GRDC

Grains Research & Development Corporation

GRDC IMPACT ASSESSMENT REPORT SERIES

JUL 09

An Economic Analysis of GRDC Investment in Oilseeds Breeding

GRDC Impact Assessment Report Series:

Title: **An Economic Analysis of GRDC Investment in Oilseeds Breeding**

July 2009

GRDC Project Code: ATR00005

This report was commissioned and published by the GRDC. 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
PO Box 385
TOOWONG QLD 4066
Phone: 07 3870 4047
Email: info@agtrans.com.au

ISBN No. 978-1-875477-93-7

Disclaimer

Impact Assessment: An Economic Analysis of GRDC Investment in Oilseeds Breeding (Brassicas and Soybeans)

Executive Summary

Although dwarfed by Australian cereal production, oilseeds play a significant role in Australian cropping systems. The investments considered in this evaluation are associated with improving the genetic material available to oilseed producers through breeding brassicas (predominantly canola) and soybeans.

Increasing yields per unit area is one of the most important components of increasing productivity and profitability of cropping systems. An important contributor to yield increases over time is the improvement in genetic material delivered by plant breeders.

Plant breeding for most crops is ongoing; the investment considered here is the GRDC investment from 2001/02 to 2011/12 for both canola and soybean crops. These GRDC investments were made in conjunction with public agencies, both State and Commonwealth.

There have been new cultivars of both canola and soybeans released as a result of the two breeding programs. Many of the new cultivars of canola are resistant to blackleg (at least in the first few years), have higher yields, are suitable to drier areas, tolerant to herbicides, and have improved quality characteristics. Soybean cultivar improvements have been associated with yield improvements to soybeans as well as quality, the latter being most important in the expanding culinary market.

In both cases the new cultivars have been continually adopted by industry. For canola, as with wheat, sorghum and maize, GRDC and the state agencies have moved away from cultivar development during the period of the investment with private sector breeders now undertaking the breeding role. The program now focuses on germplasm improvement or pre-breeding, with outputs made available to the private sector breeding activities. This change does not apply to soybeans where the small size of the industry makes the crop less attractive to private sector interest.

The improvements in yields for each crop have been analysed and part of the gains attributed to the breeding investment under consideration. The yield improvements have been masked to some extent in the eastern/southern states due to dry seasons and the increasing proportion of canola grown in drier and lower yielding areas. Both canola and soybeans have implications for the production of other crops and such benefits have been identified in the analysis.

The total investment in breeding for the two crops has been estimated to provide a net present value of $148 m and a benefit-cost ratio of 4 to 1 (analysis over 30 years and at a 5% discount rate). The investment criteria for breeding in each of the two crop types have been both positive.

The difficulty in assessing the progress made by new cultivars and the benefits they provide to producers has been highlighted by the evaluation, with added complexity provided by the ongoing breakdown of resistance to blackleg for canola.

An overview of identified benefits in a triple bottom line categorisation is shown in the following table. Not all of the identified benefits are valued in this analysis. Of the identified benefits, only the economic benefits are measurable based on the data available..

Categories of Benefits from the Investment

Levy Paying Industry	**Spillovers**		
	Other Industries	**Public**	**Foreign**
Economic benefits			
Yield increases to canola and soybean growers Maintaining oilseeds in rotations can potentially lead to reduced chemical usage on farms by oilseed levy payers and lower costs of production Yield increases to cereal growers from maintenance of oilseeds in crop rotations via provision of a disease break Fertiliser cost reduction from nitrogen supplied by soybeans in rotations	Yield increases to sugarcane growers from maintenance of oilseeds in crop rotations Maintaining oilseeds in rotations can potentially lead to reduced chemical usage on farms (e.g. fungicides for blackleg in canola crops) and fertiliser usage by sugarcane producers and hence lower costs of production		Marginal contribution to foreign consumers of canola as more canola is exported but with a very small impact on the world price
Environmental benefits			
Maintaining canola in rotations can lead to reduced chemical usage on farms and potentially to lowered chemicals in the farm environment	Maintaining oilseeds in rotations can potentially lead to reduced chemicals/ fertiliser in the cereal/sugarcane farm environments	Increased plant resistance can lead to less chemical/ fertiliser usage on oilseed/other farms and potentially to reduced export of chemicals and nutrients to public waterways	Nil
Social benefits			
Improved farmer well being through avoidance of chemical use by farmers	Nil	Potential health benefits from high oleic canola oils	Nil

1. Introduction

This evaluation refers to the GRDC oilseed breeding program for brassicas and soybeans. Brassicas are defined for the purposes of this evaluation as canola (*Brassica napus*) and Indian mustard (*Brassica Juncea)*. Canola is given more attention than soybeans in this study in line with the relative number of GRDC projects funded and the relative importance of these two crops in Australian cropping systems.

At the beginning of this investment (July 2001) canola had become a key crop in Australian broadacre cropping rotations. The area of canola grown in Australia in the five year period (1997-2001) had averaged 1.1 million ha.

The National Brassica Improvement Program (NBIP) commenced in 1992 and had been ongoing for some years with the last renegotiation in 2004. The program had developed both more productive and higher quality cultivars that formed the majority of the Australian canola crop.

Advances had been made in cultivars for lower rainfall environments, herbicide tolerant cultivars, as well as improved blackleg resistance. However, there was an identified need for further cultivar development with improved yield and quality and increased herbicide tolerance and disease resistance.

Rapid expansion of the canola area with increased stubble retention and tighter rotations had resulted in disease pressures increasing (predominantly blackleg and sclerotinia). Expansion into lower rainfall areas and use of triazine tolerant cultivars was associated with a fall in oil content of the crop.

There were four privately owned canola breeding initiatives in Australia at the commencement of the investment. During the period of this investment, the GRDC projects moved from an end point of release of cultivars in each state to the improvement of germplasm that could be used by the NBIP and private plant breeder companies alike. In fact, the September 2005 GRDC review of the NBIP recommended that the role of the NBIP should change from cultivar development to being the developer and provider of germplasm incorporating new or enhanced traits for the Australian canola industry. The recommendation was accepted and the private breeding companies were then responsible for incorporation of these traits into new open-pollinated or hybrid cultivars.

Soybeans are currently grown predominantly in inland NSW (Riverina and northwest) and Queensland (central and south) and in coastal areas of northern NSW and Queensland. Australian soybean areas have reached 50,000 ha in only two years in the past 20, in 1988/89 and in 1999/2000. The area of soybeans grown in Australia in the five year period before the investment commenced (1997-2001) had averaged 41,000 ha. Soybeans produced for oil and meal have come under increasing pressure from imports and the quantities produced for this market have fallen in the past decade. However, the quantities of soybeans produced for culinary purposes (high quality edible soybeans) have been increasing and now account for about 50% of all Australian soybean production. Soybean production in the past few years has been curtailed by drought and shortage of irrigation water in inland areas and prices for competing crops such as sorghum and cotton; however, in 2008/09 the area and yield have increased significantly due to timing of good rainfall in late 2008 and relative crop price changes. The latest production estimate for 2008/09 is for a record 136,000 tonnes.

2. Project Investment

Projects Funded by GRDC
Eleven projects have been funded by GRDC in this investment cluster as listed in Table 1. Table 2 provides a summary of the objectives of each project.

Table 1: Oilseed Breeding Projects Funded by GRDC

Project Code and Title	Other Details
Canola	
DAV457:National Brassica Improvement Program - Component 1: Lead Agency and Agriculture Victoria	Organisation: Agriculture Victoria, Department of Natural Resources and Environment Period: July 2001 to June 2004 Principal Investigator(s): Phillip Salisbury
DAN475: National Brassica Improvement Program - Component 2: Stage 2: NSW Agriculture	Organisation: NSW Agriculture Period: July 2001 to June 2004 Principal Investigator(s): Neil Wratten
DAS337: National Brassica Improvement Program - South Australian Component	Organisation: South Australian Research and Development Institute (SARDI) Period: July 2001 to June 2004 Principal Investigator(s): Trent Potter
DAV00060:National Brassica Improvement Program - DPI Victoria and Lead Agency	Organisation: Department of Primary Industries, Victoria Period: July 2004 to June 2007 Principal Investigator(s): Phillip Salisbury
DAN00063: National Brassica Improvement Program - Component 2: Stage 3: NSW Agriculture	Organisation: NSW Department of Agriculture Period: July 2004 to June 2007 Principal Investigator(s): Neil Wratten
DAS00047: National Brassica Improvement Program - South Australian Component	Organisation: South Australian Research and Development Institute (SARDI) Period: July 2004 to June 2007 Principal Investigator(s): Trent Potter
DAV00085: Australian Canola Germplasm Enhancement Program (1.4.5 Project 1)	Organisation: Department of Primary Industries, Victoria Period: July 2007 to June 2012 Principal Investigator(s): Phillip Salisbury
DAV00086: Canola Quality Juncea Program (1.4.5 Project 2)	Organisation: Department of Primary Industries, Victoria Period: July 2007 to June 2010 Principal Investigator(s): Phillip Salisbury
DAN00108: National Brassica Germplasm Improvement Program - (1.4.5: Project 1)	Organisation: NSW Department of Primary Industries Period: July 2007 to June 2012 Principal Investigator(s): John Sykes
Soybeans	
CSP338: National Soybean Improvement Program	Organisation: CSIRO Plant Industry Period: July 2001 to June 2006 Principal Investigator(s): Andrew James
CSP00104: Australian Soybean Breeding Program	Organisation: CSIRO Plant Industry Period: July 2007 to June 2012 Principal Investigator(s): Andrew James

Table 2: Project Codes, Titles and Stated Objectives

Project Code and Title	Stated Objectives
Canola	
DAV457:National Brassica Improvement Program - Component 1: Lead Agency and Agriculture Victoria	1. To develop canola quality conventional and non-GMO herbicide tolerant *B. napus* and *B. juncea* canola cultivars with a range of maturities adapted to diverse regions of Australia. 2. To develop oilseed Brassica cultivars with a range of quality types to exploit different domestic and export market opportunities. 3. To co-ordinate blackleg resistance evaluation of interstate and crop evaluation trial lines from public and private organisations.
DAN475: National Brassica Improvement Program - Component 2: Stage 2: NSW Agriculture	1. To develop canola varieties with a range of maturities adapted to the diverse growing regions of Australia. 2. To maintain an Australia-wide co-ordinated evaluation scheme (yield, quality and blackleg resistance) for advanced germplasm from both public and private breeding organisations. 3. To produce double haploid populations for use in the National Brassica Improvement Program.
DAS337: National Brassica Improvement Program - South Australian Component	1. To develop improved varieties of *B. napus* and *B. juncea* with a range of maturities and quality, adapted to diverse growing regions in Australia. 2. To conduct the South Australian component of the Australia wide coordinated evaluation scheme program (yield, quality and blackleg resistance) to assess advanced germplasm from public and private organisations.
DAV00060:National Brassica Improvement Program - DPI Victoria and Lead Agency	1. To develop canola germplasm enhanced for key specific high priority traits identified by both the oilseeds industry and the National Brassica Improvement Program (NBIP) (traits beyond those already available in canola). 2. To finalise development of canola quality and specialty conventional and non–GMO herbicide tolerant *B. Napus* and *B. Juncea* cultivars with a range of maturities adapted to diverse regions of Australia to exploit different domestic and export market opportunities. 3. To provide blackleg and agronomic screening support to the coordinated national S2 evaluation scheme for both NBIP and private breeders.
DAN00063: National Brassica Improvement Program - Component 2: Stage 3: NSW Agriculture	1. To continue to develop varieties with a range of maturities adapted to the diverse growing regions of Australia (meeting expected requirements for canola quality, high yield, blackleg resistance, high oil plus protein levels and good agronomic type). 2. To develop germplasm with traits identified as priorities by both industry and the NBIP (additional priorities). 3. To maintain an Australia–wide coordinated evaluation scheme (yield, quality and blackleg resistance) for advanced lines from both public and private breeding organisations. 4. To produce double haploid populations to accelerate the development of germplasm pools, particularly for those characters controlled by several or many genes.
DAS00047: National Brassica	1. To identify selection of early maturing canola lines with yield,

Improvement Program - South Australian Component	oil and protein better than the controls by single plant selections and further yield and quality testing. 2. To identify selections of early maturing canola quality mustard lines with yield, oil and protein better than the control by single plant selections and further yield and quality testing.
DAV00085: Australian Canola Germplasm Enhancement Program (1.4.5 Project 1)	1. To equally and fairly provide advanced germplasm containing important new or improved traits to all Australian private canola breeding companies, to ensure that Australian growers have cultivars that allow them to compete effectively on world markets. 2. To provide germplasm in an Australian adapted background with good quality and blackleg resistance in the most cost and time efficient manner.
DAV00086: Canola Quality Juncea Program (1.4.5 Project 2)	1. To develop Clearfield tolerant juncea canola cultivars adapted to low rainfall Australian cropping environments 2. To develop advanced breeding lines of triazine tolerant *B. Juncea* adapted to low rainfall Australian cropping environments.
DAN00108: National Brassica Germplasm Improvement Program - (1.4.5: Project 1)	1. To equally and fairly provide advanced germplasm containing important new or improved traits to all Australian private canola breeding companies, to ensure that Australian growers have cultivars that allow them to compete effectively on world markets. 2. To provide germplasm in an Australian adapted background with good quality and blackleg resistance in the most cost and time efficient manner.
Soybeans	
CSP338: National Soybean Improvement Program	1. Assist the soybean industry to achieve its full potential by developing cultivars with wider adaptation, earlier maturity, improved yield, higher protein content, weathering tolerance, drought tolerance, phytophthora and other disease resistances. 2. Combine these traits with processing characteristics necessary for the higher value culinary markets. 3. Develop improved linkages between elements of the National Soybean Improvement program which support the more rapid advancement of the industry and promote efficiencies in delivering improved soybean varieties to farmers and processors.
CSP00104: Australian Soybean Breeding Program	1. Develop new soybean varieties with improved yield, agronomic traits, disease resistance, weathering tolerance, broader adaptation to Australian production environments and higher value culinary or functional traits.

Investment Inputs
Estimates of the funding by GRDC and others by project by year for the nine canola projects are provided in Tables 3 and 4. Funding by project by year for the two soybean projects are provided in Tables 5 and 6.

Table 3: Investment by GRDC by in Canola Projects for Years Ending June 2002 to June 2012 (nominal $)

YE June	DAV457	DAN475	DAS337	DAV 00060	DAN 00063	DAS 00047	DAV 00085	DAV 00086	DAN 00108	Total
2002	167,853	224,994	34,000	0	0	0	0	0	0	426,847
2003	177,076	242,245	35,190	0	0	0	0	0	0	454,511
2004	183,012	248,536	36,421	0	0	0	0	0	0	467,969
2005	0	0	0	346,288	260,000	57,000	0	0	0	663,288
2006	0	0	0	354,915	270,000	59,300	0	0	0	684,215
2007	0	0	0	360,000	280,000	61,600	0	0	0	701,600
2008	0	0	0	0	0	0	250,000	100,000	249,999	599,999
2009	0	0	0	0	0	0	250,000	150,000	249,998	649,998
2010	0	0	0	0	0	0	250,000	150,000	249,999	649,999
2011	0	0	0	0	0	0	330,000	0	269,999	599,999
2012	0	0	0	0	0	0	330,000	0	270,000	600,000
Total	527,941	715,775	105,611	1,061,203	810,000	177,900	1,410,000	400,000	1,289,995	6,498,425

Source: GRDC proposals and final reports

Table 4: Investment by GRDC Partners in Canola Projects for Years ending June 2002 to June 2012 (nominal $)

YE June	DAV457	DAN475	DAS337	DAV 00060	DAN 00063	DAS 00047	DAV 00085	DAV 00086	DAN 00108	Total
2002	1,173,286	973,699	56,350	0	0	0	0	0	0	2,203,335
2003	1,218,798	993,846	58,322	0	0	0	0	0	0	2,270,966
2004	1,267,855	994,172	60,350	0	0	0	0	0	0	2,322,377
2005	0	0	0	1,092,300	867,290	91,600	0	0	0	2,051,190
2006	0	0	0	1,125,100	901,982	95,300	0	0	0	2,122,382
2007	0	0	0	1,158,800	938,060	98,800	0	0	0	2,195,660
2008	0	0	0	0	0	0	384,869	761,530	384,725	1,531,124
2009	0	0	0	0	0	0	396,414	796,753	390,410	1,583,577
2010	0	0	0	0	0	0	408,518	833,735	396,807	1,639,060
2011	0	0	0	0	0	0	421,243	0	403,460	824,703
2012	0	0	0	0	0	0	430,287	0	410,924	841,211
Total	3,659,939	2,961,717	175,022	3,376,200	2,707,332	285,700	2,041,331	2,392,018	1,986,326	19,585,585

Source: Partners' investment based on project proposals

Table 5: Investment by GRDC for Soybean Projects for Years Ending June 2002 to June 2012 (nominal $)

YE June	CSP338	CSP00104	Total
2002	469,064	0	469,064
2003	490,392	0	490,392
2004	563,027	0	563,027
2005	570,126	0	570,126
2006	604,372	0	604,372
2007	0	0	0
2008	0	450,000	450,000
2009	0	450,000	450,000
2010	0	450,000	450,000
2011	0	450,000	450,000
2012	0	450,000	450,000
Total	2,696,981	2,250,000	4,946,981

Source: GRDC proposals and progress reports

Table 6: Investment by GRDC Partners for Soybean Projects for Years Ending June 2002 to June 2012 (nominal $)

YE June	CSP338	CSP00104	Total
2002	844,315	0	844,315
2003	882,706	0	882,706
2004	1,013,449	0	1,013,449
2005	1,026,227	0	1,026,227
2006	1,087,870	0	1,087,870
2007	0	0	0
2008	0	590,065	590,065
2009	0	570,293	570,293
2010	0	550,952	550,952
2011	0	566,274	566,274
2012	0	585,082	585,082
Total	4,854,567	2,862,666	7,717,233

Source: GRDC proposals

Table 7 shows the combined GRDC and partner investment for each year.

Table 7: Total Investment by GRDC and Partners in Eleven Projects on Oilseed Breeding (Canola and Soybean) for Years Ending June 2002 to June 2012 (nom. $)

Year ending June	GRDC	Partners	Total
2002	895,911	3,047,650	3,943,561
2003	944,903	3,153,672	4,098,575
2004	1,030,996	3,335,826	4,366,822
2005	1,233,414	3,077,417	4,310,831
2006	1,288,587	3,210,252	4,498,839
2007	701,600	2,195,660	2,897,260
2008	1,049,999	2,121,189	3,171,188
2009	1,099,998	2,153,870	3,253,868
2010	1,099,999	2,190,012	3,290,011
2011	1,049,999	1,390,977	2,440,976
2012	1,050,000	1,426,293	2,476,293
Total	11,445,406	27,302,818	38,748,224

3. Activities and Outputs

Summary of Activities

Canola

DAV457 was the first project funded in this cluster. This used a modified pedigree method of breeding with a major focus on selection for blackleg resistance and quality. Other breeding methods included recurrent selection, modified backcrossing and double haploid procedures to develop the new cultivars of both *B. napus* and *B. juncea.* Crossing, single plant selections and initial yield testing followed and promising selections were tested across Australia through the coordinated inter-state evaluation scheme. The best lines were increased, protected by Plant Breeders Rights (PBR) and released as new cultivars for growers.

DAN475 used similar breeding methods to those described above in DAV457. Promising selections were then tested across Australia through the coordinated interstate evaluation scheme. This scheme continued to evaluate germplasm from both public and private breeders to identify the most appropriate lines to advance into the coordinated inter-state trials. The single plant selection scheme being used by the DPIs in SA and WA identified promising lines for their low rainfall environments.

DAS337 undertook no breeding activity per se but early generation crosses from both public and private breeding programs were tested at several sites in South Australia for yield, quality and blackleg resistance. The most promising lines were promoted into state core (S4) trials for further testing and possible release.

DAV00060 focused on the transition from germplasm improvement to cultivar development and release; the latter was increasingly being effected by private companies. Germplasm improvement in this project was centred on five areas:

- alternative sources of blackleg resistance
- enhanced drought tolerance and water use efficiency, in conjunction with an ACIAR project
- high oleic and low linolenic acid types
- improved white rust resistance in *B. juncea*
- development of zero allyl glucosinolate *B. juncea*

As with DAV00060, DAN00063 focused more on germplasm improvement as well as cultivar development and release. Focus was on blackleg and sclerotinia resistance, manganese and aluminium tolerances, development of both high oleic acid and low linolenic acid types particularly with increasing yield potential, and with herbicide tolerances. Germplasm improvement was assisted by the use of double haploids as a breeding tool and supported through a molecular marker program.

DAS00047 used single plant selections from conventional and triazine tolerant canola breeding lines from the DPI Victoria and DPI NSW breeding programs. Quality and yield of these lines were tested in South Australian conditions. Elite lines were then included in S2 or S4 trials in the next year. Best lines were then released.

DAV00085 is being jointly undertaken with DAN00108 and continues addressing the priorities identified for both agronomic (blackleg resistance, drought tolerance, shatter resistance and frost tolerance during seed development) and quality parameters (high oil and protein content, low saturated fats and low glucosinolates) in canola germplasm improvement. For each priority trait identified the following steps were undertaken:

- identify/develop screening protocols for each trait
- traits agreed to by industry and private sector
- assessment of genetic variability for each trait
- attempt to create variability in traits if required
- enhancement of trait expression through selection and breeding
- incorporation of enhanced traits as required into appropriate adapted backgrounds.

DAN00108 is being jointly undertaken with DAV00085 and commenced addressing the priorities identified above for both agronomic and quality parameters. Similar steps to those in DAV00085 were undertaken for each priority trait identified.

Clearfield (imidazolinone) tolerant juncea canola cultivars adapted to low rainfall cropping environments are being developed in DAV00086 by backcrossing for at least two generations the Canadian source of herbicide tolerance with adapted Australian juncea canola lines. Also, triazine tolerant juncea cultivars adapted to low rainfall environments are being developed by transferring the triazine tolerance from *B Napus* to juncea canola via interspecific hybridisation with at least 5-6 backcrosses required.

Soybeans

Breeding methods in CSP338 included simple crossing, top crossing and backcrossing and built on earlier Australian breeding initiatives for soybean. Extensive use was made of Japanese varieties with high quality culinary attributes. The program involved a range of research providers including CSIRO, NSW Agriculture, Queensland DPI and Victorian Department of Natural Resources and Environment. Targeted regions included northern Victoria, southern NSW, Coastal NSW, irrigated and dryland areas of southern Qld and northern NSW and coastal Queensland.

CSP00104 continued the activities of CSP338 and included pre-breeding activities, variety evaluation trials, and coordination and communication activities. In addition, strip trials in conjunction with Soy Australia were being conducted in eight locations.

Summary of Principal Outputs

A summary of the principal outputs (and expected outputs in the case of projects not yet completed) from each of the projects is reported in Table 8.

Table 8: Summary of Principal Outputs by Project

Project	Principal Outputs
DAV457: National Brassica Improvement Program - Component 1: Lead Agency and	• Herbicide tolerant cultivars with enhanced yield, blackleg resistance and quality characteristics, including a *B.Juncea* cultivar adapted to low rainfall areas • Specifically, in 2002, release of early triazine tolerant (TT) cultivar ATR Eyre and early-mid TT cultivar ATR

Agriculture Victoria	Beacon • Specifically, in 2003, the release of mid-season conventional cultivar AV Sapphire • Specifically, in 2005, the first juncea canola cultivar released on a demonstration scale • Enhanced germplasm for subsequent use in the breeding program included enhanced high oleic, low linolenic and imidazolinone tolerant (IT) germplasm • Cultivars derived from the enhanced germplasm included a high oleic low linolenic (HOLL) cultivar developed with Cargill and was released in 2005 • An IT cultivar was releases in 2007/08.
DAN475: National Brassica Improvement Program - Component 2: Stage 2: NSW Agriculture	• Cultivars with a range of maturities (both conventional and non–GMO) herbicide tolerant and with improved blackleg resistance, yield and quality • Three new conventional varieties released including: ▪ Rivette (early maturing) released September 2001 and grown commercially in 2002 ▪ Lantern (mid maturing) released September 2001 and grown commercially in 2002 ▪ Skipton (mid maturing) released in 2003 and grown commercially in 2004 • All varieties released through the Canola Alliance and marketed to growers by PlantTech • Also, herbicide tolerant and HOLL types were planned but progress was delayed by drought in 2002 so 2003 releases were delayed until 2005 or 2006
DAS337: National Brassica Improvement Program - South Australian Component	• Completed analysis of yield, quality and blackleg resistance for interstate trial lines • Evaluation of selections from NSW and Victorian breeding programs with further trials leading to release of improved cultivars • Three lines tested in S4 lines in 2004 were bulked up for released, one in 2006 and two in 2007 (superior grain yields) • Produced early maturing varieties for low rainfall areas in SA and WA and for other states as well
DAV00060: National Brassica Improvement Program - DPI Victoria and Lead Agency	• Change from cultivar development to enhanced germplasm effected • DPI Victoria produced and released 15 conventional or herbicide tolerant specialty oil cultivars during the project period as well as juncea canola cultivars • HOLL cultivars included Cargill 100 and 101 released in 2006; in 2007 two more HOLL Lines Cargill 102 and 103 were released • Conventional and TT breeding programs of DPI Vic sold to Nu Farm • Enhanced germplasm with alternative sources of blackleg resistance being utlised by breeding

	companies, as well as white rust resistance and low allyl glucosinolates • Blackleg resistance rating support to NBIP, National Variety Trials (NVT) and BMMP projects and coordination of national blackleg survival ratings • Release in 2007 of Dune - first juncea canola cultivar for low rainfall environments and for late sowing in higher rainfall areas
DAN00063: National Brassica Improvement Program - Component 2: Stage 3: NSW Agriculture	• Released three new varieties Tarcoola (early maturity conventional), WarriorCL (early mid Clearfield) and BravoTT (early–mid triazine tolerant) • Germplasm pools developed with traits identified as priorities by industry (NBIP for 2004-2007) • Double haploid populations were produced to accentuate the development of homozygous germplasm pools – basis for improvements in cultivars in future • Lines to be made available to private sector breeders for use in their programs through a germplasm exchange agreement • Coordinated S2 evaluation scheme advanced lines for both private and public breeders for yield, quality and blackleg resistance until the advent of the NVT scheme in 2005- then yield and quality responsibility of NVT and blackleg responsibility of NBIP
DAS00047: National Brassica Improvement Program - South Australian Component	• Improved early maturing canola and canola quality mustard lines with improved yield and more desirable oil and protein contents • Six of the single plant selections by SARDI have been used in the NSW breeding program and three in the Victorian program • In 2007, two canola varieties were released jointly by SARDI and the original breeder of the line (Tarcoola and ATR-Barra) • Lines selected from juncea canola have been returned to Vic DPI breeding program to improve the earliness of lines with the program • Overall, the single plant selections have provided elite lines of early maturing conventional and triazine canola with improved quality that can be used as parents and which also have been released in their own right (Tarcoola and ATR-Barra)
DAV00085: Australian Canola Germplasm Enhancement Program (1.4.5 Project 1)	• Identification of alternative sources of blackleg resistance and new combinations of resistance genes • Shatter resistance trials undertaken in 2008 were lost due to drought • Evaluation of existing variability for quality traits (low saturated fats, low glucosinolates, and high oil and protein content) in breeding lines showed considerable variability, but this pursuit was put on hold as was no longer considered a high priority

DAV00086: Canola Quality Juncea Program (1.4.5 Project 2)	• Two Clearfield (imidazolinone) tolerant lines being fast tracked (now one year ahead of schedule) and are currently in seed production for 2009 release – they were entered into multi-location breeding trials and NVT sites in 2008 • Early generation TT lines from 2007 nursery were quality tested with the best lines yield trialled in 2008, re-evaluated in 2009 and possibly released in 2011-12 or later
DAN00108: National Brassica Germplasm Improvement Program - (1.4.5: Project 1)	• Work plan developed for development of enhanced adapted germplasm with major lines selected for key traits (blackleg resistance and frost and water stress tolerance) • Regular meetings with the Canola Breeders Group and the Brassica Molecular Marker Program to assess priorities, progress, and methods, and to ensure coordination • No infection of blackleg occurred in first year due to drought - so trial was repeated again in 2008 • Also drought and shatter tolerance and frost tolerance trials failed due to drought in 2007 • Intellectual property access and benefit sharing model finalised
CSP338: National Soybean Improvement Program	• New varieties released for irrigation areas with high culinary quality and strong phytophthora resistance • Varieties released with broader adaptation to latitude and sowing date for use in multiple planting windows • New varieties produced with weathering tolerance and light hilum for coastal areas of NSW and Qld Examples of specific releases are: • Cowrie (2002) • Variety 97016-11 (Snowy) for the Riverina (2004) • Variety 98050-46 (Bunya) for N NSW to N Qld is undergoing seed increase (2004) • Variety Surf (feed only) was released in March 2004
CSP00104: Australian Soybean Breeding Program	• Variety Fraser was released in 2007 • Varieties with improved yield, agronomic traits, disease resistance, weathering tolerance, higher value culinary or functional traits and that are well-adapted to different production environments are in evaluation trials • Significant progress was made for a release of phytophthora resistance variety for the Riverina and a cultivar release for northern NSW is planned • Three new cultivar releases are planned in 2009

4. Outcomes

Project Outcomes

A summary of the principal outcomes from each of the eleven projects is reported in Table 9.

Table 9: Summary of Principal Outcomes by Project

Project	Principal Outcomes
DAV457: National Brassica Improvement Program - Component 1: Lead Agency and Agriculture Victoria	• Adoption of cultivars that increased both productivity and quality (e.g. high oleic and low linolenic oils) of canola in all major cropping areas • Beacon and Sapphire cultivars were widely adopted and planted on 300,000 ha in total in 2004 • ATR Eyre had limited impact due to release of Surpass (Pacific Seeds) and ATR Stubby (AgSeed/DPI Joint venture). • Continuation of canola as a component of sustainable rotations, increased export competitiveness, and increased genetic capital
DAN475: National Brassica Improvement Program - Component 2: Stage 2: NSW Agriculture	• Adoption of cultivars that will increase both productivity and quality of canola (e.g. high oleic and low linolenic oils) in all major cropping areas • Continuation of canola as a component of sustainable rotations, increased export competitiveness, and increased genetic capital
DAS337: National Brassica Improvement Program - South Australian Component	• Better adapted varieties for SA and other states with high yield and oil contents • Improved cultivars in SA commercialised through the Canola Alliance and delivery through marketing companies (via tenders) • Continuation of canola as a component of sustainable rotations, increased export competitiveness, and increased genetic capital
DAV00060: National Brassica Improvement Program - DPI Victoria and Lead Agency	• Enhanced grower profitability with juncea canola • HOLL cultivars quality image of the specialty oil industry which was expected to become more important • NUfarm had the marketing rights to TT, Cargill the specialty quality cultivars and SWP the juncea canola • The national blackleg survival ratings were mainly utilised by growers • Continuation of canola as a component of sustainable rotations, increased export competitiveness, continued germplasm development, and increased genetic capital within program
DAN00063: National Brassica Improvement	• All new cultivars released via Canola Alliance (unincorporated joint venture between NSW DPI, Nugrain p/l and Plant Tech p/l)

Program - Component 2: Stage 3: NSW Agriculture	• New improved cultivars have provided growers with more options for including canola in rotations. Also, a range of maturities and herbicide resistance tolerances provide opportunities for expansion of canola. Herbicide resistant varieties provided control where canola not grown successfully before and provide a mechanism to rotate herbicides, so reducing herbicide resistance.
DAS00047: National Brassica Improvement Program - South Australian Component	• Better adapted cultivars with higher yield and oil content resulting in canola and canola mustard being adopted and included in rotations on more farms in the lower rainfall areas of southern Australia
DAV00085: Australian Canola Germplasm Enhancement Program (1.4.5 Project 1)	• Adapted germplasm containing important new or improved traits expected to be provided to all private canola breeding companies • Expected utilisation of this germplasm by private breeding companies to enable Australian growers to compete effectively on world markets
DAV00086: Canola Quality Juncea Program (1.4.5 Project 2)	• Release and adoption of herbicide tolerant juncea canolas in low rainfall environments so allowing control of weeds and increasing benefits over existing canola lines due to more vigorous seedling growth, quicker ground covering ability, greater tolerance to heat and drought and enhanced resistance to blackleg
DAN00108: National Brassica Germplasm Improvement Program - (1.4.5: Project 1)	• Germplasm containing important new or improved traits expected to be developed and provided to all private canola breeding companies • Expected utilisation of this germplasm by private breeding companies to enable Australian growers to compete effectively on world markets
CSP338: National Soybean Improvement Program	• Development of a more profitable soybean industry in Australia through access to higher value markets for culinary quality soybeans • Greater security of production through provision of better-adapted cultivars with durable disease resistance, enhanced tolerance to weathering and earlier maturity • Increased tonnage of soybeans grown for domestic and export culinary markets • Higher protein soybeans which allow crushers to enhance the quality of local soybean meal and improve demand for full-fat soy meal • Access to more suitable varieties for coastal production areas which encourage adoption of soybean as a profitable grain crop
CSP00104: Australian Soybean Breeding Program	• Adoption of better adapted varieties in most soybean growing regions • Increased area of soybeans and greater profitability to growers with new varieties

	• Expanded market access including higher value markets

In summary, the principal outcomes from the investment were:

Canola

- Cultivars released with higher levels of blackleg and sclerotinia resistance than displayed by previous cultivars
- Blackleg survival ratings have assisted growers decisions on cultivar choice and hence yields
- Cultivars with greater herbicide resistance (non-GMO)
- Cultivars with vigorous early growth and higher yields
- Cultivars with high oleic acid and low linolenic acid oils leading to potential health benefits
- Cultivars of Juncea canola with improved yields, oil quality and herbicide resistance
- Improved cultivars have led to higher profitability of canola and maintained its valuable role in broadacre cropping rotations
- Enhanced germplasm supplied to breeding companies with emphasis on traits less driven by commercial imperatives.

Soybeans

- There have been a number of varieties released over the investment period. The market share of most of these varieties has been increasing over the period and by 2008/09 the Program varieties released over the period made up some 20% to 64% of the area of soybeans grown in each region.
- Cultivars have been released with improved culinary characteristics, stronger phytophthora resistance, broader adaptation to latitude and sowing date for use in multiple planting windows, and with weathering tolerance and light hilum for coastal areas
- Wider adaptation and higher value markets has led to increased profitability and localised area expansion
- Varieties released during the period 2002 to 2008 include those for the Riverina (Snowy 2005), Subtropical coastal NSW (Cowrie 2002, Bunya 2006 and Surf 2008), Inland irrigated areas in NSW and Qld (Cowrie 2002, Bunya 2006, and Fraser 2007), and Subtropical coastal Queensland (Bunya 2006 and Fraser 2007) (Andrew James, pers. comm., 2009).

5. Benefits

Canola

Yield increases

The principal benefits from the NBIP have been derived from the release of new cultivars that are more fungal disease resistant and better adapted to a range of growing conditions, including lower rainfall areas. This has had a potential impact on canola yields per ha. The development of herbicide tolerant cultivars (non-GMO types) has allowed improved weed control and also potentially raised yields.

Quality improvements
The investment has produced cultivars with high oleic acid and low linolenic acid that have been considered more desirable by consumers and which are considered health beneficial.

Juncea canola niche
Juncea canola is more suited to lower rainfall areas and has a greater stress tolerance compared to canola. The development of juncea canola cultivars which are more vigorous and more herbicide tolerant has allowed improved control of weeds in these drier areas, a problem that was inhibiting the growing of canola in such regions.

Maintenance of canola in cropping rotations
Canola has been playing an important role in providing a disease break for cereal grains such as wheat and barley in southern cropping regions. In many rotations a canola-wheat rotation is on average more profitable than a wheat–wheat rotation. For example, extensive surveys and trials across Australia have found that wheat yields are around 20% higher after canola than after wheat (Pritchard et al, 2007). Hence, if the profitability of the canola crop on its own declined due, for example, to increasing impacts of diseases such as blackleg, the profitability of the rotation may be affected.

Environmental
Maintaining disease breaks through rotations and increased plant resistance can lead to less chemical usage on farms, so benefiting the farm environment and potentially leading to reduced export of chemicals to public waterways. Specifically, knowledge of blackleg resistance in varieties can assist growers regarding the effective application of fungicides to canola crops.

Social
There are potential health benefits from HOLL canola. There is a growing preference for healthier products, with an increasing demand for canola and high oleic oils.

Soybeans

Yield increases
The principal benefits from improved cultivars of soybeans has been derived from improved adaptation to various regional areas and allowing a wider range of sowing dates, as well as a higher level of disease resistance (mainly to phytophthora).

Quality improvements
The development of cultivars that are more suited to quality food uses has lifted the value of this part of the market for soybeans. Associated with this benefit has been the contribution of the breeding project organisations to the formation of the Northern Australian Soybean Industry Association which has gone on to be the basis for Soy Australia (Andrew James, pers.comm., 2009).

Benefits in Rotations
Sugar cane growers account for 30% of NSW North Coast soybean production providing a cane break and nitrogen for the next cane planting. Queensland sugarcane producers (for example, in the Isis/Bundaberg area) have also increased

soybean production for the culinary market. In southern NSW soybeans are grown under irrigation in the summer and provide a double cropping opportunity for winter crop producers.

Environmental
Maintaining disease breaks through rotations and increased plant resistance through use of soybeans can lead to less chemical usage on cereal/sugarcane farms, benefiting the farm environment and potentially leading to reduced export of chemicals to public waterways. Nitrogen contributed by soybean crops can reduce nitrogen fertiliser required in cereal and sugarcane crops.

Overview of Benefits
An overview of benefits in a triple bottom line categorisation is shown in Table 10.

Table 10: Categories of Benefits from the Investment

Levy Paying Industry	**Spillovers**		
	Other Industries	**Public**	**Foreign**
Economic benefits			
Yield increases to canola and soybean growers Maintaining oilseeds in rotations can potentially lead to reduced chemical usage on farms by grain levy payers and lower costs of production Yield increases to cereal growers from maintenance of oilseeds in crop rotations via provision of a disease break Fertiliser cost reduction from nitrogen supplied by soybeans in rotations	Yield increases to sugarcane growers from maintenance of oilseeds in crop rotations Maintaining oilseeds in rotations can potentially lead to reduced chemical usage on farms (e.g. nitrogen fertiliser usage by sugarcane producers and hence lower costs of production)		Marginal contribution to foreign consumers of canola as more canola is exported but with a very small impact on the world price
Environmental benefits			
Maintaining canola in rotations can lead to reduced chemical usage on farms and potentially to lowered chemicals in the farm environment	Maintaining oilseeds in rotations can potentially lead to reduced chemicals/ fertiliser in the cereal/sugarcane farm environments	Increased plant resistance can lead to less chemical/ fertiliser usage on oilseed/other farms and potentially to reduced export of chemicals and nutrients to public waterways	Nil
Social benefits			

Improved farmer well being through avoidance of chemical use by farmers	Nil	Potential health benefits from high oleic canola oils	Nil

Public versus Private Benefits
The benefits identified from the investment are predominantly private benefits, namely benefits to oilseed producers in the southern and western states with some lesser benefits to Queensland soybean producers. Most spillover benefits are likely to also be private, mostly to cereal producers. There also will have been some public benefits potentially produced, mainly environmental in nature from lowered chemical usage with implications for water quality off-farm. Health benefits may also be delivered.

Benefits to other Primary Industries
The principal non-oilseed industry beneficiaries will be the cereal and sugarcane producers by way of canola being maintained in cereal rotations and soybeans being used increasingly as a break crop in cereal and sugarcane rotations.

Distribution of Benefits Along the Grains Supply Chain
Some of the potential benefits from more profitable production will be passed along the grain supply chain to oilseed processors, animal industries utilising canola and soybean meal, as well as participants in the edible soybean industry. Part of any estimated gain achieved by producers will be transferred to public and private sector plant breeders thorough royalties obtained from end point royalties.

Benefits Overseas
Growers of canola in overseas countries may benefit to some extent from cultivars produced in Australia. However, part of any benefit from overseas use will be captured by Australian holders of Plant Breeders Rights.

Match with National Priorities
The Australian Government's national and rural R&D priorities are reproduced in Table 11.

Table 11: 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

Table 12 identifies the rural research priorities that each of the benefits address.

Table 12: Categorisation of Benefits by Priorities

Benefit	National Research Priority Addressed	Rural Research Priorities Addressed
Productivity gains through yield increases and input cost reductions	Priority 3 ***	Priority 1 *** Priority 2 **
Improved quality of canola oil	Priority 2 *	
Less chemical usage on farm from disease breaks and more resistant cultivars	Priority 1 * Priority 2 *	Priority 3 * Priority 4 *

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

Additionality and Marginality
The investment in this cluster was targeted principally towards benefits to oilseed levy payers. Breeding programs are often perceived as the mainstay of productivity improvements for many crop species so that the investment would have been regarded as a high priority by levy payers. In the event that public funding were 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.

Most of the limited public spillovers that have been identified would therefore still have been delivered. If no public funding at all had been available, it is likely that the investment would have been curtailed to about 75% of what GRDC actually funded. This would have been associated with a slower rate of genetic progress, but may have sped up the transfer of cultivar production and release to the private sector. Further detail is provided in Table 13.

Table 13: Potential Response to Reduced Public Funding

1. What priority were the projects in this cluster when funded?	High
2. Would industry have funded this cluster if less funds were available?	Yes, but with a lesser amount
3. To what extent would industry have funded this cluster if only industry funds were available and no public funds?	75% of that actually funded; private sector would have taken a stronger role

6. Pathway to Adoption
Cropping farmers have to make choices continuously on cultivars and there is usually sufficient information available on past performance and on new release cultivars.

Peak adoption of a variety can take a number of years. Speeding up adoption is therefore likely to provide benefit to crop producers from earlier profitability gains.

A central objective of the National Variety Trials program (NVT) is to accelerate the adoption of superior varieties from breeding programs. Superior refers to varieties with improved yield, quality, disease resistance or combinations of these attributes (GRDC, 2009).

During the early period of benefits considered in the evaluation (post 2002), some canola cultivars were released and promoted by State agencies often in partnership with private marketing companies. From about 2006 onwards, as the cultivar development role shifted to private breeders, the latter were involved in most promotion and marketing activities.

The release of soybean cultivars has been accompanied by agronomic information derived from the breeding investment. This information has been provided to extension personnel in state agencies.

7. Measurement of Benefits

The benefits valued in the quantitative analysis are:

- the continuing disease resistance in new cultivars leading to the maintenance of canola in wheat rotations
- the yield increase from improved cultivars of canola
- the yield increases from new cultivars of soybeans
- the higher quality and prices of soybeans associated with culinary uses

Benefits from Canola Genetic Improvements

Farming systems in the four southern states of NSW, Victoria, SA and WA contribute the bulk of canola grown in Australia. The performance of the Australian canola industry since the investment began is reported in Table 14.

Table 14: Canola Industry Performance

Period	Area (ha)	Yield (tonnes/ha)	Production (tonnes) (a)	Exports (%)
Average for 1997 to 2001	1,117,020	1.34	1,451,260	66
Year ended June				
2002	1,331,500	1.3	1,730,950	n.a.
2003	1,298,000	0.7	908,600	n.a.
2004	1,211,000	1.4	1,695,400	71
2005	1,377,000	1.1	1,514,700	58
2006	971,000	1.5	1,456,500	59
2007	1,052,000	0.5	526,000	40
2008	1,061,000	1.0	1,061,000	44
2009	1,165,000	1.4	1,631,000	50
Average for 2002 to 2009	1,183,312	1.11	1,301,643	54

Source: ABARE (2008) with 2009 estimates and % exports (2004-2008) sourced from ABARE (2009)
(a) Individual year production estimated by multiplying area column by yield column

Benefit from the Maintenance of Canola in Rotations

The canola breeding program has continually released new varieties that are initially resistant to blackleg. Most new varieties eventually succumb to the disease although the use of fungicides can extend their life, albeit at an additional cost. As such, blackleg resistance is the most important attribute being pursued in the current germplasm enhancement program (Phillip Salisbury, pers comm., 2009).

Without the investment in the program being made, it has been assumed that eventually less canola would have been grown due to the lack of new varieties resistant to blackleg. It is assumed that canola areas would have been replaced with wheat and that the wheat yield for the following crop in those areas no longer growing canola would have suffered a 20% yield decline (that is, compared with canola being maintained in the rotation). It is assumed that the area decline would have commenced with a 10% decline in area in the sixth year after the program commenced (in 2006/07), and would have risen to a 30% decline by 2008/09. As the private sector breeders would have increased their investment from 2002 (in the without situation), it is assumed that new cultivar releases by private sector breeders would have eventually restored canola to its long-term average area by 2011/12.

Average wheat yields are taken as 1.7 tonnes per ha and average wheat prices at $176 per tonne at farm gate (2008/09 terms).

Benefits from Yield Increases

An analysis of the data in Table 14 shows there has been no statistically significant trend in Australian canola yields over the past eight years. Yields in NSW, Victoria and SA have all displayed apparent negative trends over the past eight years but a positive trend has been evident in Western Australia.

Droughts may have contributed to the observed static yields in the south-eastern growing regions. Other reasons why observed yields may not have displayed positive trends include:

(a) Canola has extended its presence in drier regions so causing average yield to fall
(b) Variety releases have not kept pace with the severity of fungal diseases in some regions

The Western Australian canola yields have been less affected by the weather than in the east where similar varieties are grown (Phillip Salisbury, pers.comm.,2009). While not statistically significant, WA canola yields have averaged a rate of gain of 0.8% per annum over the past 15 years and 1.5% over the last 8 years. A conservative estimate is used that yields have actually increased by 0.8% per annum Australia wide and that part of this increase has been due to the breeding program being evaluated.

The difficulty in assessing the progress made by new canola cultivars and the benefits they provide to producers has been highlighted by the evaluation. The performance of new canola cultivars released over time has been difficult to assess largely due to the yield decline due to blackleg (Neale Sutton, pers.comm., 2009). GRDC is currently investigating the performance of new cultivar releases over time from data assembled by the National Variety Trials. This investigation may allow improved assumptions for economic analyses such as the current evaluation.

Attribution of Genetic Gain to Potential Yield Increase
Thirtle (1985) estimated the share of the "biological change" in the production of five major US food crops for the period 1939 to 1978. He concluded that the biological components produced nearly 50% of the total yield growth observed. However, this included both use of improved varieties and other land–saving changes in agronomic practices.

Factors other than climate and genetic enhancement of cultivars used influence crop yields. For example, improved crop management practices or industry changes in input use will affect yield trends. Black et al (2008) explored the component contributions to the 1.7% per annum South Australian wheat yield increases between 1977 and 2006. Of the 1.7%, they estimated that 0.5% was attributed to variety improvements, a proportion of about 30%. Reading (2008) reports that two thirds of productivity originates from farming practices and one third from better varieties.

Hence, for the potential yield increase of 0.8% per annum estimated for canola over the benefit period, just one third of this gain is attributed to improved varieties (0.27% per annum) for purposes of the current evaluation.

Valuation of Additional Canola Yield
The potential benefit from genetic gain has been estimated individually for each year from 2001/02 up to 2008/09; thereafter the average production over the eight years is assumed for this purpose. The 0.27% gain per annum is applied on a cumulative basis. The annual average of the price and expected price between 2007 and 2013 has been used to value the increased production. The average production level (2002 to 2009) and price have been used for the years after 2009.

The price of wheat has been assumed at $236 per tonne (ABARE average price for wheat in 12 years to 2007/08) less an allowance for farm gate to port costs for wheat of $60 per tonne (Based on Wilkinson, 2006).

Matching Genetic Gain from New Cultivar Benefits to Investment Being Evaluated
The investment being evaluated commenced in the year ending June 2002. It is assumed that canola cultivars are produced from a 10 year breeding cycle. Hence, the influence of the investment in 2002 would have been marginal for any cultivars released in that first year, as the benefit for any release in 2002 would be attributed to the previous ten years breeding activity. However, it could be argued that approximately 10% of the benefit from that cultivar could be attributed to the investment in 2002; cultivars released in 2003 could be attributed 20% of the investment in 2003 and so on.

The last year of investment being considered is 2012. Releases in 2013, the first year after the investment has finished could be attributed 90% of the benefit for that release year and 2014 investment 80% and so on until 2022 when any releases would not be influenced at all by the current investment.

Two other factors need to be considered: variety adoption and genetic capital. Adoption (and hence the delivery of benefits) is not instantaneous after release and a lag of three years is assumed until varieties released in a particular year commence to make an impact. Genetic capital at the beginning and end of the investment period is assumed the same in terms of the time value of money. The canola breeding and cultivar release program became a genetic enhancement program during the life of the investment. However, breeding and cultivar release will proceed under the banner of the private sector so the yield increment is assumed to continue. Due to the specific focus shift within the investment being evaluated, the genetic capital at the end of the investment period may actually be higher than at the beginning. However, offsetting this will be the additional costs of the private breeders in cultivar development which are not included in the investment and are assumed recovered in end point royalties.

Counterfactual for Yield Benefits
If the NBIP and NBGIP had not existed, it is assumed there would still have been some significant breeding investment, but only by the private sector. It is assumed that the overall breeding and germplasm improvement effort (public plus private) would have contracted somewhat but would have still captured about half of the genetic gain in yields attributable to breeding (that is, with the investment being evaluated) until 2014/15 when 100% of the genetic gain assumed would have been restored.

Soybean Benefits from Genetic Improvement

Producers in NSW and Queensland account for the majority of soybeans produced in Australia. The performance of the Australian soybean industry since the investment began is reported in Table 15.

Table 15: Soybean Industry Performance 2002-2008

Year ended June	NSW Area (ha)	QLD Area (ha)	Total Area (ha)	Australian Yield (tonnes/ha)	Australian Production (tonnes) (b)
Five Year Average (1997 to 2001)	26,300	13,380	41,120	1.94	80,720
Year ended June					
2002	21,100	11,500	33,400	1.9	63,460
2003	7,300	3,000	10,300	1.8	18,540
2004	17,800	15,100	33,400	2.2	73,480
2005	17,000	8,000	26,200	2.1	55,020
2006	16,600	7,000	23,800	2.3	54,740
2007	8,500	5,100	13,600	2.4	32,640
2008	6,900	8,000	14,900	2.4	35,760
2009 (a)	24,855	33,750	59,105	2.3	135,942
Average (2002 to 2009)	14,994	11,431	26,838	2.2	58,658

Source: ABARE (2008)
(a) From Australian Oilseeds Federation, Crop Report March 2009.
(b) Individual year production estimated by multiplying yield column by area column

Soybean Yields

The soybeans yields in Table 12 have been increasing at an average rate of 0.7% per annum over the past 21 years and a faster rate in the past 8 years (1.6% per annum and statistically significant). However, areas have not increased except for the large increase in 2009.

The current and future yield increase is assumed at 1.6% per annum from the years ending 2002 onwards. Unlike canola, 50% of this gain has been assumed to be derived from cultivar improvements and accompanying information as much of the agronomic information for soybeans has been derived from the program. Also, in contrast to canola, once the cumulative gain due to breeding plateaus, then this gain is assumed to continue as there are no strong disease factors present that are identifiable.

Valuation of Additional Soybeans Produced

The potential benefit from genetic gain has been estimated for each year based on the average production levels of the eight years since the investment commenced. The 0.8% per annum gain attributable to the breeding program is assumed to apply on a cumulative basis. The price of soybeans used to value the increased production is $500 per tonne for crushing grade (based on world soybean prices) and $600 per tonne for culinary grade. The proportion of culinary grade beans produced has been assumed at 10% in 2002 rising to 50% in 2009 and thereafter.

Matching Genetic Gain from New Cultivar Benefits to Investment Being Evaluated

The investment being evaluated commenced in the year ending June 2002. The proportion of benefits each year that can be attributed to the investment has been estimated in a similar way as for canola. Variety adoption has been lagged three years after release and genetic capital at the beginning and end of the period is assumed constant.

Improved Soybean Quality

The cultivars released from the breeding program have contributed to the increase in soybean quality in past years, that is, the increase in production of culinary grade beans and the associated higher prices for culinary grade. Demand factors have been important also as have producers' willingness to change and grow soybeans. The breeding program has responded to the need and is attributed 50% of the benefits from the advent of higher quality and higher priced beans. Over the period of investment there has been a transition from black-hilum oilseed types to light hilum varieties with culinary attributes. Not all culinary types, however, have been developed by the breeding program since 2002.

Counterfactual for Soybean Benefits

If the soybean breeding program had not existed it is assumed there would have been only a small effort in cultivar improvement by the private sector. It is assumed that there would have been about only 10% of the genetic gain actually observed in the 'with program' situation. This dilution factor is far lower than that for canola due to the potential lesser influence of the private sector in soybean breeding.

Summary of Assumptions

A summary of the key assumptions made is shown in Table 16.

Table 16: Summary of Assumptions

Variable	Assumption	Source
Canola		
With the Investment		
Average Australian canola yield in past used as a base for post 2008/09	1.1 tonnes per ha per annum	See Table 14
Average annual area of canola in past eight years used as base post 2008/09	1,183,312 ha	See Table 14
Average yield gain from all sources from 2001/02 to 2008/09 and thereafter	0.8% per annum	Estimated from Western Australian ABARE data on canola yields
Proportion of yield gain due to cultivar improvement	33%	Based on Black et al (2008) and Thirtle (1985)
Value of canola	$504 per tonne	Average in 2008/09 terms of canola prices and expected prices over the period 2007 to 2013, adjusted for farm gate value (ABARE, 2009)
Lag between cultivar release and any significant adoption	Three years	Agtrans Research
Attribution of cultivar improvement to investment years	Proportion of benefits in any year post 2001 increasing from 10% (2002) to 100% (2011) and then declining to 0% (2022)	As described earlier
Wheat yield foregone if canola replaced with wheat in rotations due to canola no longer being viable due to blackleg	20%	Pritchard et al (2007)
Value of wheat	$176 per tonne at farm gate	ABARE (2008) and Wilkinson (2006)
Average yield of wheat	1.7 tonnes per ha	ABARE average yields for past twelve years
Genetic capital change	No change in discounted $ terms	Agtrans Research
Without the Investment		
Contraction of canola area	10% in 2006/07 rising to 30% in 2008/09 and decreasing to 0% in 2011/12 and thereafter	Agtrans Research
Proportion of benefits from yield increases accruing without the investment (private breeders)	50% of the yield benefits assumed	Agtrans Research

Soybeans		
With the Investment		
Average Australian yield in past eight years used as base post 2008/09	2.2 tonnes per ha	See Table 15
Average annual area of soybean in past eight years used as base post 2008/09	26,838 ha assumed post 2008/09	See Table 15
Average yield gain from all sources from 2001/02 to 2008/09 and thereafter	1.6% per annum	Estimated from ABARE data
Proportion of yield gain due to cultivar improvement	50%	Adjusted by Agtrans Research from 33% based on Black et al (2008) and Thirtle (1985)
Proportion of soybeans achieving culinary grade prices	10% in 2002 rising to 50% in 2009 and thereafter	Agtrans Research, after discussions with Andrew James
Attribution of culinary grade increase to the breeding program	50%	Agtrans Research
Value of crushing grade soybeans	$500 per tonne farm gate	Average of world indicator price for soybeans over period 2006 to 2008 of $US450 per tonne, adjusted to $360 US$ per tonne for an Australian farm gate price, equivalent to $500 per tonne $500 per tonne @ exchange rate of 0.72 US$ per A$
Positive price margin for culinary grade soybeans	$100 per tonne	Andrew James, pers. comm., 2009
Lag between cultivar release and adoption	Three years	Agtrans Research
Attribution of cultivar improvement to investment years	Proportion of benefits in any year post 2001 increasing from 10% (2002) to 100% (2011) and then declining to 0% (2022)	As described earlier
Genetic capital change	No change in discounted $ terms	Agtrans Research
Without the Investment		
Proportion of benefits accruing without the investment	10% of the benefits attributed to the investment	Agtrans Research

Results
All past costs and benefits were expressed in 2008/09 dollar terms using the CPI. All benefits after 2008/09 were expressed in 2008/09 dollar terms. All costs and benefits were discounted to 2008/09 using a discount rate of 5%. The base run used the best estimates of each variable, notwithstanding a high level of uncertainty for many of the estimates. All analyses ran for the length of the investment period plus 30 years from the last year of investment (2011/12).

The present value of benefits (PVB) from each source of benefits (canola and soybeans) was estimated separately and then summed to provide an estimate of the total value of benefits.

Investment criteria were estimated for both total investment and for the GRDC investment alone. Each set of investment criteria were estimated for different periods of benefits. The investment criteria were all positive as reported in Tables 17 and 18.

Table 17: Investment Criteria for Total Investment and Total Benefits for Each Benefit Period
(discount rate 5%)

Criterion	**0 years**	**5 years**	**10 years**	**20 years**	**25 years**	**30 years**
Present value of benefits (m$)	78.07	107.15	139.75	186.68	192.78	196.45
Present value of costs (m$)	48.81	48.81	48.81	48.81	48.81	48.81
Net present value (m$)	29.27	58.34	90.95	137.87	143.98	147.64
Benefit-cost ratio	1.60	2.20	2.86	3.82	3.95	4.02
Internal rate of return (%)	18.9	22.8	24.2	24.8	24.8	24.8

Table 18: Investment Criteria for GRDC Investment and Benefits to GRDC for Each Benefit Period
(discount rate 5%)

Criterion	**0 years**	**5 years**	**10 years**	**20 years**	**25 years**	**30 years**
Present value of benefits (m$)	22.76	31.23	40.73	54.41	56.19	57.26
Present value of costs (m$)	12.72	12.72	12.72	12.72	12.72	12.72
Net present value (m$)	10.04	18.51	28.01	41.69	43.47	44.54
Benefit-cost ratio	1.79	2.46	3.20	4.28	4.42	4.50
Internal rate of return (%)	23.3	26.8	27.9	28.3	28.3	28.3

The proportion of total benefits from the canola and soybean breeding programs was 76% and 24% respectively. The soybean investment alone provided a benefit–cost ratio of 3.0 and the canola investment a benefit-cost ratio of 4.5.

It could have been expected that the soybean breeding investment would have given significantly lower returns due to the small size of the industry and the relatively large investment (33% of the total investment was in the soybean breeding cluster). Some of the reasons for this positive outcome for soybean breeding would appear to be:
(i) a more active private sector involved with canola breeding that would have bridged the gap in the 'without investment' situation
(ii) higher annual yield gains assumed for soybeans and a higher proportion of gains attributed to the breeding investment due to the agronomic information produced
(iii) the quality improvement in soybeans due to the investment
(iv) higher level of gains retained from soybean cultivars released due to absence of serious resistance

There are four sources of benefits valued in the analysis. Table 19 shows the relative estimates of the contribution from each source.

Table 19: Contribution of Source of Benefits to Present Value of Benefits

Source of Benefit	**Relative Contribution to Present Value of Benefits (%)**		
	To Canola benefits	To Soybean benefits	To Total benefits
Canola - maintenance of area	41	0	31
Canola – yield increase	59	0	45
Soybean – yield increase	0	53	13
Soybean – quality improvement	0	47	11
Total	100	100	100

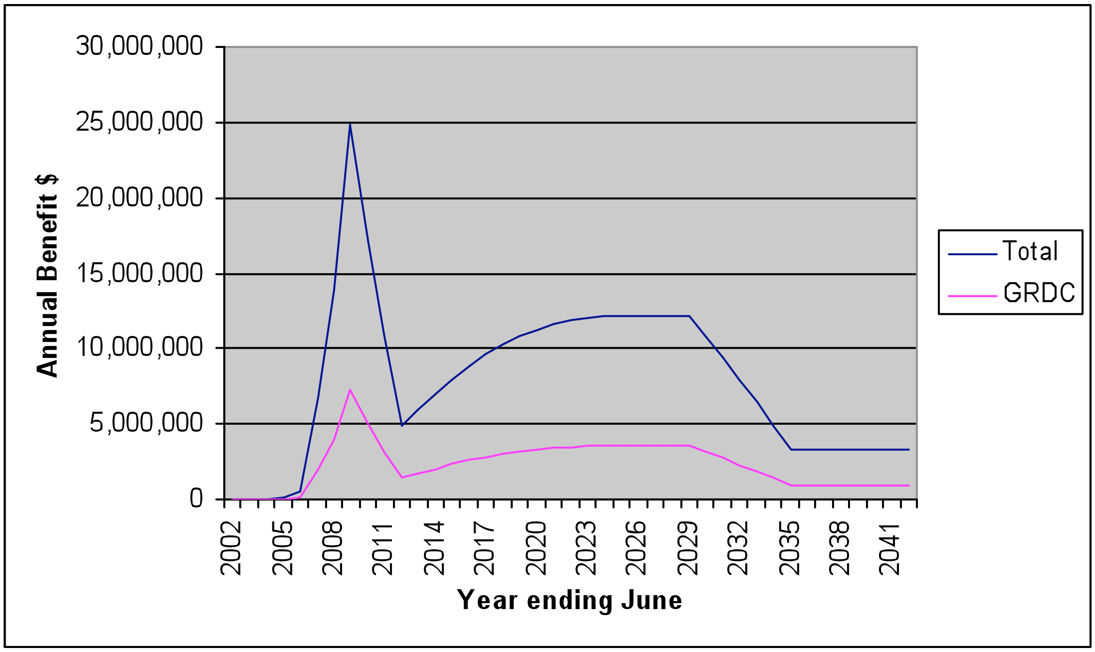
The quantified benefits are allocated to the Rural Research Priorities as expressed in Table 20.

Table 20: Allocation of Quantified Benefits to Rural Research Priorities

Rural Research Priority	**Allocation**
1. Productivity and adding value	100%

The annual net benefit cash flows for both total investment and GRDC investment for the 30 year period from the year of first investment are shown in Figure 1.

Figure 1: Annual Benefit Cash Flow



Sensitivity Analyses

Sensitivity analyses were carried out on several variables and results are reported in Tables 21 and 22. The sensitivity analyses were performed using a 5% discount rate with benefits 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 21 shows the sensitivity of the investment criteria to changes in the assumptions regarding the annual yield gains from new cultivar releases produced by the two breeding programs.

Table 21: Sensitivity of Investment Criteria to Yield Gains from New Cultivars of Canola and Soybeans
(Total investment, 5% discount rate, 30 years)

Criterion	Half Base	Base (0.8% canola p.a. and soybeans 1.6% p.a.)	Double Base
Present value of benefits (m$)	142.2	196.45	293.60
Present value of costs (m$)	48.81	48.81	48.81
Net present value (m$)	93.41	147.64	244.79
Benefit cost ratio	2.91	4.02	6.02
Internal rate of return (%)	21.7	24.8	29.1

Table 22 shows the sensitivity of the investment criteria to changed assumptions regarding the proportion of the yield gain that can be attributed to breeding, with the base being 33% for canola and 50% for soybeans.

Table 22: Sensitivity of Investment Criteria to the Assumed Attribution of Yield Gains to Genetic Improvement
(Total investment, 5% discount rate, 30 years)

Criterion	Lower (50% less)	Base (33% for canola and 50% for soybeans)	Higher (50% more)
Present value of benefits (m$)	139.94	196.45	252.95
Present value of costs (m$)	48.81	48.81	48.81
Net present value (m$)	91.13	147.64	204.15
Benefit-cost ratio	2.87	4.02	5.18
Internal rate of return (%)	21.6	24.8	27.3

8. Confidence Rating

The results produced are highly dependent on the assumptions made, many 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 23). 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 23: Confidence in Analysis of Oilseed Breeding Investment

Coverage of Benefits	Confidence in Assumptions
High	Medium

9. Conclusions and Lessons Learned

New cultivars of both canola and soybeans have been released since 2002 as a result of the breeding programs. Many of the new cultivars of canola are resistant to

blackleg (at least in the first few years), have higher yields, are suitable to drier areas, tolerant to herbicides, and have improved quality characteristics.
Soybean cultivar improvements have been associated with yield improvements to soybeans as well as quality, the latter being most important in the expanding culinary market.

In both cases the new cultivars have been continually adopted by industry. For canola, as with other crops, GRDC and the state agencies have moved away from cultivar development during the period of the investment with private sector breeders now undertaking the breeding role. The canola program now focuses on germplasm improvement or pre-breeding, with outputs made available to the private sector breeding activities on a non-exclusive basis. This change does not apply to soybeans where the small size of the industry makes the crop less attractive to private sector interest.

The improvements in yields for each crop have been analysed and part of the gains attributed to the breeding investment under consideration. The yield improvements have been masked to some extent in the eastern/southern states due to dry seasons and the increasing proportion of canola grown in drier and lower yielding areas. Both canola and soybeans have implications for the production of other crops and such benefits have been identified in the analysis.

The total investment in oilseed breeding for the two crops has been estimated to provide a net present value of $148 m and a benefit-cost ratio of 4 to 1. The investment criteria for breeding in each of the two crop types have been both positive. The canola investment contributed 67% of the total costs and delivered 76% of the estimated benefits. The soybean breeding made up 33% of the investment and provided 24% of the total benefits.

The difficulty in assessing the progress made by new canola cultivars and the benefits they provide to producers has been highlighted by the evaluation. The performance of new canola cultivars released over time has been difficult to assess largely due to the yield decline due to blackleg. GRDC is currently investigating the performance of new cultivar releases over time from data assembled by the National Variety Trials. This investigation may allow improved assumptions for economic analyses such as the current evaluation.

Acknowledgements

Vince Fernandes, Impact and Business Analyst, Grains Research and Development Corporation
Andrew James, CSIRO Plant Industry
Steven Jones, Aglign Consulting, Brooklyn, NSW
Phillip Salisbury, University of Melbourne
Neale Sutton, Operations and Technical Support, National Variety Trials

References

ABARE (2008) Australian Commodity Statistics, Canberra.

ABARE (2008) Australian Commodities, Vol 15, No 4.

ABARE (2009) Australian Crop Production, as at 11 February 2009, Canberra

ABARE (2009) Australian Commodities, Vol 16, No 1.

Australian Oilseeds Federation, Crop Report, March 2009.

Black I, Dyson C, Hayman P and Alexander B (2008) "The Determinants of South Australian Wheat Yield Increases", Proceedings of the 14th Australian Agronomy Conference, Adelaide.

GRDC (2009)

Pritchard F, Ballinger D, and Potter T (2007) "Growing Dryland Canola in 2007"

Reading P (2008) "Positioning the Australian Grain Industry for Growth – Innovation", Australian Grains Industry Conference, July.

Thirtle C (1985) "Technological Change and the Productivity Slowdown in Field Crops: United States, 1939–78", South. J. Agric. Econ. 17:33–42.
Wilkinson I (2006) "Grain Prices and Selling Costs for 2005/06", Page 52, Farm Weekly Guide 2006

Wilkinson I (2006) "Grain Prices and Selling Costs for 2005/06", Page 52, Farm Weekly Guide 2006