cereal varieties, but there would be a number of future steps required before new varieties were successfully developed and benefits captured by Australia.

The most prominent and most well defined commercial application underway is that of increasing the dietary fibre content of wheat due to the manipulation of the family of genes involved in expressing levels of beta-glucans. Such manipulation has implications for human health via reduced cardiovascular disease and colorectal cancer. Already a significant level of expression of beta glucans has been attained and proof of concept has nearly been completed.

Without the investment in UA523 to UA529 and the following projects to December 2007, it is assumed the discovery and patenting of the beta-glucan synthase would not have occurred, either in Australia or elsewhere.

This cluster represents a high risk–high return investment for GRDC. Research in this cluster is highly strategic and long term. The valuation of benefits from the investment needs to lean heavily on other projects and events along the biotechnology product pipeline requiring the use of hypothetical costs and expected values of both benefits and costs. The results show that the expected value of the original investment by GRDC is positive with a net present value of $3.8 million and a benefit cost ratio of 1.4 to 1. These results should be considered an underestimate as the technology valued is only one of the two potential commercial applications that resulted from the GRDC investment.

Background

The interest in gene manipulation for grains has been increasing over the past decade. In particular the area of functional genomics (determining the function and expression of newly discovered genes) has been given increased attention not only in Australia but also elsewhere, especially in the USA and Europe.

Investment in cereal genomics had been growing in the early 2000s in both the public and private sectors. Access to and control of gene sequences and the associated intellectual property were seen as key factors in maintaining a competitive plant improvement program and the maintenance of control over improved cereal varieties. Loss of control could act to the detriment of Australian grain production and its relative profitability with overseas grain producers.

As Australian scientists had been at the forefront of research into plant cell walls, grain physiology and plant molecular genetics in the past, GRDC decided that a competitive advantage may be able to be maintained and a biotechnology niche developed in functional genomics associated with the genomics of cell wall and grain development in cereals and their relationship with grain quality. Initially, the genomics of cell wall development was also examined in vegetative tissues and this work led to new collaborative projects with DuPont Pioneer. However, as the UA523-529 projects were rolled into UA000083, the work was focused on the development of grain and its regulation.

The Investment

Program Objectives

The overall objective of the investment in this series of projects was to apply emerging tools, technologies and expertise in cereal genomics to specific targets of relevance to Australian cereal industries, namely the definition of factors that control early seedling growth and vigour as well as grain quality.

Projects Funded by GRDC

Seven projects were initially funded by GRDC in this investment as listed in Table 1.

Table 1: Functional Genomics Projects Funded by GRDC

Project Code and Title	Aims/Objectives
UA523: Functional Genomics in the Growth and End-Use Quality of Cereals: Coordination	(i) To develop expertise in functional genomics technologies that would enhance Australia's capacity to be part of the revolution in agricultural biotechnology (ii) To provide the coordination and management of the overall functional genomics program (UA523 to UA529)
UA524: Functional Genomics in the Growth and	The broad aim of the project was to identify genes for the major enzymes involved in synthesising

End-Use Quality of Cereals: Genes and Enzymes Responsible for Cell Wall Synthesis in Cereals	components of cereal cell walls, using barley protoplasts as a model system
UA525: Functional Genomics in the Growth and End-Use Quality of Cereals: Coordination of Gene Expression and Enzyme Activity in Young Seedlings	The broad aim of the project was to contribute to the overall objective of the program through generating and screening of expressed sequence tag libraries, defining expressed protein profiles, analysis of cell walls and the functional analysis of key major and regulatory genes in elongating coleoptiles
UA526: Functional Genomics in the Growth and End-Use Quality of Cereals: Coordination of Gene Expression and Enzyme Activity in Developing Grain	The broad aim of the project was to contribute to the overall objective of the program through describing in detail the coordination of gene expression and enzyme activity in the endosperm during grain development
US527: Functional Genomics in the Growth and End-Use Quality of Cereals: Construction of Cell and Tissue Specific Libraries from Developing Wheat	The key objective of the project was to develop a series of cDNA libraries from components of the ovule and early grain development of wheat
UA528: Functional Genomics in the Growth and End-Use Quality of Cereals: Transcript Analysis from Specific Cells and Tissues	The key objective of the project was to develop methods for measuring transcript levels in components of the egg sac and during early grain development of wheat
UA529: Functional Genomics in the Growth and End-Use Quality of Cereals: Analysis of Genes Controlling Early Embryo and Endosperm Development	The key objective of the project was to analyse the sequences produced in UA527 and UA528 to identify full length genes, characterise expression patterns and develop functional information

Investment Contributions

Estimates of the funding by project by year for the GRDC investment in the seven projects are reported in Table 2.

Table 2: Investment by GRDC by Project for Years ending June 2000 to June 2004 (nominal $)

Project	1999/00	2000/01	2001/02	2002/03	2003/04	TOTALS
UA523	55,842	58,448	61,816	274,667	66,022	516,795
UA524	228,420	262,987	286,105	296,961	306,987	1,381,460
UA525	281,575	290,115	298,801	307,482	315,472	1,493,445
UA526	209,560	215,933	322,408	229,393	235,339	1,212,633
UA527	142,482	143,396	144,345	145,328	145,977	721,528
UA528	56,010	57,818	59,687	61,619	63,245	298,379
US529	56,010	57,818	59,687	61,619	63,245	298,379
Totals	1,029,899	1,086,515	1,232,849	1,377,069	1,196,287	5,922,619

Source: GRDC

There also were in-kind contributions from the research partners (Melbourne University and Adelaide University). Table 3 provides estimates of the partners' aggregate investment in the seven projects for each year, as well as the combined GRDC and partner investment.

Table 3: Investment by GRDC and Others in UA523 to UA529 for Years ending June 2000 to June 2004 (nominal $)

Year	1999/00	2000/01	2001/02	2002/03	2003/04	TOTALS
GRDC	1,029,899	1,086,515	1,232,849	1,377,069	1,196,287	5,922,619
Partners	1,743,000	1,763,000	1,783,000	1,803,000	1,181,800	8,910,000
Total	2,772,899	2,849,515	3,015,849	3,180,069	2,378,087	14,832,619

Source: Partners' investment based on project proposals

There was a continuation of the investment in the seven projects through two other GRDC projects. The first was a small ($20,000) priority setting project carried out in 2004 (GRD191). The second project ran from July 2004 to December 2007 (UA00083). This was a 3.5 year project that consolidated the previous seven projects into a single project. As for the earlier projects, UA00083 was funded by GRDC, Adelaide University and the University of Melbourne. This was the final investment in this stream of GRDC funding. The total investment in the continuing projects is shown in Table 4

Table 4: Total Investment by GRDC and Others in GRD191 and UA00083 for Years ending June 2005 to June 2008 (nominal $)

Year	2004/05	2005/06	2006/07	2007/08	Total
GRDC	620,107	1,200,104	600,000	300,000	2,720,211
Partners	959,800	1,744,800	1,744,800	872,400	5,321,800
Total	1,579,907	2,944,904	2,344,800	1,172,400	8,042,011

Investment Description and Outputs

Process Description
The program focused initially on the central role of the cell walls, the primary determinants of seedling growth and development, as well as key components in pathogen resistance, human nutrition and in determining many quality characteristics of the mature grain.

Seedling vigour, growth and grain quality were examined, not only with a view to the discovery of genes and the mechanisms of their regulation but also the key enzymes and proteins that ultimately control seedling growth and grain development and the structure of the product of the enzymes.

UA0083 focused on beta-glucan synthases and on the regulation of grain development.

Outputs
The GRDC supported projects (UA523 to 529) identified and cloned a large number of genes and/or proteins with putative function. The overall investment produced a number of patent applications in which GRDC has an intellectual property interest.

Of the patent applications two technologies and their related patent applications were licensed to the Australian Centre for Plant Functional Genomics (ACPFG):

- Polysaccharide Synthase (IP status - a PCT application)
- Tissue Specific Expression (IP status – provisional)

These are the only technologies developed by the GRDC investment that are likely to be commercialised in the medium term future.

One aspect of the polysaccharide technologies is being pursued in term of cellulose synthase and is being funded at the ACPFG by Dupont-Pioneer and the Australian Research Council under an ARC Linkage grant. Another application is with beta glucan synthase and this is being pursued by CSIRO under its Food Futures National Research Flagship for improving the human nutritional quality of cereals.

The tissue specific expression technologies (derived from the transcription factor projects) have received interest from Monsanto and Dupont-Pioneer.

Outcomes

Establishment of the Australian Centre for Plant Functional Genomics
The ACPFG was formed in January 2003 and was fully operational by 2004. The GRDC projects gave the Centre an initial focus to build its overall program. In addition they allowed the development of functional genomics technology platforms and associated expertise. The ACPFG is currently working on improving the resistance of wheat and barley to hostile environmental conditions using functional genomic technologies. These

issues include drought, salinity, high or low temperatures and mineral deficiencies or toxicities. Gene technology has the potential to combat some of these challenges.

The Centre has now secured funding for a second five year period from 2008, and involves three major nodes – University of Adelaide, University of Melbourne, and University of Queensland, with a smaller node to be established at the University of South Australia. Programs at the Centre as of 2008 are focused on drought and salinity tolerance in cereals, in particular wheat and barley. Smaller programs on mineral nutrition are also in place. Forward and reverse genetics approaches to enhancing abiotic stress tolerance in wheat and barley are being pursued and are supported by the appropriate technology platforms, genetic resources, research infrastructure and expertise.

Commercialisation and Capturing of Benefits
The GRDC investments have contributed to the development of functional genomics technology platforms and associated expertise. The patent applications have formed the basis for the development of commercial relationships between the ACPFG and Dupont Pioneer and could lead to the development of other commercialisation partnerships with multinational agricultural biotechnology companies. The next phase is product development of the more promising genes that have high potential value for the grains industry.

Benefits

The long-term benefits are likely to be prospective new cereal varieties, but there would be a number of future steps required before new varieties were successfully developed and benefits captured by Australia.

The shorter-term benefits are:

- an Australian ticket to participate in the growing international activity in cereal genomics
- scientific capacity building

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 Future Benefits from the GRDC Investment

Benefits
<u>Industry Productivity and Profitability</u> • Higher yielding new varieties reducing cost of production per tonne • Varieties with a higher fibre content that attracts price premiums • Varieties with a stronger stem strength that reduces lodging and hence can increase yields • Varieties with altered grain characteristics, including increased grain size and altered grain shape that can enhance milling yields • Avoidance of lowered competitiveness of Australian grains industry through

reduced dependence on GM varieties produced overseas
Environmental • Barley varieties that reduce water consumption in the malthouse
Social • Improved health of cereal consumers due to higher fibre content • Increased capacity of Australian science to be engaged in genetic manipulation activities in plants

Public versus Private Benefits
The benefits identified from the investment in functional genomics for grain are a mixture of private and public benefits. Some of the potential benefits from higher yields and also those for improved quality will be passed along the supply chain to grain processors, and other users of grain including intensive animal producers and ultimately consumers. As the grains industry (particularly wheat) is predominantly export orientated, benefits will be captured in the main by grain producers.

It is likely that some form of functional genomics investment for grain crops would have eventuated if GRDC had not supported the program over this period. It is uncertain whether the APFGC would still have been formed if GRDC had not supported the investment described here. The GRDC recognised the massive investments in cereal functional genomics technologies around the world and rightly understood that if it were not to invest in the technologies then Australian producers could well be placed at a distinct disadvantage internationally. Hence it was likely that if the government contribution to GRDC was removed altogether, there probably would have been some form of functional genomics program with a lowered investment by GRDC and hence less progress would have been made.

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

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 GRDC investment will make its principal contributions to Rural Research Priority 1 through its potential impact on higher cereal yields and value, as well as Rural Research Priority 2 though improved quality and consumer benefits.

The functional genomics investment is likely to make a contribution to National Research Priority 2 through its impact on human health (increased fibre). Frontier technologies have been used in genomic mapping. The investment therefore has made a large contribution to National Research Priority 3 and has demonstrated innovation skills and new technologies (Supporting Rural Research Priorities 1 and 2).

Quantification of Benefits

No commercial benefits to date have emerged from the investment. However, there is a range of potential benefits that may eventuate.

One approach to quantifying the benefits from this investment is to assume some future probabilistic scenario(s) including further development of the IP, and eventual production of a new variety with assumed improved qualities. This would require specifying the various steps that would need to be undertaken, the likelihood of success of each step, their costs, and their timing.

The most prominent and most well defined commercial application underway is that of increasing the dietary fibre content of wheat due to the manipulation of the family of genes involved in expressing levels of beta-glucans. Such manipulation has implications for human health via reduced cardiovascular disease and colorectal cancer. Already a significant level of expression of beta glucans has been attained and proof of concept has nearly been completed. The pursuit of proof of concept is being sought in a project funded under the CSIRO Food Futures Flagship via the CSIRO Flagship Collaboration Fund. The research is being conducted by the University of Adelaide, University of Melbourne and University of Queensland on non-starch polysaccharide technology for "high fibre" grains.

Counterfactual – With and Without

Without the investment in UA523 to UA529 and the following projects to December 2007, it is assumed the discovery and patenting of the beta-glucan synthase would not have occurred, either in Australia or elsewhere.

This cluster represents a high risk–high return investment for GRDC. Research in this cluster is highly strategic and long term. To justify the investment, prospective payoffs need to be very large. Hence any quantification of benefits from the investment needs to lean heavily on other projects and events along the biotechnology product pipeline requiring the use of hypothetical costs and expected values of both benefits and costs.

Assumptions for Estimating Benefits

The following assumptions are made with a high degree of uncertainty as those with knowledge of costs and who could make improved estimates of probabilities and timing are not at liberty to discuss these issues due to confidentiality provision of funding organisations. The following analysis therefore should be considered tentative.

The series of steps assumed to take the knowledge and patent of the control of beta glucan in wheat to a commercial reality to an end point of capturing benefits for Australia includes:

(i) Proof of concept

Proof of concept is currently being sought for manipulation of the gene construct that controls the production of beta glucans in wheat and attaining high level of expression in pot trials. It is assumed that the ability to achieve this will be attained in 2008/09 at a total cost of $1m per annum for three years; these costs are already committed. It is assumed that the likelihood of achieving proof of concept is 70%.

(ii) Licence to effect field trials

To conduct field trials will require the approval of the Office of the Gene Technology Regulator (OGTR). An application has been submitted already to do this during 2008/2009. It is assumed that the likelihood of acquiring this permission is 95%. The cost of gaining this licence has been negligible.

(iii) Field trial success

The maintenance of expression of the trait in the plants grown in the field is assumed to have a likelihood of 80%. This success is assumed to be achieved in 2009/2010 at a cost of $300,000. Success is defined as sufficient evidence to proceed to commercialisation.

(iv) Cholesterol lowering capacity

In contrast to barley and oats where the endosperm walls are largely made up by beta glucans, wheat has a low beta glucan content of less then 1%. Soluble fibre such as beta glucan has been shown to impact on the glycaemic, insulin, and cholesterol response to foods (Brennan and Cleary, 2005), so acting as important functional food ingredients and bestowing potential nutritional benefits.

There is a significant risk that the beta glucan produced in wheat will not lower cholesterol in the same way that oats does. The probability of demonstrating sufficient capacity to lower cholesterol is estimated at 60% at a cost of $1 m.

(v) Successful commercialisation

The probability of successful commercialisation is assumed to be 70% and will take a further five years at a total cost of $10 m. It is assumed that commercialisation is effected in 2014/15 through the genetic modification approach where an existing wheat variety is transformed via insertion of a selected gene (probably from barley) and associated gene promoters. The transformation process may take up to one year but the ensuing tissue culture and field trials to produce elite plants may take another four years.

(vi) Licence to commercialise
Full scale commercialisation will require the approval of the OGTR. It is assumed that the likelihood of acquiring this permission is 75%. It is assumed that attaining this permission (submissions etc) will take a further three years and will be achieved in 2017/18 at a further cost of $3 m for the domestic market. In addition, an estimate of an additional cost of $30 m is likely for overseas markets (Andreas Betzner, pers. comm., 2008).

(vii) Value and Adoption
The increased farm gate price to the grain producer from the high beta glucan wheat is assumed to be 15% above average farm gate prices. The rate of adoption will depend on the comparative profitability of growing the new high fibre variety compared with the then existing varieties. It is assumed that the maximum level of adoption of the new variety will reach 10% of the Australian wheat crop and it will take five years to reach this adoption level.

There will be an increased cost to grow the new variety in terms of a royalty determined by the commercialisation arrangements. The royalty from the use of the IP may be only small as it is assumed that the CSIRO/ACPFG (and hence GRDC) will own all or some of the IP; otherwise the growing cost will be the same as for other varieties. Also it may be preferable to collect any royalty payment on the input side (seed wheat sales) rather than on sale wheat. In either case this is assumed a transfer payment between Australian interests as most of the IP is assumed to be owned in Australia.

The level of beta glucans in the new variety is assumed to be 7.5% DM in the grain.

(viii) Commercialisation Overseas
It is assumed that the technology results in licensing of high fibre varieties using the ACPFG technologies to be grown overseas and that a royalty to Australian interests of $3 per tonne of high fibre wheat accrues to Australia. It is assumed that 12 million tonnes of high beta glucan wheat is grown overseas under licence, with the first year of growing in 2018/19.

(ix) Other Risk Factors
There are other risk factors involved apart from those listed above. These may include competitors developing similar processes earlier than Australia, filing a blocking patent etc. The assumption that none of these critical knock-out factors will apply is 70%.

Summary of Key Assumptions
A summary of the key assumptions made in the analysis is provided in Tables 7 and 8.

Table 7: Key Assumptions in Steps to Taking High Fibre Wheat to Market (tentative)

Step	Status	Probability of Attainment	Year Completed	Cost (m$)
Proof of concept without projects		0.0		
Proof of concept with project	Nearly complete	0.70	2008/09	$1 m per annum for three years
Permission from Australian GM regulator to conduct field trials	Application for licence submitted	0.95	2008/09	$0
Field trial success	Not yet attempted	0.75	2009/10	$300,000
Demonstrate cholesterol lowering capacity	Not yet attempted	0.60	2009/10	$1,000,000
Success of full scale commercialisation and adoption	Not yet attempted	0.70	2014/15	$ 10 m over five years
Permission from Australian GM regulator for full commercialisation	Not yet attempted	0.80	2017/18	$3,000,000
Overseas regulatory approval	Not yet attempted	0.80	2017/18	$30,000,000
No other critical knockout factors applying		0.70	2018/19	Nil

Table 8: Other Assumptions

Factor	Assumption	Source
Average Australian production of wheat	21,675,000 tonnes per annum	ABARE Food industry Statistics, average for years ending 2002 to 2006
Average world production of wheat	600,000,000 tonnes of wheat per annum	ABARE Commodity Statistics (2006)
Mature adoption level	10% of Australian wheat after 5 years from year of first release (first year of adoption assumed to occur in 2018/19) (a)	Agtrans estimate

Quantity of wheat grown overseas subject to the royalty	12 million tonnes after 5 years from first Australian release	Agtrans Research
Level of beta glucan expressed in transformed wheat variety	7.5% DM in grain	Agtrans Research
Value of wheat	$175 per tonne at farm gate	Based on NSW DPI gross margins
Value of beta glucan in Australian grown wheat	15% additional value of wheat per tonne (a)	Agtrans Research
Royalty to Australian interests from overseas grown wheat	$3 per tonne of high fibre wheat (b)	Agtrans Research

(a) The Australian grower achieves a 15% increase in price for the beta glucan wheat. By the time this gets to breadmakers and supermarkets, this could be diluted as many of the value added costs may not increase. However, it would not be unreasonable for consumers to pay up to 15% more for high beta glucan flour products as specialty health breads currently gain such premiums.

(b) The only income Australia would receive would be the royalty from sale of transgene wheat; other benefits would accrue to the overseas market chain and overseas consumers.

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 costs for the R&D included the costs for the seven cluster projects plus the two additional projects (UA00083 and GRD191). Analyses were conducted for both the total investment in the cluster plus the two additional projects, as well as for the GRDC contribution to the cluster investment. The expected values of other costs (e.g. follow on R&D, field trials, etc) were subtracted from the revenue stream.

The base analysis 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 the final year of benefits assumed (2032/33)).

Each set of investment criteria were estimated for different time periods of benefits. The investment criteria were positive after a 20 year time period as reported in Tables 9 and 10.

Table 9: Investment Criteria for Total Investment in Cluster
(discount rate 5%)

Criterion	**0 years**	**5 years**	**10 years**	**15 years**	**20 years**	**25 years**
Present value of benefits ($ m)	-1.95	-4.18	-8.16	6.57	28.18	45.12
Present value of costs (m$)	27.19	27.19	27.19	27.19	27.19	27.19
Net present value (m$)	-29.15	-31.38	-35.35	-20.62	0.99	17.92
Benefit cost ratio	-0.07	-0.15	-0.30	0.24	1.04	1.66
Internal rate of return (%)	negative	negative	negative	negative	5.1	7.0

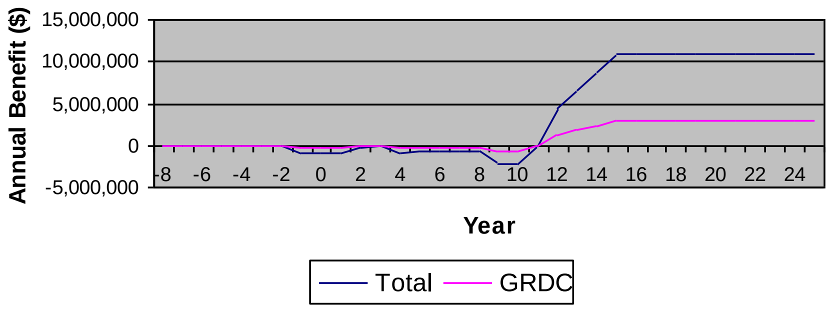
Table 10: Investment Criteria for GRDC Investment in Cluster
(discount rate 5%)

Criterion	**0 years**	**5 years**	**10 years**	**15 years**	**20 years**	**25 years**
Present value of benefits (m$)	-0.54	-1.16	-2.26	1,82	7.80	12.49
Present value of costs (m$)	8.70	8.70	8.70	8.70	8.70	8.70
Net present value (m$)	-9.24	-9.85	-10.96	-6.88	-0.89	3.80
Benefit cost ratio	-0.06	-0.13	-0.26	0.21	0.90	1.44
Internal rate of return (%)	negative	negative	negative	negative	4.6	6.4

In terms of the quantified benefits, it is estimated that all could be attributed to the productivity and adding value component of the rural research priorities. No attempt has been made to value the community benefits involved from the enhanced biotechnology capacity.

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

Figure 1: Annual Benefit Cash Flow



Sensitivity Analyses

Sensitivity analyses were carried out on a range of variables and results are reported in Tables 11 to 13. 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 in the cluster. All other parameters were held at their base values.

If the probabilities are all set to 1, that is, the project proceeds successfully on all counts with the expected costs and timing, the NPV is $408 m, the benefit cost ratio 16 to 1 and internal rate of return is 18%. Hence allowing for the probabilities of success (allowed for in all other analyses including Tables 9 and 10), reduces the investment criteria significantly.

The sensitivity of the investment to tonnage of high beta glucan wheat grown overseas is shown in Table 11. The break even tonnage grown overseas for the investment to remain profitable at a 5% discount rate is 4.2 m tonnes, provided the wheat tonnage grown in Australia remains at 10%. If no high beta glucan wheat is grown overseas, the investment nearly breaks even (internal rate of return of 4%) based on Australian production. If beta glucan wheat is grown overseas at the level assumed, but not grown in Australia, the internal rate of return is just below 2%.

Table 11: Sensitivity to Assumption Regarding Proportion of Overseas Wheat Grown that is High Beta Glucan
(GRDC investment in cluster, 5% discount rate; 25 years)

Criterion	0.5%	Base (2%)	4%
Present value of benefits (m$)	8.10	12.49	18.35
Present value of costs (m$)	8.70	8.70	8.70
Net present value (m$)	0.59	3.80	9.65
Benefit cost ratio	0.93	1.44	2.11
Internal rate of return (%)	4.7	6.4	8.0

The sensitivity of the investment to a change in the price streams (both Australian produced and overseas grown) for beta glucan wheat is shown in Table 12.

Table 12: Sensitivity to Assumptions Affecting Price Streams
(GRDC investment in cluster, 5% discount rate; 25 years)

Criterion	10% price increase for domestic, and $2 per tonne for overseas royalty	15% price increase for domestic, and $3 per tonne for overseas royalty (Base)	20% price increase for domestic, and $4 per tonne for overseas royalty
Present value of benefits (m$)	7.46	12.49	17.53
Present value of costs (m$)	8.70	8.70	8.70
Net present value (m$)	-1.24	3.80	8.83
Benefit cost ratio	0.86	1.44	2.02
Internal rate of return (%)	4.4	6.4	7.8

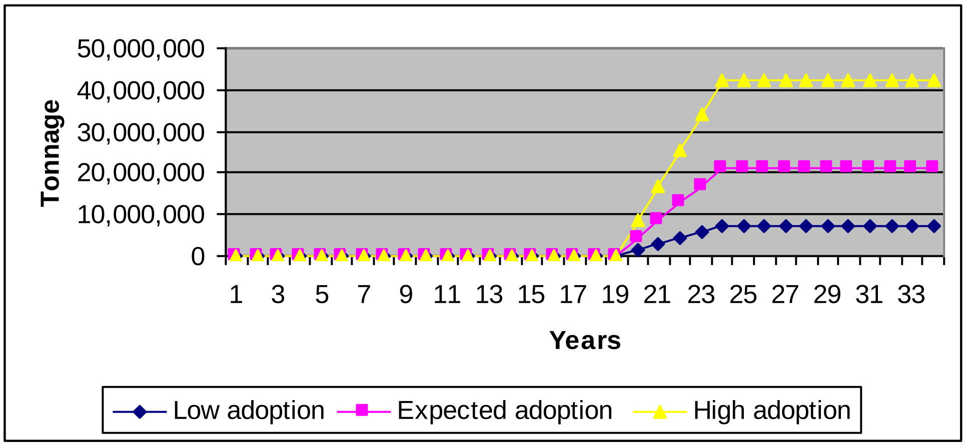
Table 13 presents the net present value (NPV) for low, expected and high adoption assumptions for each of the 0, 5, 10, 15, 20 and 25 year timeframes (for all investment).

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

NPV	Project Horizon					
	0 years	5 years	10 years	15 years	20 years	25 years
Low (50% of expected)	-29.15	-31.38	-35.35	-28.63	-17.82	-9.36
Expected (base)	-29.15	-31.38	-35.35	-20.62	0.99	17.92
High (150% of expected)	-29.15	-31.38	-35.35	-12.62	19.80	45.21

Figure 2 shows the low, expected and high adoption trends (tonnages)

Figure 2: Low, Expected and High Adoption



Conclusions

The GRDC investment in this area has been strategic and knowingly made under a high risk–high return part of the Corporation's investment plan. The analysis is necessarily probabilistic given the uncertainties involved. Given the assumptions made the results are positive.

The investment criteria should be considered an underestimate as the technology valued is only one of the two potential commercial applications that resulted from the GRDC investment. Further, the capacity building in frontier technologies for Australia has been enhanced significantly in the area of cereal genomics

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