



# An Economic Analysis of Investment in the National Variety Trials (NVT)



**An Economic Analysis of Investment in the National Variety Trials**

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Enquiries should be addressed to:

Mr Vincent Fernandes

Corporate Strategy & Impact Assessment

Grains Research and Development Corporation

PO Box 5367

KINGSTON ACT 2604

Phone: 02 6166 4500

Email: v.fernandes@grdc.com.au

Author:

Agtrans Research in conjunction with Barry White

PO Box 385

TOOWONG QLD 4066

Phone: 3870 4047

Email: info@agtrans.com.au

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## Executive Summary

An economic evaluation of the initial GRDC investment in the National Variety Trials (NVT) has demonstrated that although there is a high level of grower and adviser awareness of NVT, the likely benefits on current indications are only achieving a modest rate of return. The NVT aimed to contribute to more rapid adoption by providing the grains industry with more reliable, unbiased and timely information on the performance of new varieties in relation to those grown currently. But new varieties have traditionally taken some time to have an impact given the lags in adoption and the years required to bulk up seed. In addition, the last decade has been a difficult one for growers in terms of what many see as risky decisions on adopting new varieties. The new varieties trialled by the NVT are from breeding programs for ten crops covering wheat, coarse grains, pulses and canola. The total cost in present value terms of the GRDC investment over the five years to 2008/09 was of the order of \$20 million. The overall benefit to cost ratio was a modest 1.2 to 1 and the internal rate of return on funds invested was 10.3 percent.

The investment included nine service agreements to undertake trials on specific crops in different regions and to manage the overall NVT. The NVT aims to accelerate the confident adoption of superior varieties released from breeding programs regardless of where they are bred. This is achieved by an extensive system of the order of over 500 trials sown at 250 locations each year. By 2007 results were available on-line.

The need for a NVT grew out of the rapid changes in plant breeding over the last decade. Introduction of End Point Royalties (EPR) has seen private sector investment dominate particularly for wheat breeding. The shift has been from largely state and institution-based programs where variety trials had an established tradition as an extension of breeding programs, to commercial operations.

GRDC commissioned a review of progress made by the NVT in 2008 and concluded that despite difficult seasons the arrangements were satisfactory and were working well. However in relation to the central question for this evaluation, the review stated: *"We saw no unequivocal evidence that NVT had increased the rate of adoption of newly released varieties"*. Steps were recommended and later implemented by GRDC to provide improved evidence, for example from grower surveys and monitoring of adoption. Some of the evidence from surveys simply shows that growers use varieties that range from recent to old. But in 2008, 77 percent were growing some areas of wheat varieties more than ten years old.

There was clearer evidence from grain deliveries that the national average rate of varietal turnover has been paradoxically decreasing for wheat and barley. The turnover rate can be measured by the weighted average age of the most popular varieties. In the GRDC Northern Region the increase in average age has been rapid, from 9 years in 2006 to 14 in 2009 (an international review stated that an age of 14 was in the upper range for developing countries). For the rest of Australia the age has been more stable at about 9 years. For the Northern Region, the implications are a much reduced capacity of the industry to adapt and respond whether that is to climate change or to new strains of diseases.

The conclusion is, given there are serious implications from such a rapid decline in varietal turnover in a region, high priority should be given to analysing the underlying factors. The analysis would need to include a more objective analysis of

grain deliveries in terms of age of varieties and of possible interactions between grower expectations of genetic gain and varietal turnover. Such an analysis could have major implications not just for NVT but more generally for a range of GRDC priorities and strategies. For example the reduced rate of varietal turnover would be reflected in industry level measures of productivity.

Survey information shows a high level of grower awareness of NVT and of high levels of use by advisers. NVT Online is being increasingly used. However a conservative assumption has to be made for this evaluation given the conflicting evidence on the reduced rate of turnover associated with the increasing age of varieties. The NVT goal of speeding up adoption would be achieved by reducing average age of varieties and therefore increasing turnover. The assumed impact of the NVT was for a small increase in the rate of adoption compared to what it would have been without NVT. The rate is assumed to increase from 2007 to 2011. For the purpose of calculation, the increased rate of adoption was assumed to have yield impacts equivalent to a 10 percent increase in a base annual rate of yield increase of 0.75 percent. A variety adoption model was developed to account for the complex lagged impacts of an increased adoption rate on the changing market share and on a yield index.

The benefits valued in this analysis are a conservative estimate because of uncertain but positive benefits that could not be quantified. They total \$24.2 million (present value terms) from a total investment of \$20.2 million (present value terms) providing a benefit cost ratio of 1.2 to 1 (over 30 years, using a 5% discount rate). The Internal Rate of Return for the evaluation was 10.3 percent. The analysis has not evaluated the likely future benefits from the development of an integrated national data base of varietal performance. Neither have the potential efficiency gains been evaluated compared to the system that preceded NVT which was based on state-based trials. Superior varieties have only been defined in general terms and not by analysing components, particularly relating to yield, quality and disease resistance. A sensitivity analysis did show that an assumption of more rapid adoption, by bringing adoption forward three years, would increase the present value of benefits by two thirds. This does demonstrate that the lag in adoption which NVT aims to reduce is a key factor and benefits will increase as NVT is more widely used.

The following table (from Section 5 – Benefits) summarises the notable benefits resulting from the investment in the NVT.

Categories of Notable Benefits from the Cluster Investment

Benefit	Levy paying industry and its supply chain	Spillovers		
		Other industries	Public	Foreign
Economic	Increased profitability from increased yields, and disease resistance due to earlier use of superior varieties.			
Environmental	Minor reduction in fungicide use.			
Social	Enhanced skills and capacity in statistical analysis of NVT contributing to more efficient variety testing.			

## 1. Introduction

This evaluation is of the first five years 2005-2009 of investment in the NVT (National Variety Trials). Breeding and testing of new varieties of grains has changed dramatically since the creation of the Plant Breeder's Rights legislation in 1994. Private investment funded by End Point Royalties (EPR) now dominates. The shift for most grains has been from largely state and institution-based programs where variety trials were an extension of breeding programs, to commercial operations. Following strong support from growers and from industry, GRDC developed the NVT as a national system in 2005.

The NVT replaced the previous Crop Variety Trials (CVT) to better develop and provide standards to underpin a national approach, and to make high quality data easily accessible from a national data base. The NVT is managed by ACAS (Australian Crop Accreditation System), a not-for-profit company established to provide information on the performance of field crop varieties. ACAS represents the GRDC as NVT funders, Grain Producers Australia, and the Australian Seed Federation.

Timescales for the breeding, testing and adoption of new varieties are often more than two decades. A decade can be needed from first crossing to release of a new variety which could then have a life of over a decade. EPR was introduced from 1996; however there are varieties still grown where no EPR is payable. There are long lags involved which an evaluation needs to take into account. Investment in breeding is for the long term. A longer timescale is also relevant for an evaluation where NVT needs to be compared to the system that might have evolved if GRDC had not funded the current system. During the early 1990s there were eleven wheat breeding programs, five of which were servicing the then recently defined GRDC Northern Region (Clements et al 1992). Now, with the rationalisation made possible with changes to GRDC regionalisation and funding, and with EPR, there are three national wheat breeding companies and one smaller specialised program for the high rainfall zone.

NVT has evolved from a long tradition of public sector procedures for variety testing and release. The historical perspective is relevant because many growers had a degree of comfort and confidence in the old system, despite some shortcomings. The review by Lazenby et al (1994) outlined the then similarities and differences between the states. Notable differences of concern included procedures for release and recommendation of new varieties and in one state, average delays of up to two years before varieties released interstate were recommended. The Clements et al review mentioned assertions of public breeding programs being strongly competitive (but between state-based semi-monopolies). Further "*deliberate actions were taken to exclude varieties developed in other regions or states*". Nevertheless the review had data showing that varieties bred interstate accounted for 40 percent of production (based on four years over the decade to 1991). By 2005 the proportion would have reduced particularly following the success of Western Australian bred varieties in Western Australia.

NVT data is available on-line so growers can access reliable and unbiased information on the latest varieties relevant to their region. A major aim of NVT is to accelerate the confident adoption of superior varieties released from breeding programs regardless of where they are bred. All Australian winter cereal, pulse and canola breeders are included. This is achieved by an extensive system of the order of over

500 trials sown at 250 locations each year. There are 10 of the 25 crops covered by GRDC through research levies in the NVT. The crops in the NVT account for about 90 percent of the gross value of production of GRDC crops. The crops tested are:

<u>Wheat</u>	<u>Pulses</u>	<u>Other</u>
<u>Coarse Grains</u>	Lupin	Canola
Barley	Lentils	
Triticale	Field Pea	
Oats	Faba Bean	
	Chickpea	

Sorghum is the largest crop not included, partly because of the spread of planting times presenting difficulties for standardised testing. Other crops not included are generally minor crops often grown in particular regions. They consist of four coarse grains, six pulses and four oilseeds.

The NVT was independently reviewed in 2008. The focus of the review was on a range of operational and strategic issues, many of which had emerged in the first few years. The review summarised by Juttner (2009) found that overall *"the NVT concept and operational arrangements are sound and working well on the ground."* The review had one specific term of reference aimed at directing its focus to outcomes rather than outputs and processes. Terms of Reference 1.2 asked: *"Is the current NVT system facilitating an increased rate of new cultivar adoption by grain growers?"* In the absence of any relevant outcome objectives, the review team reverted to key performance indicators (KPI) for varietal adoption from the GRDC strategic plan (GRDC, 2007). These included measurable indicators for growers, advisers and breeding programs in terms of adoption relating to NVT. However, as the review team stated, they were not made aware of any process at that time whereby GRDC collects the data needed to actually address the KPI, including on:

- the rate of adoption of new varieties,
- the proportion of advisors using NVT results, and
- the number of breeding programs participating.

Overall the review team concluded: *"We saw no unequivocal evidence that NVT had increased the rate of adoption of newly released varieties"*. Since the review was completed, GRDC has responded to the review recommendations relating to NVT outcomes. In particular grower surveys have been expanded to include grower use of NVT data.

The evaluation is based on superior varieties, for example from higher yields, disease resistance and quality improvements resulting in increased profitability to growers. A cost benefit framework is utilised and supported where possible with non-financial information on impacts. The major outcomes are then valued to estimate impacts mainly from an economics perspective (and social and environmental perspectives where appropriate) A sensitivity analysis of the assumptions is undertaken, confidence estimates are provided, and the conclusions and lessons learnt are then discussed in the final section of the report.

## 2. Project Investment

### Projects Funded by GRDC

Nine projects have been funded by GRDC in this investment cluster in the period from 2005 to 2009 as listed in Table 1.

NVT is funded through GRDC's Varieties Line of Business (LOB) and its strategy to '*Facilitate faster adoption of superior varieties*'. This includes the specific objective of '*Accelerating grower adoption of superior varieties, and the promotion of results from the National Variety Trials Program*' and the more detailed critical success factors and key performance indicators (KPIs) from GRDC's Variety LOB Strategic research and development (R & D) plan 2007-12.

The projects were part of the GRDC Output Group 2 – Varieties. The current GRDC objective for Varieties is:

*"Growers have access to superior varieties that enable them to effectively compete in global grain markets".*

Table 1: NVT Projects Funded by GRDC to 2009/10

<b>Project Code/Duration</b>	<b>Project Name</b>	<b>Institution/ Project Manager</b>
AGT00006 11/04/05 - 31/01/10	NVT Service Agreement-trials	Kalyx Agriculture Pty Ltd Ashley Bacon
AGI00001 09/05/05 -31/03/10	NVT Service Agreement-trials (inc GM canola)	Agrisearch Pty Ltd David Leah
AVS00001 16/05/05 -31/03/10	NVT Service Agreement-trials/pathology	Agriculture Victoria Services Angela Clough Grant Holloway
DAN00078 11/04/05 - 28/02/10	NVT Service Agreement-trials/pathology	NSW DPI Frank McRae, Andrew Millgate
DAS00057 06/06/05 -28/02/10	NVT Service Agreement - pathology	SARDI Hugh Wallwork
DAS00058 20/05/05 -28/02/10	NVT Service Agreement - trials	SARDI Rob Wheeler
US00043 17/06/08 -30/06/09	NVT Service Agreement pathology -	University of Sydney Robert Park
DAW00171 30/06/08 -28/02/10	NVT Service Agreement pathology -	DAFWA Rob Loughman
CAS00001 01/07/05 - 30/06/09	NVT Service Agreement - management	ACAS Alan Bedggood

Table 2 provides a summary of the objectives for the nine projects as contained in service agreements.

Table 2: Project Codes and Stated Objectives

<b>Project Code</b>	<b>Stated Annual Objectives</b>
AGT00006	<ul style="list-style-type: none"> <li>• Trials planted for specified wheat and canola crops in Western Australia zones, and</li> <li>• Site data including yield, laboratory and disease data provided to NVT.</li> </ul>
AGI00001	<ul style="list-style-type: none"> <li>• Trials planted in Victoria (cereals and canola), New South Wales (canola) and Queensland (wheat and barley) in NVT sowing window, and</li> <li>• Site data including yield, laboratory and disease data provided to NVT.</li> </ul>
AVS00001	<ul style="list-style-type: none"> <li>• Trials planted in Southwest, Wimmera and Mallee of Victoria, for specified cereal, canola and pulse crops, and</li> <li>• Site data including yield, laboratory and disease data provided to NVT.</li> </ul>
DAN00078	<ul style="list-style-type: none"> <li>• Trials planted in New South Wales, for specified cereal and pulse crops, and</li> <li>• Site data including yield, laboratory and disease data provided to NVT.</li> </ul>
DAS00057	<ul style="list-style-type: none"> <li>• Establish disease resistance for South Australia NVT cereal entries by fungal and nematode resistance screening using glasshouse assays, controlled environment rooms and field trials as appropriate.</li> </ul>
DAS00058	<ul style="list-style-type: none"> <li>• Conduct field trials for specified cereals, pulses and canola across South Australia grain growing regions, and</li> <li>• Site data including yield, laboratory and disease data provided to NVT.</li> </ul>
US00043	<ul style="list-style-type: none"> <li>• Provide a rust screening service for early and late sown wheat, barley, oat and triticale NVT entries using glasshouse and field testing, and</li> <li>• Undertake DNA testing for markers for three resistance genes for bread wheat entries</li> </ul>
DAW00171	<ul style="list-style-type: none"> <li>• Record and report stripe rust severity of inoculated lines from Sydney University established at Manjimup, and</li> <li>• Record and report stem and leaf rust severity of inoculated lines from Sydney University established at Carnarvon</li> </ul>
CAS00001	<ul style="list-style-type: none"> <li>• Employ an NVT Manager to implement, oversee and manage NVT;</li> <li>• Collect and publish trial data from Service Providers</li> <li>• Develop and maintain a database containing Trial Data</li> <li>• Increase use of NVT data</li> </ul>

### **The Review of NVT Management**

Through the CAS00001 project, GRDC contracts ACAS Limited as the NVT Manager. A NVT Management Committee represents the service providers to coordinate the trials. ACAS advises the GRDC on fulfilment of performance milestones that trigger

payments to Service Providers by the GRDC, and also provides advice on corrective action in the case of non-fulfilled milestones. A feature of NVT is the independence of trial providers from breeders. However, the national breeding system was still evolving during the early days of the NVT. As some state departments divested their breeding roles, they were then able to become involved as service providers and make use of their extensive experience in that role.

The NVT review concluded that *“the NVT concept and operational arrangements are sound and working well on the ground.”* But there had been implementation problems inevitable in such a large national activity and there were some exceptional drought years at some locations where trials had to be relocated or abandoned. The year 2006 was disastrous because of drought and operational problems. Then in 2009 data from 23 percent of trials was not available or acceptable because of drought, frost or other factors (GRDC 2010a). However the trials overall were generally and eventually planned to ensure that sufficient data was available each year, in some cases by shifting locations and in others by using irrigation.

The NVT review team did identify considerable variation in the quality of service delivered by the service providers. Submissions had been requested from industry and grower organisations on NVT performance. One half of the submissions were from Queensland. A particular concern was that the NVT program was not a suitable replacement for hard copy Variety Guides (GRF 2008). GRDC has responded to the major concerns by introducing auditing procedures and variety guides where these were no longer available as well as changing contracts for the service providers for projects beyond the initial ones. In addition 15 regional advisory committees were to be established to provide a mechanism for more effective local industry input and to disseminate NVT results. By 2011 most committees have met.

The NVT has demonstrated flexibility to adapt as the operating environment changes. For example, following legislative changes in relation to genetically modified (GM) canola, additional GM canola trials were planted in 2010 in Western Australia.

### **Investment Inputs**

Estimates of the funding by GRDC for each project are shown in Table 3. As shown in Table 1 several projects did not finish until early 2010 so that they were able to run trials for the 2009 winter crop. However the funding for that was generally allocated in 2008/09. The projects were service agreements contracted by GRDC and did not include matching funding. Table 4 shows the GRDC investment for each year.

Table 3: Investment by GRDC in the Projects for Years Ending June 2005 to June 2009 (nominal \$)

<b>Project</b>	<b>GRDC</b>
AGT00006	2,838,088
AGI00001	2,550,877
AVS00001	2,372,759
DAN00078	2,859,659
DAS00057	410,378

DAS00058	2,970,899
US00043	204,474
DAW00171	10,217
CAS00001	3,087,262
Total	17,304,613

Table 4: Total Investment by GRDC for Years Ending June 2005 to June 2009 (nominal \$)

<b>Year ending June</b>	<b>GRDC</b>
2005	416,210
2006	3,005,535
2007	3,455,619
2008	4,565,680
2009	5,861,569
Total	17,304,613

### 3. Activities and Outputs

NVT is designed to give growers independent and sound information by conducting trials for currently grown varieties, some older reference varieties, and three types of breeding material:

- lines that meet NVT criteria in terms of years until they will be released,
- lines that are repeated for a second year, and
- released varieties yet to be grown on a large scale.

Lines and varieties can be nominated independent of their state of origin. Varieties can remain in the NVT depending on how widely they are grown. The NVT system continues to evolve in response to feedback from industry. For example companies are able to nominate the regions where the potential new variety will be best suited. Comparisons of performance across regions are made possible by standard protocols including a national system of reporting disease ratings developed by ACAS, an important change from the state-based to a national system.

Figure 1 is an NVT output of long-term yield results for 63 wheat varieties and lines for main season trials for a Victorian district. The four leading varieties are unreleased (shown by xxxx) and their yield is averaging about 10 percent more than for the commonly grown reference variety (Yitpi released in 1999). They are followed by some recently released varieties averaging about 5 percent better than the reference variety. The variety Rosella at 90 percent was released in the mid 1980s. The example although used to show yield rankings, supports an estimate of about 10 percent yield increase (by comparing top varieties) over the last decade. It should be noted however that the NVT data set includes readily accessible data on a wide range of attributes other than yields.

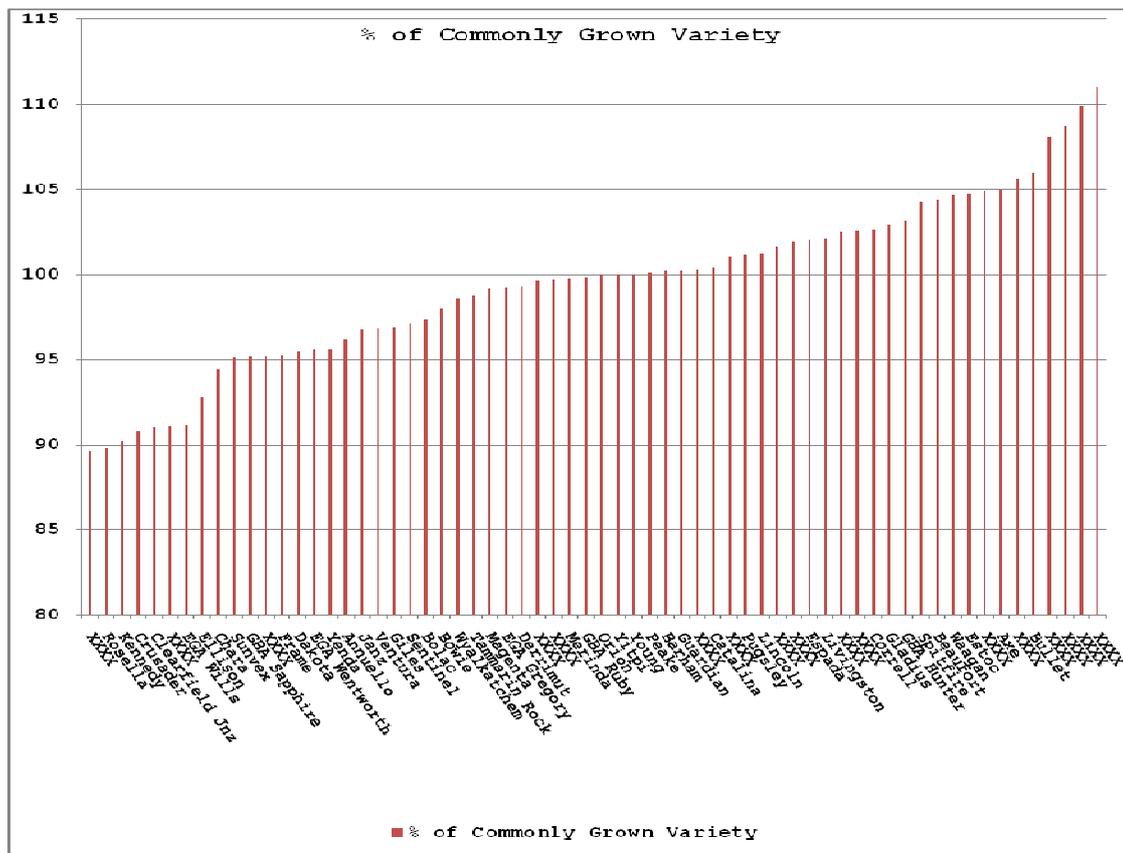


Figure 1: An example of NVT data: Average Yields of Wheat Varieties and Unreleased Lines included in Trials for a Victorian District as a Percentage of Yield of a Popular Variety.

The NVT Review proposed a more formalised advisory and consultative mechanism for stakeholder involvement in NVT. Planning was undertaken during the period included in the evaluation and most Committees are now providing input. The Central Queensland Committee has reported on ongoing operational aspects and see their role as a very useful input. Their concerns with the initial implementation are no longer an issue. One aspect of current concern was the large number of varieties which were not seen as ever likely to be relevant to Central Queensland, including for example varieties with inadequate rust resistance (Graham Spackman, pers. comm. 2011). There may be legitimate statistical or other reasons for including what are seen as not locally relevant varieties, but these reasons do not appear to have been communicated.

As was shown in Table 2 most of the projects are contracts to conduct trials in specific regions on new and existing varieties for the one or more of the 10 crops included in the NVT. The ACAS project was the overall management project with the following general activities:

1. Management and development of a National Variety Trials program;
2. Implementation and management of ACAS protocols for undertaking crop variety trials and ensuring stringent quality control;

3. Collection, management and processing of data and information from NVT through the development and maintenance of an information technology platform according to ACAS's software development program;
4. Management and development of an audit process of all stages of information generation, collection and management; and
5. Timely provision and publication of accurate, independent and credible information from NVT.

As an example of the State-based NVT data Wheeler (2010) reported on the South Australian wheat trials which included 37 advanced breeder lines and 37 new and older commercial varieties tested at 25 SARDI managed National Wheat Variety Trial sites across South Australia in 2008.

### **Typical Annual Activities for each Regional Trial Project**

Activities were directed towards ensuring that data was on the NVT website to inform decisions for the next crop. The projects had a similar seasonal cycle with the following fixed annual milestones:

#### **Milestone 1:**

Trials planted within the NVT sowing window for each crop within each region as specified and/or as directed by the NVT Manager.

#### **Milestone 2:**

Variations to trial randomisations reported to the NVT manager and modified in the ACAS database ASAP after sowing or by July 31.

#### **Milestone 3:**

Site characterisation completed and information provided to the ACAS database for each NVT trial site by 31 August each year, in relation to soil test results and GPS coordinates.

#### **Milestone 4:**

Trial management information supplied to the ACAS database by August 31 each year, in relation to:  
Paddock history, sowing date, fertiliser usage and chemical applications to date.

#### **Milestone 5:**

High quality raw trial data (including laboratory data) and opportunistic observations provided to the NVT Manager each year, in relation to:

##### Cereals:

- yield, by 31st January
- % protein; screenings; test weight; falling number (only as directed by the NVT Manager), by 28th February
- days to flowering relative to standard varieties at previously nominated sites as directed by the NVT Manager, by 31st January

##### Pulses:

- yield, by 31st January
- seed size, receival seed discolour ratings (lentils and faba beans), by 28th February
- days to flowering relative to standard varieties at previously nominated sites, by 31st January

##### Canola:

- yield, by 31st January
- % protein, by 28th February
- days to flowering relative to standard varieties at previously nominated sites as directed by the NVT Manager, by 31st January

#### **Milestone 6:**

Trial report provided to the NVT Manager by 31 January every year, detailing site relevant information in relation to:

Rainfall; disease incidence and (if applicable) variety ranking; and abiotic stress factors: e.g. heat, frost, waterlogging (factors affecting yield)

#### **Outputs**

Data from the trials is analysed by the biometrics group SAGI (Statistics for the Australia Grains Industry). As an example of a recent wheat analysis which included eight years of data, 1,544 trials contained data from 210,000 plots for 1,388 lines and varieties (GRDC 2008a). Standardised protocols for trials make a national analysis possible and should lead to more reliable predictions of relative performance at trial locations. Research is expected to be published soon on an improved approach to genotype by environment interactions using for example measures based on environmental similarity such as soil acidity or frost event and sowing date interactions (Brian Cullis, pers. comm. 2011).

The NVT website ([www.nvtonline.com.au](http://www.nvtonline.com.au)) makes the up to date information available to the grains industry. The site had a major upgrade in 2007. Features are regularly being introduced on the program's website including a searchable database and downloadable reports.

### **3. Outcomes**

Some specific highlights (GRDC 2010a) of the NVT results for varieties released in 2009–10 showed that:

- the top new wheat varieties yielded up to 12% more than current dominant varieties with comparable quality and disease resistance,
- the top new barley varieties yielded up to 16% more than current dominant varieties,
- over 90% of the canola varieties that were targeted at blackleg-prone areas had a blackleg resistance rating of 7 (moderately resistant) or above and,
- trial results also showed that 90% of wheat second-year entries (retentions) in NVT trials met current regional minimum disease standards for rust resistance.

A general summary of the principal outcomes follows:

- improved profitability of grain production by providing NVT information so that growers can more confidently adopt higher performing varieties to replace their existing varieties,
- reduced chemical use by growing varieties with improved resistance to diseases, and
- improved research capacity by standardising and consolidating national data on performance of grain varieties.
- contributions to more efficient trials by new approaches to characterising genotype by environment interactions.

- planning completed for improved communications by establishing Advisory Committees to facilitate interaction with growers and improve feedback on trial locations and operations.

## 5. Benefits

The major benefit delivered by the investment has been the increased profitability of grain production from the more rapid adoption of better performing varieties. Most of the benefits are to grain growers.

Benefits other than from increased yields by more rapid adoption are considered to be relatively minor. The yield increase will include contributions from increased disease resistance. There are other examples contributing to minor environmental benefits, including reduced use of fungicides.

### Overview of Benefits

An overview of benefits in a triple bottom line categorisation is shown in Table 6.

Table 6: Categories of Notable Benefits from the Cluster Investment

Benefit	Levy paying industry and its supply chain	Spillovers		
		Other industries	Public	Foreign
Economic	Increased profitability from increased yields, and disease resistance due to earlier use of superior varieties.			
Environmental	Minor reduction in fungicide use.			
Social	Enhanced skills and capacity in statistical analysis of NVT contributing to more efficient variety testing.			

### Public versus Private Benefits

The benefits identified from the investment are predominantly private benefits, namely benefits to grain producers and their supply chains. There also will have been some minor public benefits produced, mainly environmental and social in nature, for example from reduced use of fungicide.

### Benefits to other Primary Industries

Benefits to other industries are limited.

### Distribution of Benefits along the Grains Supply Chain

A very high proportion of grain production is exported so benefits to the domestic supply and value added chain are limited. On the assumption that Australia is essentially a price taker as an exporter, it is unlikely that the small increase in exports compared with the counterfactual would have been at a reduced price. The benefits accrue primarily to grain growers. Some of the benefits from reduced unit production costs due to increased yield will be shared along the supply chain with plant breeders, seed producers and grain handlers.

### Benefits Overseas

It is unlikely that any of the outputs produced by this investment will benefit overseas grain industries.

### Match with National Priorities

The Australian Government's national and rural R&D priorities are reproduced in Table 7.

Table 7: National and Rural R&D Research Priorities 2007-08

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

Table 8 identifies the relative importance of the rural research priorities addressed by the cluster as a whole.

Table 8: Categorisation of Benefits by Priorities

Benefit	National Research Priority Addressed	Rural Research Priorities Addressed
Increased profitability		Priority 1***
Increased disease resistance	Priority 4*	Priority 5*
Capacity building		Supporting Priority 1**

\*\*\* Strong contribution    \*\*Some contribution    \* Marginal contribution

### Additionality and Marginality

The investment in this cluster was targeted principally towards benefits to grain producers. These projects would have been regarded as a very high priority by levy payers. In the event that the government matching contribution to GRDC was restricted, it is likely that most of the projects in the cluster would have still been funded by industry, assuming a levy system was still in place.

If no public funding at all had been available for GRDC, it is estimated that the investment would have been limited to about 80 percent of the investment actually recorded. The state agencies and other players in the supply chain would probably not have contributed more resources to meet the GRDC shortfall. It should be noted

that the investments were made over a period when there was a rapid change in the commercialisation of plant breeding made possible by EPR. Alston and Venner (2002) concluded from an analysis of the U.S. Plant Variety Protection Act that the main impact from intellectual property protection for plant breeders was as a marketing tool. The authors were not able to identify increased private sector investment or increased yields resulting from the Act. Their conclusion suggests a possible argument for a contribution from plant breeders to NVT funding. The market failure argument for an NVT would appear to be stronger for smaller crops. The following comment illustrates an Australian plant breeder outlook on NVT: *“With ongoing improvements we hope that soon breeding companies such as ours will no longer need to divert valuable End Point Royalty income from new variety development into marketing ...”* (Jefferies 2008). In summary it is difficult to speculate on additionality and marginality aspects during a period of rapid change in institutions and markets which would have created further opportunities and incentives to adapt.

A summary of the potential response to reduced public funding is provided in Table 9.

Table 9: Potential Response to Reduced Public Funding to GRDC (assuming the reduction occurred prior to the GRDC investment in the cluster)

1. What priority were the projects in this cluster when funded?	High priority for GRDC and industry
2. Would the investments still have been made in this cluster if 50% less public funds were available to GRDC?	Yes, but with less total funding
3. Would industry and others have funded this cluster if no public funds were available to GRDC?	Yes, to the extent of about 75 % of that actually funded

## 6. Pathway to Adoption

The key measure of NVT performance is the increased rate of adoption of newly released varieties. However as noted the NVT Review *“saw no unequivocal evidence that NVT had increased the rate”*. The Review did recommend measures to provide some evidence. The new information will draw on particularly from grower surveys and from production data. However the crucial evidence sought is not whether growers use NVT, but whether *“NVT had increased the rate”*.

The change from the traditional approach of state-based testing to the NVT has been driven by the increasing commercial focus of plant breeding programs in Australia and the need for growers to obtain information about new varieties from what they perceive as a trusted source independent of breeding programs. Growers had a degree of comfort with the old system, despite what they may have seen as shortcomings. The NVT was therefore challenged to create a system where there was no scope for bias and where there was full transparency. Most importantly growers wanted reliable information on new varieties so they could assess the claims of commercial breeders. Growers need to be confident their decisions to purchase seed are based on reliable information. Purchases of new seed need to compete with farmer saved seed of varieties where local performance is well known.

To meet grower concerns, the NVT review also proposed improved dissemination of results; such dissemination has since been funded by GRDC. Examples include delivering NVT data through departmental sowing guides, the 2010 NVT Queensland Wheat Varieties Guide, the 2010 Farm Gross Margin Guide and the 2010 South Australian Crop Harvest Report.

The GRDC grower survey (IPSOS 2010) has several results with some relevance to NVT and to more rapid adoption. Results over time show a generally high and increasing awareness of NVT. Results also highlight the difficulty of attributing various sources of NVT information to NVT.

- *"In all regions more than half of all growers were aware of National Variety Trials and State Sowing Guides; awareness was consistently lowest for NVT Online."*
- An increasing proportion (now one quarter) was accessing NVT Online.
- *"Of growers who pay for agronomic advice, 68% said their advisor made reference to NVT information".* (However the summary states in relation to agronomists, few are strong advocates for GRDC in general).
- *"Most growers turn to other growers (79%) for general agronomic advice, closely followed by agronomists at 77%."*
- *"GRDC activities or initiatives are a strong influencer for adoption of new cereal varieties, up (to 38%) significantly from 18% in 2008, becoming the most commonly sighted influence".*

Note however, the last response was in the context of a question not designed to actually discriminate between influences on varietal adoption. It had a clear prompt: *"Thinking about the adoption of these new cereal varieties, was it in any way the result of GRDC activities or supported projects specifically?"* Seed suppliers/breeders and NVT each accounted for seven percent of top responses.

For prompted responses on sources of influence in motivating change on-farm in the last two years, information picked up from the internet was the only response with less than 50 percent of growers.

Growers typically seek information from a wide range of sources before they would purchase seed for a new variety. A very high proportion of grain production is from farmer-saved seed. Risks inherent in adopting a new variety are to some extent reduced by the initial small-scale planting as part of the process of building up seed from a small initial purchase. Variety guides gives farmers information on a wide range of attributes additional to yield. As the NSW Varietal Guide (I&I NSW, 2011) states: *"Profitable yields result from good management, of which variety choice is only a minor part. ... Use varieties yielding consistently well over several years that offer the best combination of yield potential, grain quality and disease resistance "*.

Given an average adoption pattern resulting in a period of five years to a maximum of 15 percent adoption reported by Brennan and Bialowas (2001), NVT impacts in the early years would have been mostly from increased adoption of older varieties released prior to NVT and to a lesser extent increases from recently released varieties. There will be exceptions, for example as reported by Wheeler (2007) for South Australia, Gladius, an apparently outstanding variety released in 2007. However as demonstrated in the exceptional 2010 season adoption prospects can change as experience accumulates over a wider range of sites and seasons. Gladius along with some other varieties was shown to be susceptible to sprouting.

The NVT website is being increasingly used. NVT reports show for a recent 12 month period visits were up 13 percent. Peak visits are around February. There have been 32,000 visits to the NVT website in the past 12 months for 100,000 page views. Literature items (PDF trial reports, etc) downloaded were a total 22,490 in the past 12 months.

## 7. Measurement of Benefits

The benefits valued in this analysis are limited to the increased profitability from increased yields of new varieties. The more rapid adoption of new varieties contributes to increased turnover by their replacing older lower yielding varieties. The scope is limited to the gains that can be attributed to the GRDC investment in NVT over the five year period to June 2009. The final year of funding included the 2009 winter crop trials. A simple model of variety adoption is used to take account of the impacts beyond the period of funding. Benefits not specifically valued are also discussed in this section. A summary of the key assumptions made in estimating benefits is presented at the end of this section in Table 10.

The Counterfactual or "Without Investment" Scenario – This scenario has two key roles:

1. Defining a likely alternative or base scenario to compare the investment in NVT against, and
2. Identifying costs that would have been avoided by not having to invest in the alternative.

The comparison is between the investment in NVT and a "Without Scenario", not simply the status quo or what was in place previously but what would have evolved. The scenario is difficult to define in any detail because of the number of varieties and because the breeding arrangements for some crops were in a rapid transition from public institution-based to breeding by private companies.

Ideally the benefits resulting from NVT would be aggregated from an analysis of the ten crops and their production environments. The market can be viewed as a large number of segments defined by the ten crops and various agro-ecological regions in which new varieties compete with existing varieties for market share. The NVT includes up to 300 varieties.

The simplest approach is to assume that without NVT for the major crop wheat, the breeding and seed companies would be likely to continue to actively promote their own products and current public sector investments including in communication activities would largely continue. But for the smaller crops in NVT, the pulses, coarse grains and canola, it is likely that the GRDC would have recognised a need to maintain variety trials coordinated with existing public sector funded breeding programs for various minor crops. The arrangements would be similar to those in place prior to the NVT and similar to the current ones for crops not in the NVT. The analysis assumes that the "Without Scenario" would have been achieved by expenditure of \$2 million annually, equivalent to about one half of the cost of NVT. The allowance is more than a proportionate basis given economies of scale and that a series of crop based variety trials would not have been as efficient as NVT. That amount as a cost saving is then included as a benefit attributable to the NVT. The main other benefit attributable to NVT will then be the benefits for the major crop

wheat, additional to what would have been achieved by the "Without Scenario" investment.

The "With Investment" Scenario –this is defined by the actual adoption pattern since the start of the NVT. It is reasonable to assume some lag before benefits begin particularly to allow for grower awareness of NVT to increase and for implementation problems including those relating to extreme frosts and droughts in the first three years of NVT. Benefits from new varieties being adopted at the beginning of NVT need to take account of information generated over several years prior. This is achieved by a lagged rate of adoption.

As an example of implementation problems for the 2006 season, the percent sites harvested were only 10 percent of sites in Queensland and 20 percent in Victoria. As the NVT reported: "*In Queensland, trials haven't performed well and the results will be very limited due to drought and operational issues*" (NVT Online, January 2007). The NVT website went online in 2006. Based on the survey data in the previous section, it will be assumed for this analysis that growers and advisers had an increasing level of awareness of NVT by 2006 and began to make more widespread use of NVT data by 2007.

At the individual grower level, the decision to adopt a new variety requires a comparison of the benefits compared with continuing the current mix of varieties. The benefit in terms of extra yield or disease resistance for example will be seen as to some extent uncertain and therefore risky compared with the current varieties. Additional costs of new varieties are estimated at \$40/ha (Juttner 2008) and include the cost of purchased seed compared with costs involved in preparing the farmer's saved seed, and EPR if a currently grown variety was released before EPR was introduced. The decision to adopt a new variety will then have impacts for a decade or more if the variety is successful and retained. The variety decision also needs to be considered in the context of other agronomic decisions facing a grower. For example, an uncertain gain of the order of 5-10 percent from replacing an old variety can be compared with yield drops of 4-7% with each week of delay in sowing after the optimum time for a specific variety (I&I NSW 2011).

Benefits estimated by a model of variety adoption - Benefits will be evaluated from more rapid adoption of higher yielding varieties. A variety adoption model will be used to estimate the change in a yield index for different assumptions relating to adoption. The key assumption is that more rapid adoption can be simply measured by the rate of turnover of varieties taking into account their age as defined by year released.

Ideally a simplified model of the mix of varieties being used by growers would help to more accurately define the evolution of benefits over the life of the varieties. The model would need to take into account the changing market shares of all varieties involved. Brennan and Bialowas (2001) have done a comprehensive analysis of the adoption patterns of NSW varieties. They used the WAA (Weighted Average Age) of the mix of varieties planted in a season to show varietal turnover and related adoption and disadoption patterns. As they stated, "*the higher the WAA, the slower the rate of varietal change.*" But it should be added that the rate of genetic gain as measured for example by a yield trend excluding management influences, is also a key factor. A WAA of about 7 years was typical for NSW shires in the 1990s and an

average of 10 varieties were grown per shire. Peak adoption for a variety was often about 15 percent after five years declining to 4 percent by age 10.

The above outline can be used to develop a simple variety adoption model to track impacts over time more accurately. Key relationships are:

- An initial distribution of the mix of varieties based on year released, for the previous decade,
- An assumed base rate of increase in yields which defines the yield index for each year to apply to an average of the releases for the year,
- A Relative Advantage (RA) factor being the ratio of the yield index for that year's release to the weighted average yield across all years,
- An Age factor to represent a decline in performance for older varieties (Mackay et al 2011),
- A Lag factor which defines current percent adoption as determined by the previous year's adoption, and
- The change in adoption as defined by an RA, Age and Lag factor changing the previous year's adoption.

The above assumptions are all that are required to provide a realistic generic simulation of varietal adoption patterns under varying assumptions relating to the rate of yield increase being achieved. DAFWA (2011) has published detailed data from Co-operative Bulk Handling Ltd on the percentage of area sown to wheat varieties in Western Australia. Wyalkatchem released in 2001 has been the dominant variety for many years. Over the last few seasons it has averaged close to 30 percent of area sown. The model parameters can be readily changed to simulate a size distribution similar to the Western Australia one as shown in Figure 2. The WAA for Western Australia is 9 years compared with 7 years for the simulation. WAA of this magnitude demonstrate a relatively low rate of varietal turnover. The WAA model average is comparable with the 1990s average of about 7 years determined for NSW shires.

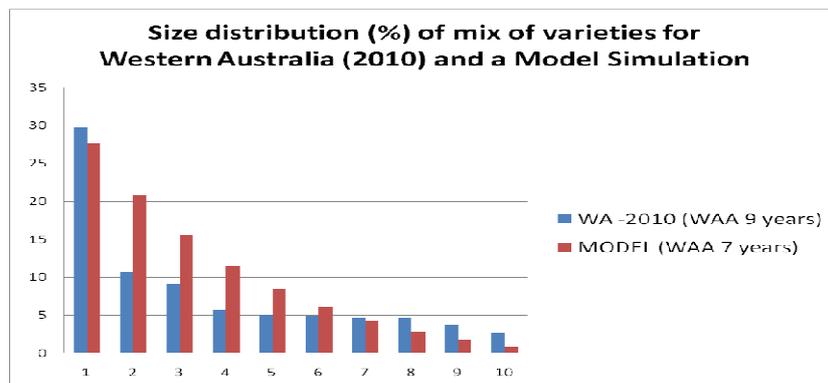


Figure 2: A comparison of the relative distribution of the 2010 mix of Western Australian wheat varieties and of a simulation using a model of varietal adoption. (The weighted average age, WAA, of the varieties is shown for each).

The variety adoption model can be used to simulate the potential benefits from more rapid adoption provided it captures some of the dynamic features of adoption patterns as improved varieties increase their market share at the expense of older varieties. An improved variety will also crowd out adoption of subsequent releases to

some extent. This is a consequence (in the model and in reality) of the dependence of adoption next year on the current share so that a dominant older variety persists to some extent. The impacts of changes in adoption rates will unfold over periods of a decade or more depending on the lifespan of the varieties involved and their yield relative to other varieties.

Some of the features of the model and its validity in estimating benefits from increased turnover can be demonstrated by the outputs in Figure 3. Adoption patterns for releases over four consecutive years of a longer sequence of releases are shown. The yield trend and the model were configured by adjusting parameters to show some aspects of the dynamics and the need for an evaluation to take that into account. The first two were low yielding and achieved low maximum rates. The maximum rate for the second was reduced because adoption each year is partly determined by the magnitude of the adoption the previous year. The third release being high yielding quickly dominated the two lower yielding ones. The final release, also high yielding did not achieve a high maximum as it was crowded out by the previous release. In all cases adoption levels eventually reduce as subsequent varieties are higher yielding reflecting the underlying rate of genetic gain.

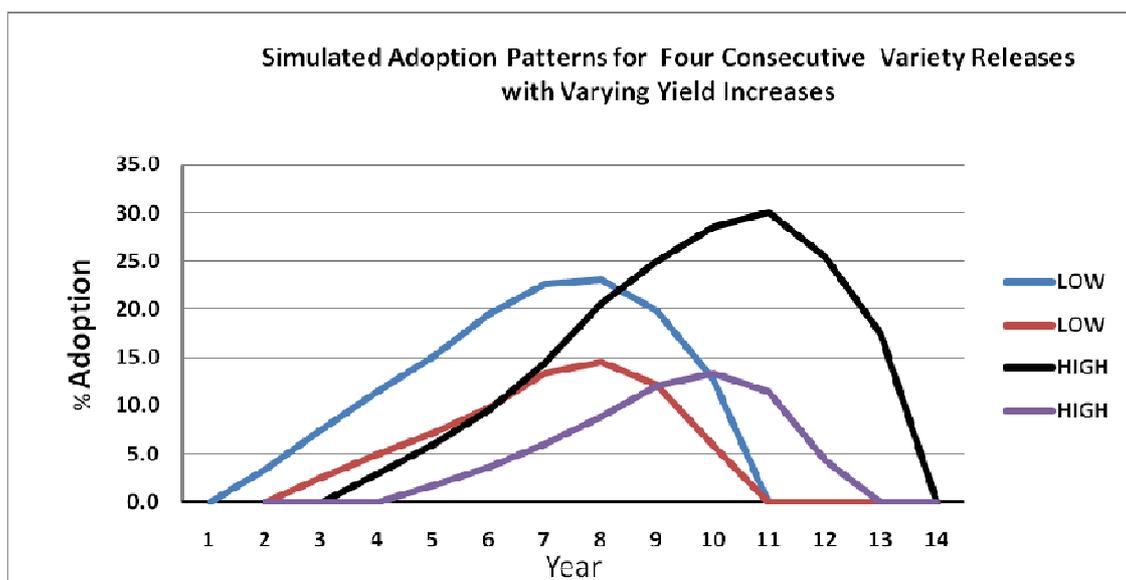


Figure 3: An example of simulated adoption patterns for four consecutive variety releases with different yield increases using the variety adoption model.

Variety turnover for the Australian wheat crop – Two sources clearly show that turnover has been low. Fellowes and Marshall (2007) stated "Over the last five years 35% of AWB collections have been from varieties over 10 years old. Given that total productivity improvement is 1% pa of which 0.5% is genetic (estimate), then the theoretical 'lost opportunity' value is \$80-90 M..... there is an argument for resourcing more rapid adoption". IPSOS (2010) showed that over one half of growers of winter cereals were growing some old varieties (10 to 15 years old). The wheat percent was 65, down from 77 percent in 2008. For barley, oats and triticale there were generally one or two varieties accounting for most of the new ones that growers mentioned. The barley variety Hindmarsh accounted for 60 percent of new

varieties mentioned in the South. The wheat variety EGA Gregory (released in 2004) was the highest mentioned new variety at a regional level being 36 percent in the North. Note that a new variety can be mentioned by many growers but only account for a small proportion of deliveries. Small areas are grown initially to build up seed and to further trial a new variety in relation to existing varieties.

As an outcome of the NVT Review some limited confidential data on the top five popular varieties (Juan Juttner, GRDC, pers. comm. 2011) is available for deliveries to major accumulators in mainland States and including a north south split in NSW. The aggregated data can be used to investigate WAA for the Australian wheat crop as a more quantitative framework to evaluating the NVT as shown by variety turnover.

Before proceeding, there needs to be some consideration of bias from using top five data. For Western Australia, a WAA for the top ten varieties was about a year greater than for the top five. This would seem to indicate that adoption is more rapid for newer varieties than is the decline for older varieties, and is consistent with Brennan and Bialowas data for NSW. However at a state level the top five in most cases account for close to two thirds of the intake, large enough to justify using the data for initial spatial and temporal comparisons of WAA. Northern NSW was an exception with a lower percentage indicating a more diverse mix of varieties, possibly reflecting more diverse markets and sources of varieties.

Analysis of the WAA for the total Australian intake (as a simple unweighted arithmetic average of state and NSW N and S) showed an upward trend. The increase was paradoxical, from 7.1 to 10.6, an unexpected 50 percent ageing which is a very unusual and rapid slowing in the rate of varietal turnover. The data was further analysed by state and by Northern and Southern NSW to clarify the trend. There was a clear pattern of an increase in WAA in Northern NSW and Queensland which comprise the GRDC Northern Region, and a more stable pattern in the rest of Australia. The pattern is shown in Figure 4.

Brennan and Bialowas provide a summary of their review of other international WAA analyses. An average age of 7.2 was typical in one review from 1970 to 1986 across a wide range of countries but in another study, the range for developing countries was from 8.0 to 14.7. Values of WAA as high as 14 indicate an exceptionally low level of turnover of varieties. One consequence is long lags in adoption of varieties bred to resist evolving strains of diseases and loss of resistance, or to respond to market signals in relation to quality.

Figure 4 as a graph of WAA is also a graph of the rate of varietal turnover, at least in respect of the major and most popular varieties. Given an assumption that NVT has increased adoption, it could then be concluded for the "Without NVT Scenario", WAA would have been even further increased, at least to some extent in the Northern Region, and in the "Other Australian" states. Brennan and Bialowas showed that rapid change of the order of five years in a decade was not unusual in WAA at a shire level particularly in southern NSW. But rapid change will be less probable at state and regional level aggregations where change could normally be expected to be slower. In the survey of eight NSW shires from 1965 to 1997, only one shire recorded a WAA as high as 14, and that was for only a few years in the 1970s.

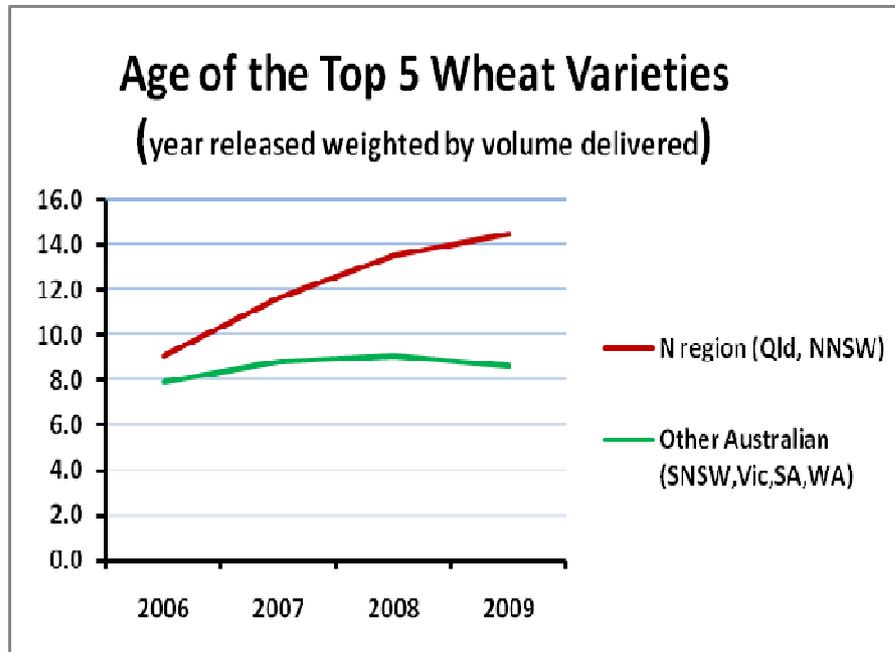


Figure 4: A Comparison from 2006 to 2009 of the Weighted Average Age of the Top 5 Varieties for the GRDC Northern Region and for Other Australian for Wheat Delivered to Accumulators.

Variety turnover for crops other than wheat – data is available for several other NVT crops but has not been analysed in any detail. The impact of the NVT was assumed to continue at the same rate in the “Without Scenario” so data on trends is not required for this analysis. The benefit in this analysis arises from the cost saving involved (the assumption was a simplification to make the analysis feasible). There are likely to be examples for some smaller crops where adoption has been rapid, but that would still leave the question of attribution to NVT. The data for barley does suggest a high WAA of the order of 10 years and thus a low rate of varietal turnover. The WAA for barley is to be expected given the current dominance of varieties such as Gairdner released in 1997 and to a lesser extent Baudin released in 2002. Also varieties such as Schooner released in 1983 are still grown. Canola is an exception to the pattern for wheat and barley with rapid variety turnover. However analysis is complicated by the range of varieties for different herbicide tolerance and growing season regimes.

Adoption Rates – Before making assumptions on the difference NVT has made to adoption rates and implicitly to WAA, the possible factors leading to the rapid increase in WAA in the Northern Region need to be discussed. One view from an understanding of adoption of new varieties from EPR district patterns is a link to relative affluence reflecting districts that are higher yielding and more reliable (Steve Jefferies, pers. comm. 2011). There are many other candidates ranging from institutional changes to the recent pattern of the seasons. One difference is the Northern Region has greater opportunities for local value-adding from the large feed

lot industry. A tentative list based on a range of discussions (see Acknowledgments section) follows. The likely net impact on the demand for new varieties is also flagged where there is a clear link.

- Deregulation – changes over the last decade may have been a factor given the increased local demand and greater on-farm storage,
- Drought – the last decade in the Northern Region was extreme by any measure with multiple impacts ranging from concerns about the quality of NVT data to grower interest and capacity to adopt new varieties,
- Declining rate of genetic gain, or alternatively perceptions of that, and how that interacts with rate of adoption of new varieties,
- Disease – increasing concerns resulting in a rethink for some of the roles of new and old varieties, for example for crown rot versus root lesion nematode resistance (Daniel et al 2011),
- Disruptions to established arrangements – these included breeding programs and the conduct of NVT trials leading to discontinuities and potential loss of confidence in results,
- Delivery of benefits from pre-breeding and concern that the lags are inevitably long,
- Diversity of cropping – there has been less emphasis on the once dominant objective of growing varieties to meet a now more restrictive prime hard wheat classification to more emphasis on rotations and opportunity cropping making greater use of summer rain, summer crops and pulse crops,
- Depth of Planting – a concern that crops produced by small-scale low-speed NVT trial equipment may not perform as well as what growers achieve in terms of moisture seeking,
- Delivery standards and concerns that “raising the bar” on standards for Prime Hard wheats has made it more difficult for breeders and for growers, as well as creating opportunities for perverse incentives for variety declarations.
- Declarations (to avoid EPR and also from blending to achieve a more favourable classification based on protein quality) – there are concerns that it is a significant issue, for example attributed to GRDC and SRDC who considered “*mendacious variety declaration to be a major threat to their business*” (ACIP 2010). However the ACIP report quoted examples of misdeclarations of only a few percent.

The above list is tentative, sometimes anecdotal and likely incomplete. But it does suggest that there were factors peculiar to the Northern region that could account for the remarkably different pattern of WAA and a reduced or at least altered demand for new varieties. Perhaps a more positive implication is the scope for major gains. Ideally it would be preferable to undertake a disaggregated regional analysis of NVT benefits but that would require making many more assumptions not supported by data. The preferred approach therefore is to take a conservative national view on NVT benefits and to emphasise in the Conclusions Section the priority need for further analysis of the rate of varietal turnover particularly in the Northern Region.

The IPSOS has a range of questions relevant to adoption of new varieties but none that can be readily or unambiguously interpreted in relation to turnover. In response to a question on whether growers felt new varieties met expectations well, the lowest and highest agreement by agro-ecological zones were both in Western Australia. Agreement was a low 47 percent in the Sandplain (48 percent in the Central zone) and highest at 72 percent in the East zone. (The survey results suggested that grower interpretations of “expectations” included low as well as high making interpretation problematic.)

The base rate for yield increase for the "Without Scenario" - The variety adoption model can be used to simulate impacts and benefits from small changes in adoption as determined by specific assumptions on yields of new releases. The source of benefits proposed was from more rapid adoption resulting in an increased trend in yields. As the benefit is from an increase in yield, the base yield level for the increase may not be critical. However it will be the focus of a sensitivity analysis. For wheat, estimates of around 0.5 percent per annum are typical for recent levels of genetic gain (Fellowes and Marshall 2006, and Tony Fischer, pers. comm. 2011).

Current annual rates of genetic gain of the order of 1 percent are evident from NVT data if measured by simply comparing the top new wheat varieties (up 12 percent) and barley (up 16 percent) with current dominant varieties mostly released up to a decade or more ago (GRDC 2010a). An evaluation of the Western Australian breeding program (GRDC 2010b) indicated a rate of 0.62 percent over the last decade. For barley the estimated rate was 0.75 percent (GRDC 2008b). The implication is that the rate as measured by actual adoption using NVT differences is currently less than potential as indicated by comparisons of top varieties. A value of 0.75 percent will be used for the base run in the model and applied to all crops. The sensitivity of the assumption will be tested by comparing higher and lower rates.

Benefits from an increased trend in yield -given the evidence above for slow rates of turnover and low recent rates of adoption, a conservative approach will be taken for the impacts of NVT. It would be difficult to make any other judgement. The analysis has shown that the rate of turnover for wheat has been traditionally slow. The issue is the extent to which NVT can change that in the short term. It would appear that one of the main reasons why turnover is low is that the underlying rate of genetic gain is not rapid enough to provide the incentives in terms of economic gains and the inherent risks associated with adopting a new variety.

In an analysis of investment in the Australian Winter Cereals Molecular Marker Program (GRDC 2009), an increase in the base rate of 10 percent was assumed. The traditional rate for wheat and barley was assumed to be one percent increasing to 1.05 percent for the "Without Scenario" and to 1.1 percent for the "With Scenario".

Rapid rates of adoption are occasionally recorded for individual varieties. Wyalkatchem reached 30 percent five years after release in 2001 and remained at about that level for the rest of the decade (GRDC 2010b). Over that period, the rate of increase as measured by the yield ratings weighted by percent adoption averaged 0.62 percent annually. For an outstanding release such as the mungbean (not a NVT crop) variety Crystal, adoption reached 80 to 90 percent within a couple of years of release (DEEDI 2010). Rates clearly also depend on the geographic area and the scope, for example a variety or a total crop. But by definition, if the rate of turnover is low and the average age of varieties is therefore high or increasing, rates of adoption will be low, entrenched and hard to change.

For the analysis to proceed, a judgement has to be made on how the NVT has changed the rate of adoption. For this analysis of an investment over the period from 2005 to 2009, more rapid adoption equivalent to 10 percent increase in the 0.75 percent base rate of genetic yield increase is assumed and phased in from 2007 to 2011, and then continued on so that the adoption pattern is realistic and without artificial discontinuities. The benefit is then the value attributed to the increase in the average yield index compared to the base rate index. The NVT investment is

assumed to continue after 2009 but an adjustment is made for benefits attributable to the investment up to 2009. This is achieved by progressively reducing benefits by a factor increasing from 10 percent in 2010 to 100 percent in 2020. The basis for that assumption follows. The increase in yield over the period from 2007 to 2011 is expressed in the model by assumptions increasing more rapid adoption of higher yielding newer varieties compared with older varieties. These changes have impacts on the average weighted yield of the mix of varieties for up to a decade. The changes result in more rapid turnover and a lowering of the weighted average of the mix of varieties. Recall that in the model, 'variety' effectively defines a year of release and a yield to apply in that specific year as determined by the trend operating.

### **Benefits not Valued**

The principal additional benefits that can be identified but have not been specifically valued in the analysis include:

- Benefits from more rapid adoption of improved varieties for crops other than wheat (on the basis that they were included in the Without Scenario),
- Benefits longer term to the direction of breeding programs from earlier access to information on industry trends,
- Improvements in pest and disease resistance that are not reflected in increased yield,
- Improvements in statistical procedures leading to more efficient identification of superior varieties,
- Improvements in grain quality, and
- The increase in the real value of the NVT database over the period of the investment from 2005 to 2009.

In relation to the last point, NVT began in 2005 and inherited a large database assembled from the CVT predecessors. The early benefits from NVT would need to be attributed in part to the CVT data. By 2009 the database would have increased in value based on its potential to contribute to future benefits. The simplest realistic approach is to assume the value increases at the discount rate of 5 percent annually so there is no net gain in present value terms.

### **Attribution**

The benefits as calculated include a return on investments by other agencies, for example state departments involved in disseminating NVT through annual sowing guides produced using NVT data. The analysis assumes an attribution of one quarter of benefits to other agencies. Note that attribution is not required for commercial entities that benefit for example through EPR or seed sales.

## Summary of Assumptions

A summary of the key assumptions made is shown in Table 10.

Table 10: Summary of Assumptions

Variable	Assumption	Source
<b>"With Scenario"</b> (NVT funding 2005-09 resulting in more rapid adoption of higher yielding varieties. Variety testing for other current NVT crops is assumed to be funded by the "Without Scenario", which results in a cost saving.)		
<u>Production Base</u> • Gross Value of wheat production	• \$5,000 million	• ABARE (2009)
<u>More Rapid Adoption</u> • Increase in the Yield Index (from a Variety Adoption Model).	• More rapid adoption (equivalent to a 10% increase in the 0.75% pa base rate of genetic yield increase) phased in from 2006 to 2010	• GRDC (2010a) showing new wheat varieties yielded up to 12% more than current dominant varieties and author estimate of the base rate for all NVT crops.
<b>"Without Scenario"</b> (Yield increase at the base rate of 0.75% pa)		
• GRDC Investment in variety testing for crops other than wheat	• \$2m annually (treated as a cost saving and therefore a benefit in the benefit calculation)	• Author estimate
<b>Benefits Calculation</b> (for the assumption that variety testing for crops other than wheat is funded by the "Without Scenario", there is no benefit calculation required for other crops.)		
• Benefit basis	• Change in the yield index for the "With" less "Without" Scenario	• Author estimate
• Adjustments for attribution to NVT investment to 2009 only	• Benefits are progressively reduced by a factor increasing from 10% in 2011 to 100% in 2020.	• Author estimate (to account for declining influence of the data base as no NVT funding is assumed past 2009)
• Value of additional production	• 80% of the increase in the yield index applied to the gross value	• Author estimate of 20% adjustment of gross grain price to account for selling costs/tonne.
• Attribution to other agencies	• 25 %	• Author estimate

## Results

All past costs and benefits were expressed in 2010/11 dollar terms using the CPI. All benefits after 2010/11 were expressed in 2010/11 dollar terms. All costs and benefits were discounted to 2010/11 using a discount rate of 5%. The base run used the best estimates of each variable, notwithstanding the level of uncertainty for many of the estimates. All analyses ran for the length of the investment period plus 30 years from the last year of investment to the final year of benefits assumed.

Investment criteria were for the GRDC investment alone. The projects were contracts with no matching investments from partners. Each set of investment criteria were estimated for different periods of benefits.

Table 11: Investment Criteria for the GRDC Investment and Benefits to GRDC for Each Benefit Period from Last Year of Investment (2008/09) (discount rate 5%)

Criterion	Period from Last Year of Investment (2008/09)						
	0	5	10	15	20	25	30
Present value of benefits (m\$)	8.5	16.9	24.3	24.3	24.3	24.3	24.3
Present value of costs (m\$)	20.2	20.2	20.2	20.2	20.2	20.2	20.2
Net present value (m\$)	-11.8	-3.3	4.0	4.0	4.0	4.0	4.0
Benefit cost ratio	0.42	0.84	1.20	1.20	1.20	1.20	1.20
Internal rate of return (%)	neg	neg	10.3	10.3	10.3	10.3	10.3

The analysis was undertaken in aggregate for all benefits from outputs over the period from 2004/05 to 2019/20 when benefits from the investment declined to zero. The only benefits quantified were the increase in the net value of production of wheat from higher yielding varieties. Therefore no results are presented for any components of the benefits.

The annual cash flows of undiscounted benefits are shown in Figure 5, including the 30 year period from the final year of the investment.

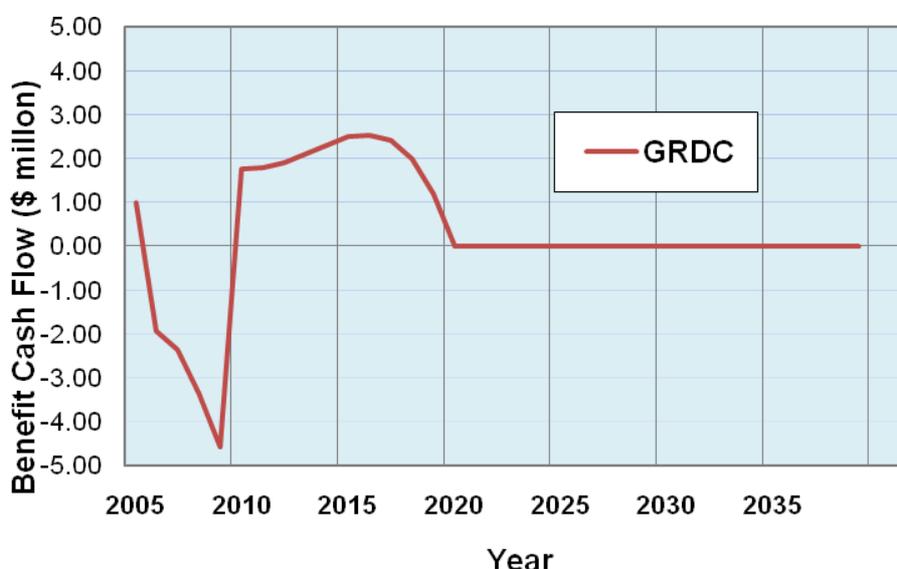


Figure 5: Annual Benefit Cash Flow

### Sensitivity Analyses

Sensitivity analyses were carried out on key variables. The results are reported in Tables 12 to 15. The key variables were selected to take account of assumptions about which there was most uncertainty. All sensitivity analyses were performed using a 5% discount rate with benefits attributed to GRDC taken over the life of the investment plus 30 years from the year of last investment. All other parameters were held at their base values.

Table 12 shows the impact of the discount rate on the investment criteria.

Table 12: Sensitivity to the Discount Rate  
(GRDC investment, 30 years)

Criterion	Discount rate		
	0%	5%	10%
Present value of benefits (m\$)	28.18	24.27	21.86
Present value of costs (m\$)	18.95	20.24	21.63
Net present value (m\$)	9.23	4.02	0.23
Benefit cost ratio	1.49	1.20	1.01

Table 13 shows the sensitivity of the investment criteria to changed assumptions on the rate of yield increase assumed caused by the NVT. The benefits are determined from the increased trend which is a constant trend above the base rate. However a higher gain interacts by contributing to more rapid adoption by increasing the rate of turnover of varieties. Table 13 shows the break-even impact of the NVT is just above a 5% increase in the base rate of gain assumed (the 0.75% per annum).

Table 13: Sensitivity to Changes in the Increased Rate of Yield Increase  
Assumed for the "With Scenario"  
(GRDC investment, 5% discount rate, 30 years)

Criterion	Increased Rate of Yield Increase above the 0.75% Base Case		
	5 % (of 0.75%)	10% (of 0.75 %) Base case	15 % (of 0.75%)
Present value of benefits (m\$)	19.67	24.27	28.92
Present value of costs (m\$)	20.24	20.24	20.24
Net present value (m\$)	-0.57	4.02	8.67
Benefit cost ratio	0.97	1.20	1.43
Internal rate of return	4.90	10.3	15.10

Table 14 shows the sensitivity of the investment criteria to the assumed base rate of gain without the NVT investment, that is, to changes in the 0.75% yield increase per annum.

Table 14: Sensitivity to Changes in the Base Rate of Yield Increase  
Assumed for the "Without Scenario"  
(GRDC investment, 5% discount rate, 30 years)

Criterion	Rate of Yield Increase "Without Scenario"		
	0.5 %	0.75 % Base case	1%
Present value of benefits (m\$)	20.47	24.27	28.50
Present value of costs (m\$)	20.24	20.24	20.24
Net present value (m\$)	0.22	4.02	8.25
Benefit cost ratio	1.01	1.20	1.41
Internal rate of return	5.30	10.3	14.9

Table 15 shows the sensitivity to bringing forward or delaying the benefit streams that result from the 10 percent increase in the rate of gain. Delaying the benefits three years is equivalent to a slowing of the adoption of information from NVT. The delay substantially reduces profitability of NVT. Conversely there are major benefits from speeding up adoption.

Table 15: Sensitivity to Bringing Forward or Delaying Benefits  
(GRDC investment, 30 years)

Criterion	Bringing Forward or Delaying Benefits		
	Forward 3 Years	Base case	Delaying 3 Years
Present value of benefits (m\$)	40.15	24.27	17.61
Present value of costs (m\$)	20.24	20.24	20.24
Net present value (m\$)	19.91	4.02	-2.63
Benefit cost ratio	1.98	1.20	0.87
Internal rate of return	28.90	10.3	0.50

## 8. Confidence Rating

The results produced are highly dependent on the assumptions made, some of which are uncertain. There are two factors that warrant recognition. The first factor is the coverage of benefits. Where there are multiple types of benefits it is often not possible to quantify all the benefits that may be linked to the investment. The second factor involves uncertainty regarding the assumptions made, including the linkage between the research and the assumed outcomes. A confidence rating based on these two factors has been given to the results of the investment analysis (Table 16). The rating categories used are High, Medium and Low, where:

- High: denotes a good coverage of benefits or reasonable confidence in the assumptions made
- Medium: denotes only a reasonable coverage of benefits or some significant uncertainties in assumptions made
- Low: denotes a poor coverage of benefits or many uncertainties in assumptions made.

Table 16: Confidence in the Analysis of the NVT Investment

<b>Coverage of Benefits</b>	<b>Confidence in Assumptions</b>
High	Low

## 9. Conclusions and Lessons Learned

The NVT was implemented in 2005 through nine projects contracted to manage and operate variety trials for ten of the 24 GRDC crops. Total cost in present value terms of the GRDC investment over the five years to 2008/09 was of the order of \$20 million. The projects were contracted and there were no partner investments. Present value of benefits at \$24 million (over 30 years, using a 5% discount rate) were only slightly in excess of the present value of costs so that the overall benefit to cost ratio was a modest 1.2 to 1; the internal rate of return on funds invested was 10.3 percent.

A review of the NVT in 2008 concluded that despite implementation problems the arrangements were satisfactory and were working well. But the review was not able to source evidence to deliver on the impact of the NVT on increasing the rate of adoption of newly released varieties. Despite recommendations which were generally actioned by GRDC, this evaluation has had the same difficulty.

There was some evidence (confidential data made available by GRDC) on intake of varieties by year released for wheat and barley that showed the Australian average weighted age of varieties was of the order of ten years. The result is not surprising given the age of the dominant varieties in each state. All were released a decade or more ago. This inevitably results in a very low rate of turnover considered for example in the context of the time taken to breed a variety more resistant to disease and for it to achieve widespread adoption. The low rate of turnover suggests there would have been much scope for NVT to increase turnover, an increasingly important goal given the challenges of adapting to climate change. But analysis of the national data for wheat showed that the weighted age had paradoxically increased markedly in the GRDC Northern Region to 14 years (actually more typical of the upper range from a review of developing countries). For the rest of Australia, age had remained stationary at an average around 8 years. Any early benefit of NVT in the Northern Region would have already been expressed as a lowering of the age down to 14. The most likely conclusion had to be that NVT to date had only resulted in at best modest increases in the rate of adoption of superior varieties.

The increase attributable to NVT had to be measured against a counterfactual scenario of what would have eventuated if GRDC had not invested in the current NVT. The increase would have to be assessed for 10 crops and taking into account impacts from adoption of several hundred varieties in NVT. In the absence of data, a feasible scope for the evaluation was achieved by assuming a counterfactual scenario whereby GRDC continued variety trials for crops other than wheat similar to the arrangements for crops not currently in NVT and for current NVT crops prior to NVT.

Grower surveys and monitoring the mix of varieties delivered to major accumulators were two measures implemented by GRDC following the NVT review. But although data from those sources do show changes in variety adoption rates they do not help in identifying what can be attributed to NVT. There are three issues:

1. The underlying rate of genetic gain of varieties coming into the NVT (and how it is measured) is a key driver of the adoption rate and hard to measure in the short term,
2. The benefit from adopting one outstanding new variety will not have a significant impact until several years after release, and net impacts need to account for reduced adoption of earlier and later released varieties, and
3. The overall benefit from NVT will arise mainly from a speeding up of adoption for a given rate of genetic gain given that any impact of NVT on genetic gain will be minor and a decade away given the breeding cycle.

The analysis had to make assumptions on the rate of adoption attributable to NVT that were a synthesis of answers to three basic questions:

- Were Australian growers inherently cautious adopters of new varieties?
- Was this compounded by the seemingly rare appearance of what were seen to be superior varieties, and grower expectations of the rate and value of genetic gain being achieved? and
- Would more reliable information delivered sooner after release of a variety make a difference?

The evaluation assumed that NVT resulted in a rate of increase in farm wheat yield performance which was assumed equivalent to a 10 percent increase on the underlying annual genetic gain of 0.75 percent. However given adoption lags and reduced attributions to NVT outside the investment period the benefits were modest even when applied to the national wheat crop. Given cautious adoption of new varieties, NVT has a major challenge to change that in the short term.

A sensitivity analysis showed that the conclusion that the investment at this early stage of implementation was only moderately profitable was sensitive to the underlying assumptions on the rate of genetic gain and particularly on the adoption lag. There was a possibility that the rate of genetic gain of 0.75 percent was too conservative but that depended on what is the appropriate basis to measure genetic gain.

The conclusion is therefore that given there are serious implications from the observed rapid ageing of varietal turnover, high priority be given to analysing the underlying factors including a more objective analysis of the mix of varieties in deliveries to the accumulators. Such an analysis of the drivers of adoption could have major implications not just for NVT but more generally for a range of GRDC priorities and strategies. One obvious implication is that any reduced rate of varietal adoption would be reflected in a declining rate of productivity increase. But the studies of productivity decline in the grain industry have not focussed on that possibility.

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