GRDC
Grains Research & Development Corporation
Your GRDC working with you

GRDC IMPACT ASSESSMENT REPORT SERIES

MAR 13

An Economic Analysis of GRDC Investment in the Lentil Breeding Program

GRDC Impact Assessment Report Series:

Title: An Economic Analysis of GRDC Investment in the Lentil Breeding Program

March 2013
GRDC Project Code: ATR00015

This report was commissioned and published by the GRDC.

Enquiries should be addressed to:
Ms Jan Edwards
Impact, Business and Portfolio Analyst
Grains Research and Development Corporation
PO Box 5367
KINGSTON ACT 2604
Phone: 02 6166 4500
Email: jan.edwards@grdc.com.au

Author:
Agtrans Research
PO Box 385
TOOWONG QLD 4066
Phone: 07 3870 4047
Email: info@agtrans.com.au

ISBN No. 978-1-921779-51-0

GRDC
Grains Research & Development Corporation
Your GRDC working with you

An Economic Analysis of GRDC Investment in the Lentil Breeding Program

Table of Contents

Executive Summary

Lentils are an annual winter grain legume crop grown mainly in the southern states of Victoria and South Australia and in areas with 350 - 500 mm of annual rainfall.

As with other grain legumes, lentils can be grown in rotation with cereals where they can offer advantages to the next cereal crop.

There are both red and green lentils, with the former the principal type due to a yield advantage, despite green lentils having a price advantage. Most Australian grown lentils are exported (Middle East and South Asia), with only a small volume serving the domestic human consumption market.

Lentil production in Australia has expanded from less than 1,500 hectares in 1994 to the current area of over 150,000 hectares.

The breeding strategy for pulses as a whole (including lentils) has been driven since 2006 by Pulse Breeding Australia (PBA). Previous to 2006, the lentil breeding investment was conducted through the “Coordinated Improvement Program for Australian Lentils” (CIPAL).

Previous to the R&D investment being analysed in this evaluation (2000 to 2016), an Australian lentil improvement program had been ongoing for some time with the last GRDC project (DAV373) finishing in the year 2000. During the last two years of the DAV373 project, three new varieties had been released (Cumra, Cassab, and Nugget), all being selected from imported lines.

Genotypes with traits such as early flowering, high vigour, increased height, lodging resistance, asochyta blight resistance, botrytis grey mould resistance, tolerance to high soil boron, and superior quality had been identified through the CIPAL Program. These genotypes gave the period of investment considered in this current analysis a sound base to produce further improvements in new varieties.

The current economic evaluation refers to two completed and one ongoing GRDC project investments in lentil breeding. The principal outputs of these lentil investments have been improved varieties. Important traits from these improved varieties have been yield and yield stability and disease resistance. Improvements in these traits were delivered in the new varieties released from 2008 to 2012. Further improvements are expected in releases between 2012 and 2016. Higher yields and increased disease resistance can translate into higher profits from the lentil crop, in turn potentially increasing the attractiveness of lentils in rotations.

The investment in the three projects (DAV00434, DAV00072 and DAV00119) has produced a number of actual and potential benefits some of which have been valued in this analysis. The total investment of $20 million (present value terms) has been estimated to produce total gross benefits of $60 million (present value terms) providing a net present value of $40 million, a benefit-cost ratio of 3 to 1 (over 30 years, using a 5% discount rate) and an internal rate of return of over 21%.

A summary of the principal benefits from the investment is shown in the following table.

Triple Bottom Line Summary of Principal Benefits from the Investment

Levy Paying Industry	**Spillovers**		
	Other Industries	**Public**	**Foreign**
Economic benefits			
Increased profitability of lentils via increased yields, reduced input costs of fungicides, and improved product quality Potential for increased area of lentils grown in cereal rotations with associated productivity and sustainability benefits Increased confidence, profits and expansion for lentil processing companies Potential increase in capital value of lentil germplasm in the program between 2000 and the end of the program in 2016	Potential for increased area of lentils grown on cropping farms leading to benefits to other crops in the rotation	Nil	Nil
Environmental benefits			
Reduced use of chemicals (fungicides) in growing lentils	Nil	Reduced use of chemicals (fungicides) in growing lentils Reduced use of nitrogenous fertilisers (and hence export to the environment) from new areas of lentils	Nil
Social benefits			
Improved farmer wellbeing through reduced chemical use by farmers	Nil	Potentially reduced chemical export to waterways resulting in positive potential impact on regional wellbeing Increased regional investment and employment	Nil

Introduction

Lentils are an annual winter grain legume crop grown mainly in the southern states of Victoria and South Australia and in areas with 350 - 500 mm of annual rainfall (Pulse Australia, 2010). Lentils have some drought tolerance but are intolerant of waterlogged and acid soils, salinity and boron.

Because lentils are suited to alkaline soils, they tend to be concentrated in the Victorian Wimmera and Mallee areas, and the mid-north and Yorke Peninsula of South Australia (Brennan et al, 2002). The states of NSW and WA grow some small areas of lentils.

There are both red and green lentils, with the former the principal type due to a yield advantage. Large green lentils have a price advantage over red lentils in many years. Most Australian grown lentils are exported (Middle East and South Asia), with only a small volume serving the domestic human consumption market.

Lentils are suitable for both ruminant and non-ruminant feeds; however, the prices obtained on the export human consumption market usually preclude their use for animal feed, and only weather damaged grain enters the feed industry.

As with other grain legume crops, lentils can be grown in rotation with cereals and other crops where they can contribute nitrogen to the next crop, as well as provide a disease break, increase water use efficiency, and provide the ability to use different herbicide groups to control weeds (Victoria No-Till Farmers Association, 2012).

Area and Yield

Lentil production in Australia has expanded from less than 1,500 hectares in 1994 (Pulse Australia, 2010) to over 150,000 hectares in the past three years as shown in Table 1. Table 1 shows areas, yields and total tonnages for Australian lentils over the past 18 years. The significant growth in the Australian lentil area over this period shows a statistically significant linear trend of about 9,500 ha per annum. If only the period 2000 to 2012 is considered, the linear trend is still significant but at the lesser rate of 7,200 ha per annum.

Yield per ha has been volatile over the period and visually exhibits a long-term average of around one tonne per ha (Figure 1).

Ascochyta blight (AB) is the most serious disease of lentils in Australia, followed by Botrytis grey mould (BGM).

Table 1: Areas, Yields and Tonnages for Australian Lentil Production

Year ended June	**Area (ha)**	**Yield (tonnes per ha)**	**Production (tonnes)**
1995	6,000	0.45	3,000
1996	8,000	2.18	17,000
1997	18,000	2.04	38,000
1998	57,000	0.63	36,000
1999	82,000	0.56	46,000
2000	75,000	1.37	103,000
2001	111,000	1.27	141,000
2002	51,000	1.33	62,000
2003	165,000	0.41	67,000
2004	131,000	1.34	175,000
2005	119,000	0.70	83,000
2006	113,000	1.85	210,000
2007	153,000	0.24	36,000
2008	130,000	1.01	131,000
2009	117,000	0.55	64,000
2010	219,000	1.14	380,000
2011	173,000 (s)	1.17 (s)	288,000 (s)
2012	164,000 (f)	1.31(f)	234,000(f)
Simple Average from 2000 to 2012	132,385	1.03	151,846
Simple average last 5 years	160,600	1.13	219,400

Source: ABARES Australian Crop Report, various issues
s = estimated
f = forecast

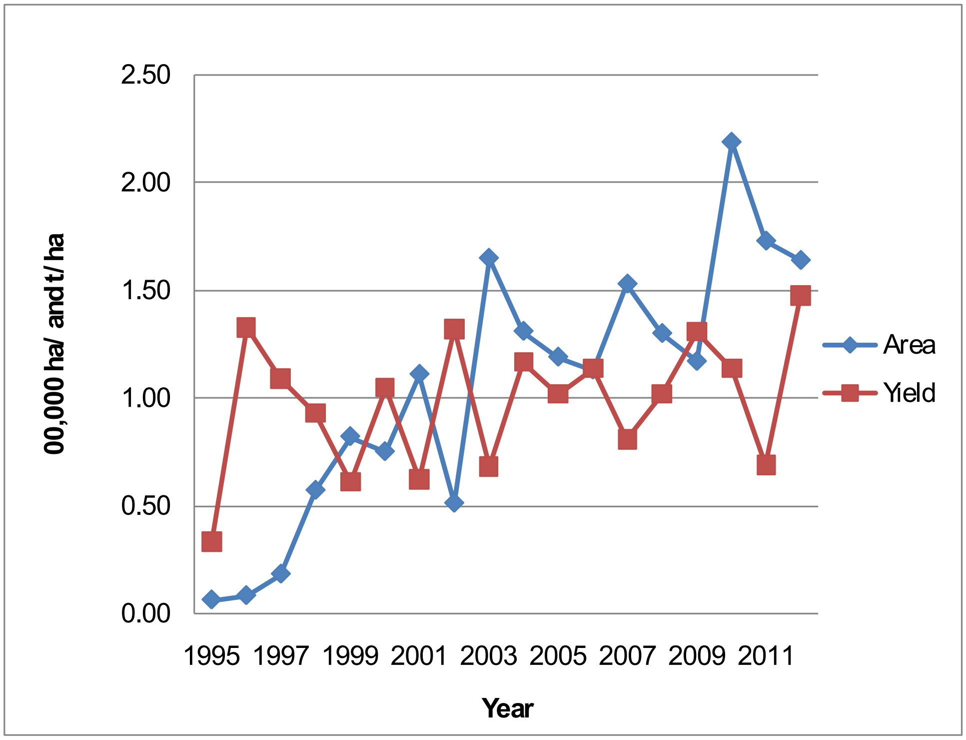

Figure 1: Australian Lentil Area and Yield

Industry and Breeding Structures

Pulse Australia is a peak industry body that represents all sectors of the pulse industry in Australia (including lentils), from growers and agronomists through to researchers, merchants, traders and exporters (Pulse Australia, 2012).

The breeding strategy for pulses as a whole is now driven by Pulse Breeding Australia (PBA). PBA is an umbrella organisation for five Australian temperate pulse breeding programs (chickpeas, field peas, faba beans, lentils and lupins) and has operated since 2006.

PBA is an unincorporated joint venture between the GRDC, Pulse Australia, the University of Adelaide, the South Australia Research and Development Institute (SARDI), the Victorian Department of Primary Industries (DPI VIC), the NSW Department of Primary Industries (NSW DPI), Queensland Department of Primary Industries and Fisheries (DAFF QLD) and the Department of Agriculture and Food Western Australia (DAFWA) (GRDC, 2012).

National breeding of lentils by PBA aims to increase lentil production in Australia through the release of superior high quality red and green lentil varieties (Pulse Breeding Australia, 2012).

The Victorian Department of Primary Industries has been the lead agency in both previous lentil breeding programs and the PBA programs that have been supported by GRDC.

Previous Investment in Lentil Breeding

Prior to 2006, the lentil breeding investment was conducted through the “Coordinated Improvement Program for Australian Lentils” (CIPAL). Unlike most other crops, lentil breeding has operated as an integrated national program since its inception in 1994, pre-dating the formation of the national breeding programs in cereals and other pulses that have occurred through privatisation and the formation of PBA (Michael Materne, pers. comm., 2013).

CIPAL had been ongoing for some time with the last GRDC project (DAV373) before the current investments finishing in the year 2000. During the last two years of the DAV373 project, three new varieties were released including Cumra (early flowering), Cassab (increased yields in the medium to low rainfall areas), and Nugget (increased yields in the medium to high rainfall areas of the south east). All of these new varieties were selected from lines imported from the International Centre for Research in Dry Areas (ICARDA) who were a strategically important component of CIPAL due to their history in breeding lentils for environments similar to Australia. Nugget became the dominant lentil variety in Australia.

CIPAL developed genotypes with traits such as early flowering and maturing, high vigour, increased height, lodging resistance, AB resistance, BGM resistance, tolerance to high soil boron and sodium chloride, and superior quality that positioned the period of investment considered in this current analysis to produce further improvements in new varieties through a breeding program.

During the previous project, CIPAL had maintained the strong linkages with ICARDA and with the Canadian lentil breeding program, resulting in germplasm introduction that has benefited the Australian program.

Prior to DAV373, the area of Australian lentils had increased from about 1,500 ha in 1994 to over 100,000 ha in the year 2000, mainly based on improved lentil varieties released in 1993 and 1994 (GRDC, undated).

The Investment

This evaluation refers to two completed and one ongoing GRDC investments in lentil breeding funded over the 17 year period from 2000 to 2016. As one of the projects is not yet completed, the following economic evaluation is based partly on expectations rather than verified benefits. Details of the three projects are provided in Table 2.

Table 2: Lentil Breeding Projects Evaluated

GRDC Project Code and Title	**Other Details**
DAV00434: Coordinated Improvement Program for Australian Lentils (CIPAL)	Organisation: Victorian Department of Primary Industries Period: July 2000 to June 2005 Principal Investigator: Michael Materne
DAV00072: Australian Lentil Breeding Program	Organisation: Victorian Department of Primary Industries Period: December 2005 to June 2011 Principal Investigator: Michael Materne
DAV00119: PBA Lentil Breeding – expansion project	Organisation: Victorian Department of Primary Industries Period: July 2011 to June 2016 Principal Investigator: Michael Materne (to Dec 2012)

All three projects were led by the Victorian Department of Primary Industries (DPI VIC). Project DAV00434 ran from July 2000 to June 2005, followed by DAV00072 which ran from December 2005 to June 2011. The current project (DAV00119) continued on from DAV00072 from 2011 and is due for completion in June 2016.

Investment Inputs

Estimates of the GRDC funding by project by year for each of the three projects are provided in Table 3. Other project funding includes contributions from the research partners. Table 3 also provides estimates of the partners’ total investment in each of the projects for each year and summarises the combined GRDC and partner investment for each year.

Table 3: Investment by GRDC by Project for Years ending June 2001 to June 2016 (nominal $)

	GRDC				**Other**				**Total**			
Project Year	**DAV 00434**	**DAV 00072**	**DAV 00119**	**Total**	**DAV 00434 (a)**	**DAV 00072 (b)**	**DAV 00119**	**Total**	**DAV 00434**	**DAV 00072**	**DAV 00119**	**Total**
2001	285,000	0	0	285,000	315,396	0	0	315,396	600,396	0	0	600,396
2002	270,000	0	0	270,000	324,876	0	0	324,876	594,876	0	0	594,876
2003	388,792	0	0	388,792	334,646	0	0	334,646	723,438	0	0	723,438
2004	376,691	0	0	376,691	344,751	0	0	344,751	721,442	0	0	721,442
2005	392,297	0	0	392,297	355,077	0	0	355,077	747,374	0	0	747,374
2006	0	221,229	0	221,229	0	252,165	0	252,165	0	473,394	0	473,394
2007	0	455,731	0	455,731	0	519,459	0	519,459	0	975,190	0	975,190
2008	0	469,402	0	469,402	0	535,045	0	535,045	0	1,004,447	0	1,004,447
2009	0	483,484	0	483,484	0	551,096	0	551,096	0	1,034,580	0	1,034,580
2010	0	497,990	0	497,990	0	567,627	0	567,627	0	1,065,617	0	1,065,617
2011	0	512,929	0	512,929	0	584,657	0	584,657	0	1,097,586	0	1,097,586
2012	0	0	700,000	700,000	0	0	635,772	635,772	0	0	1,335,772	1.335,772
2013	0	0	700,000	700,000	0	0	663,471	663,471	0	0	1,363,471	1,363,471
2014	0	0	700,000	700,000	0	0	691,920	691,920	0	0	1,391,920	1,391,920
2015	0	0	700,000	700,000	0	0	721,650	721,650	0	0	1,421,650	1,421,650
2016	0	0	700,000	700,000	0	0	751,554	751,554	0	0	1,451,554	1,451,554
TOTAL	1,712,780	2,640,765	3,500,000	7,853,545	1,674,746	3,010,049	3,464,367	8,149,162	3,387,526	5,650,814	6,964,367	16,002,707

Source: GRDC

(a) Includes VIC DPI, SARDI, Agriculture WA, Tasmanian Institute of Agricultural Science, Agriculture NSW
(b) Includes DPI VIC, SARDI, DAWA, NSWDPI and Tasmanian Institute of Agricultural Science

Description of the Projects

Tables 4, 5 and 6 provide a summary of each project with regard to its rationale, objectives, activities and outputs, outcomes, and benefits.

Table 4: Summary of DAV00434: Coordinated Improvement Program for Australian Lentils (CIPAL): July 2000 to June 2005.

Rationale	This project continued the investment in lentil breeding from Project DAV373 that was completed in June 2000.
Objectives	To develop superior red and green lentil varieties for grain growers in southern Australia by 2005. To enhance lentil germplasm for immediate implementation in the lentil breeding program. To enhance germplasm with resistance to major exotic diseases of lentils.
Activities and Outputs	Breeding objectives and methods were refined during the project. Single seed descent, early pedigree seed multiplication and more extensive screening for abiotic stresses and diseases were employed. The program maintained links with ICARDA and established links with lentil breeders in Canada and USA; elite germplasm was exchanged annually. The first Australian bred lentils were commercialised in 2005. One release was a red lentil (Nipper) with good seed quality and resistance to AB and BGM. Another was a green lentil (Boomer) with a larger seed and improved disease resistance. Lentils with novel quality (Spanish Brown, French Green, zero tannin, green cotyledon) were commercialised for product development with PB Seeds. Multiple lines of each type were commercialised with expectations that one or two would be released of each type. All were bred by the breeding program utilising germplasm from Canada, India, the Middle East and USA. The novel lentils have been multiplied and high value markets developed through the PB Seeds brand and other labels since 1998. Byron black, Spanish brown and French green lentils are now being sold into restaurants and high value small packaging. Limited area is needed for these markets and expansion will only occur when larger export markets are secured. The green cotyledon lentil is being multiplied for product development in 2013 (Michael Materne, pers. comm., 2013). The green lentil Tiara, suited to spring sowing, was commercialised for agronomic development with AWB Seeds in 2005 but it did not lead to significant spring production due to competition from high value crops in favourable spring sowing areas and dry years in grain cropping areas. Tiara was introduced into Tasmania from overseas. The widely adapted green lentil Boomer has now superseded the specific need for a variety specifically suited to spring sowing (Michael Materne, pers. comm., 2013). The high yielding, salt tolerant red lentils Flash (CIPAL0411) and Bounty CIPAL0415) were commercialised in 2006 and released to growers in 2009. Flash has been high yielding in shorter season environments, for example, it has been 12% higher yielding than Nugget in <400mm rainfall sites in SA. It has foliar resistance to AB but is susceptible to BGM, making it most suited to drier areas. Bounty was more widely adapted and has consistently yielded about 10% higher than Nugget and had similar disease responses. Screening techniques were well established by project end; these included screening for BGM and AB resistance, and boron, salinity and herbicide tolerance; future breeding was expected to focus on combining these traits with high yield, good seed quality and improved harvestability. At the end of the project a steady release of varieties to growers was expected over the next five years. These were expected to be: 1) High yielding lines CIPAL0411 (PBA Flash) and CIPAL0415 (PBA Bounty). 2) Lines with AB and BGM resistance and with higher yield, broader adaptation and increased vigour and height than Nipper (PBA Ace). 3) Clearfield Nipper (PBA Herald). 4) High yielding, broadly adapted, AB and BGM resistant lines with salt tolerance.
Outcomes	The project recognised that a longer term commercial partner would be preferred to ensure that the best varieties were released to growers as quickly as possible. Commercialisation and seed increase for Nipper and Boomer was slower than expected due largely to a lack of good data and poor seed increase as a result of droughts. The uptake of Nipper was expected to be dependent on the conditions in the following two seasons. Nipper uptake was greatest in the more favourable lentil growing areas in Victoria and South Australia because of the dry years and it has become established in the southern Wimmera with better seasons due to good disease resistance, harvestability, salt tolerance and price potential (Michael Materne, pers. comm., 2013).

	Average to high rainfall was expected to favour the economics of growing Nipper compared to Nugget and Northfield. Nipper has practically replaced Northfield and some Nugget production area. Boomer production has been small due to uncertainties with marketing and production. It had “bad years” when released but remaining growers, often linked to markets, have been successful (Michael Materne, pers. comm., 2013). Nipper was associated with a potential reduction in fungicide costs due to its disease resistance (one to two less fungicide treatments than Nugget and Northfield varieties saving $15 per ha per treatment). Nipper also has been good to harvest. It has better yield than Northfield and equivalent to Nugget in trials but consultants and farmers say anecdotally that it does better on poorer soils in the Wimmera due to salinity tolerance (Michael Materne, pers. comm., 2013). Nipper has provided a quality premium up to $50 per tonne over Nugget in some years.
Benefits	Increased profitability from new varieties due to higher yields and higher quality. Input cost saving from less use of fungicides Reduced chemical runoff from farms. Potential for expansion of lentil areas allowing capture of rotational benefits.

Table 5: DAV00072: Australian Lentil Breeding Program: July 2005 to June 2011

Rationale	This project continued the breeding program from Project DAV00434. Improved genetic material was considered one of the strategies to improve lentil profitability.
Objectives	To deliver superior red and green lentil varieties that will increase lentil production and profitability in Australia through greater productivity, reliability of yield and quality, reduced inputs and new market access. To develop breeding lines containing new traits or combinations of traits for future breeding and /or release.
Activities and Outputs	PBA Flash (CIPAL0411) was released to growers in 2010 as a high yielding variety suitable for most lentil areas and for most medium size lentil markets. PBA Bounty (CIPAL0415) was released to growers in 2010 as a small seeded broadly adapted high yielding variety. PBA Blitz (CIPAL0610) was released to growers in 2011 as a high yielding, early flowering and maturing variety with good disease resistance. PBA Jumbo (CIPAL0605) was released to growers in 2010 as a high yielding large seeded red lentil suited to most current lentil growing areas. PBA Herald XT (CIPAL0702), an imidazolinone tolerant line, was released to growers in 2011. All the above varieties were commercialised through PB Seeds. The prospective lines CIPAL1101 and CIPAL1102 had better yield and wider adaptation than PBA Herald XT and were expected to be released in 2013. Other lines were identified that performed well in the dry and short seasons and at the Melton site where AB and BGM are prevalent (04-190L-05HG1002-05HSHI2007 and 04-299L-05HG1001-05HSHI2007). Line 04-299L-05HG1001-05HSHI2007 was reported also as being moderately tolerant to salinity. A broader range of germplasm than existed previously had been developed by the end of the project.
Outcomes	PBA Flash has already been grown over a large area of Victoria and South Australia due to its earlier maturity and good harvestability; however, it was expected that the area of Flash would contract due to the new BGM resistant variety PBA Blitz for drier areas and PBA Jumbo and PBA Herald that may be grown in medium rainfall areas. The area of Flash grew to larger than expected predominantly due to good harvestability and faster harvesting. The on-farm results from Flash in contrast to Bounty reinforced the breeding objective to improve harvestability (Michael Materne, pers. comm., 2013). Demand for PBA Bounty has been lower than PBA Flash due its poorer harvestability. PBA Blitz moved into drier areas such as northern Yorke Peninsula but didn’t move as far as expected into medium rainfall areas due to good performance of PBA Flash and farmers being comfortable that they could manage AB. Uptake of Herald was good in 2012 and is expected to displace Flash further in better areas where weed control is critical (Michael Materne, pers. comm., 2013)
Benefits	Increased profitability from new varieties due to higher yields and higher quality. Reduced fungicide applications. Reduced weed control costs and improved harvestability and harvesting speed. Reduced chemical runoff to waterways.

	Potential for expansion of lentil areas allowing capture of additional rotational benefits.

Table 6: Summary of PBA Lentil Breeding – expansion project DAV00119: July 2011 to June 2016

Rationale	This project continued the breeding program from Project DAV00072. This next phase of lentil breeding was to focus on combining traits for high and reliable yield, disease resistance, tolerance to abiotic stresses, harvestability and resistance to herbicides to improve reliability of yield and quality. This was to be achieved through an increased emphasis on early generation controlled environment screening, efficient evaluation in the key target regions of SE Australia and increased research to understand the potential to reduce quality problems associated with excessive heat and rain during the harvest period.
Objectives	To deliver superior red and green lentil varieties that will increase lentil production and profitability in Australia through the delivery of varieties with improved yield, stability of yield and quality, and which are lower cost and easier to grow and manage in rotations. To develop breeding lines containing new traits or combinations of traits for future breeding and /or release.
Activities and Outputs	Actual and expected major releases during this project include: A high yielding early maturing red lentil variety (PBA Bolt) for short season and low rainfall areas, released in 2012. A high yielding disease resistant red lentil variety (PBA Ace) to replace Nugget in the medium rainfall areas, released in 2012. A broadly adapted imidazolinone tolerant red lentil variety with 20% higher yield than CIPAL0702 (PBA Herald) for growers in the medium to low rainfall areas, expected to be released in 2013. Specific lines continuing towards release as at 2011 were : CIPAL0801 (PBA Bolt)- early maturing lentil with good lodging resistance and yield in the Mallee. CIPAL0803 (PBA Ace)- high yielding medium maturity lentil with good disease resistance for mid north, Wimmera and Southern NSW. CIPAL0901 - Large seeded, very early drought tolerant lentil for low rainfall non- traditional lentil areas. CIPAL0902 - high yielding early maturity lentil for all areas, particularly the Yorke Peninsula. CIPAL1001 - early mid maturing lentil with most reliable yield of any lentil but not "showy". CIPAL1101 (PBA Hurricane) - High yielding, disease resistant imidazolinone tolerant lentil. CIPAL1104 - high yielding, disease resistant medium green lentil with improved resistance to shattering to replace Boomer and expand green lentil production. A broader range of germplasm than existed at the beginning of the project is being targeted by the end of the project in 2016; traits being targeted in these lines include boron and salt tolerance, AB and BGM resistance, anthracnose and Fusarium wilt resistance, and imidazolinone and metribuzin tolerance.
Outcomes	PBA Bolt (CIPAL0801) was released to growers in 2012. PBA Ace (CIPAL0803) was released to growers in 2012. PBA Hurricane (CIPAL1101) is expected to be released in 2013 and is expected to replace Herald XT in all areas and expand production in dry areas. A large seeded green lentil (CIPAL 1207) will be fast tracked as a high quality alternative to CIPAL1104. Other prospective releases include: CIPAL0901, a drought tolerant line, but in recent years its yield advantage has not been significant as previously expected. CIPAL 0902 is now unlikely to be released. CIPAL1001, a high yielding lentil as a replacement for Ace in medium rainfall areas, possibly to be released to growers in 2013 or 2014. CIPAL1104, a medium green lentil, possibly to be released in 2013 if economics are justified in relation to CIPAL1207; the option is for CIPAL1207 to be released to growers two years later.
Benefits	Increased profitability from new varieties due to higher yields and higher quality. Reduced fungicide applications. Reduced weed control costs and improved harvestability and harvesting speed. Reduced chemical runoff to waterways. Potential for expansion of lentil areas allowing capture of additional rotational benefits.

In summary, the principal expected outputs from this investment are contributions to the development of new varieties targeted at lentil growers. The principal short-term outcome from these investments is the adoption of new superior varieties being grown, or expected to be grown, by lentil producers.

Benefits

The principal benefit from this lentil breeding investment is an increase in the profitability of growing lentils. Other benefits include some environmental improvements due to lowered fungicide use on more resistant varieties and the impact on the overall contribution to profitability and sustainability of crop rotations that now include lentils in the rotational mix. Rotational benefits from lentils include not only disease breaks and nitrogen contributions, but also improved weed control through crop topping early maturing varieties and herbicide tolerance.

Direct Lentil Enterprise Profitability Improvements

The principal direct profitability benefits from the new varieties produced by the breeding investment include higher yields, reduced input costs and improved quality. Higher yields will be driven by not only higher yield potential but also a range of improvements including:

- resistance to lodging and improved harvestability
- reductions in crop failures due to improved resistance to disease such as AB and BGM and greater tolerance to salinity and of drought.

Apart from improved yields, there is an associated profitability benefit from greater disease resistance via the reduced input costs from a lower number of fungicide sprays required. Several sprays may be avoided from some of the new varieties due to this increased resistance. Also, the more erect varieties enable faster harvesting speed with associated reductions in labour costs and risk of weather damage that can dramatically reduce yield and price (Michael Materne, pers. comm., 2013).

Some benefits may also be derived from improved quality of the new lentil varieties that can result in new levels of demand and higher prices.

Lentil Expansion and Rotational Improvements

Indirect benefits may be captured by grain growers who increase their areas of lentils or by new growers of lentils. These indirect benefits will be captured via crop rotations that include lentils and may include increased yields of other crops in the rotation due to disease breaks, improved weed control and reduced use of nitrogenous fertiliser for other crops due to the nitrogen fixation by the leguminous lentils. Hence, crop rotations incorporating lentils can be more sustainable and more profitable in the long term.

If new improved lentil varieties merely replace existing lentil varieties, the new benefits to the rotation may be minimal. However, if the new varieties elicit an area increase in lentils (either from new growers or existing growers increasing their area of lentils) with the area increase due to higher profitability of the new types, then there will be additional rotational benefits captured by these increased lentil areas. For example, area increases can be driven by new lentil varieties that make production viable in drier areas.

Also, new varieties may also be critical in maintaining lentil area and the existing rotational benefits due to the changing status of factors such as weeds, diseases and management practices (Michael Materne, pers. comm., 2013).

Environmental benefits

The reduced use of fungicides to combat AB and BGM may lead to reduced off farm export of chemicals to waterways. Maintaining disease breaks through rotations and increased herbicide resistant plants also can lead to less chemical usage on farm. Such reduced usage may benefit the farm environment and potentially lead to reduced export of chemicals to public waterways. Nitrogen supplied by lentils can reduce the amount of fertiliser N required and possibly reduce undesirable nutrient loss off-farm.

The reduced reliance on fungicides has been apparent in practice. For example, Nipper has been very successful as it is resistant to both diseases. PBA Blitz, PBA Ace, PBA Herald and PBA Hurricane will expand resistance across most lentil areas. PBA Bolt is also an improvement over PBA Flash in the Mallee. PBA Flash is the limiting variety for disease but should be phased out in the next few years (Michael Materne, pers. comm., 2013).

Social benefits

Some social benefit may be derived from improved profitability and sustainability of cropping farms that can maintain expenditure in the local community. Improved farmer wellbeing through reduced chemical use by farmers and any potential reduction in chemicals in the wider environment may provide positive community wellbeing benefits. If the new varieties result in more lentils being grown, some small processors and local communities in Victoria and South Australia may benefit.

Genetic capital growth

In the longer term the germplasm capital existing in the program at the end of the investment period in 2016 is likely to be greater than that at the start in the year 2000. This benefit can be interpreted as the germplasm in the program that will exist in 2016 having a greater potential to produce improved varieties in the future than the germplasm existing at the beginning of the investment (2000).

Breeding programs move in phases and the next germplasm value development will be in combining a larger range of traits (disease, harvestability, salinity, boron, vigour, herbicide tolerance) into high yielding reliable varieties for all areas. The future development of metribuzin tolerant lentils will also be of high value. Greater use of wild relatives is also planned from overseas and locally derived breeding (Michael Materne, pers. comm., 2013).

Overview of Benefits

An overview of benefits in a triple bottom line categorisation is shown in Table 7.

Table 7: Categories of Principal Benefits from the Investment

Levy Paying Industry	**Spillovers**		
	Other Industries	**Public**	**Foreign**
Economic benefits			
Increased profitability of lentils via increased yields, reduced input costs of fungicides, and improved product quality Potential for increased area of lentils grown in cereal rotations with associated productivity and sustainability benefits Increased confidence, profits and expansion for lentil processing companies Potential increase in capital value of lentil germplasm in the program between 2000 and the end of the program in 2016	Potential for increased area of lentils grown on cropping farms leading to benefits to other crops in the rotation	Nil	Nil
Environmental benefits			
Reduced use of chemicals (fungicides) in growing lentils	Nil	Reduced use of chemicals (fungicides) in growing lentils Reduced use of nitrogenous fertilisers (and hence export to the environment) from new areas of lentils	Nil
Social benefits			
Improved farmer wellbeing through reduced chemical use by farmers	Nil	Potentially reduced chemical export to waterways resulting in positive potential impact on regional wellbeing Increased regional investment and employment	Nil

Public versus Private Benefits

The benefits identified from the investment are predominantly private benefits, namely benefits to lentil growers. Private spillover benefits are likely to be captured by cereal growers who include additional areas of lentils in their cropping rotations. Other private benefits may accrue to lentil processors. For example, the higher yields and increased area provide greater confidence for processors such as the Australian Milling Group to expand their operations. (http://archive.premier.vic.gov.au/newsroom/5094.html).

There are some small public benefits potentially produced; these are mainly environmental in nature from lowered fungicide, other chemicals and fertiliser usage with potential implications for water quality off-farm. Social benefits include reduced use of chemicals and increased regional employment.

Benefits to other Primary Industries

Other farm industries that may benefit from the investment are restricted to other crop growers. While lentils are a useful source of energy and protein for livestock, their market for human consumption usually precludes them from use as animal feeds due to price.

Distribution of Benefits along the Lentil Supply Chain

Some of the potential benefits from more profitable production of lentils will be shared along the supply chain with processors, exporters and consumers. Part of any estimated gross gain achieved by lentil growers will be returned to breeders via end point royalties through Plant Breeders Rights.

Benefits Overseas

Growers of lentils in overseas countries are unlikely to benefit significantly, except in the Middle East where climatic conditions are similar to Australia. There have been reports that Australian lentils are suited and grown in Turkey from exported grain, just as Canadian varieties are grown in the Russia and neighbouring countries (Michael Materne, pers. comm., 2013).

Match with National Priorities

The Australian Government's national and rural R&D priorities are reproduced in Table 8.

Table 8: National and Rural R&D Research Priorities 2007-08

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

Sources: National Research Priorities (2013)
http://www.arc.gov.au/pdf/nrps_and_goals.pdf
Rural Research Priorities: DAFF (2007 and valid as of February 2013)
http://www.daff.gov.au/_media/documents/ag-food/innovation2/Priorities_Booklet_FINAL.pdf

Table 9 identifies the national and rural research priorities that each of the principal benefits address. Both supporting priorities associated with the Rural Research Priorities are addressed by the investment.

Table 9: Categorisation of Principal Benefits by Priorities

Benefit	**National Research Priorities Addressed**	**Rural Research Priorities Addressed**
Productivity gains for lentils and associated cereal crops	Priority 3 ***	Priority 1 *** Priority 2 *
Improved disease control with lowered	Priority 3 ***	Priority 1 ***

costs from reduced use of fungicides	Priority 4 *** Priority 1 *	Priority 3 ** Priority 5 **

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

Additionality and Marginality

The investment in this cluster was targeted principally towards benefits to lentil growers. The investment would have been regarded as a high priority by lentil growers as well as by some cereal growers. In the event that public funding was restricted, it is likely that the investment would have still been funded by GRDC, albeit possibly at a lower level, 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 50-75% of what GRDC actually funded. This would have been associated most likely with a reduced rate of genetic progress. Further detail as assessed by Agtrans Research is presented in Table 10.

Table 10: Potential Response to Reduced Public Funding

What priority were the projects in this cluster when funded?	Medium to High
Would industry have funded this cluster if less public funding were available?	Yes, but with a slightly lesser amount
To what extent would industry have funded this cluster if only industry funds were available and no public funds?	50-75% of that actually funded

Pathway to Adoption

Since 2006 PBA has been responsible for the release and commercialisation of all new varieties emanating from the lentil breeding program. PBA establishes Release Advisory Groups (RAGs) and selects the commercialisation partner. Pure seed is then made available to the successful commercialiser. The successful tenderer needs skills in seed multiplication, promotion and distribution. Representatives from the state government, GRDC and industry select the successful commercial partner. These representatives are members of the RAG, as are representatives of the commercial partners. The RAGs make all decisions on variety progression and release, identify future issues that will impact on varieties, prepare the PBA variety brochure, and report to the PBA Board (Michael Marterne, pers. comm., 2013).

A process has been established whereby the pipeline licensee is encouraged to carry out early evaluation and multiplication of pre-commercial cultivars within the variety pipeline on a speculative basis in anticipation of their future release. The aim is to reduce the time taken in the commercialisation stages so that varieties reach growers faster. It has been estimated that the time to release has been reduced by at least two years by using the new system.

The seed is then bulked up by the commercialiser and distributed to the regions. A variety brochure is usually produced and some form of promotional strategy is implemented.

The varieties are protected by Plant Breeders Rights under the *Plant Breeders Rights Act 1994*. Co-owners of the varieties are the GRDC and its funding partners.

Improved varieties are generally regarded as research and development outputs that are rapidly adopted by producers, especially where information on prospective performance is readily available and where high confidence in the claimed characteristics of a new variety is perceived. This confidence is influenced by the extent of testing of a variety before release. The National Variety Trial (NVT) Program assists in this regard.

Promotion of information on new varieties concerning potential profitability including the acceptability of any new varieties in the market place, both domestic and international is effected by the commercialising seed company, Pulse Australia, and the state agencies involved with PBA. PBA Variety brochures are developed for all new varieties to ensure farmers select the best variety for their farm and maximise the potential yield and price. PBA links closely with the southern pulse agronomy project to evaluate varieties for major agronomic requirements prior to release. This information is conveyed at annual field days in the major pulse areas that successfully attract the major consultants, private agronomists and marketers who are responsible for influencing practice change on farm. Information is included in the PBA variety brochures (Michael Marterne, pers. comm., 2013).

Most of the cost of commercialisation is covered indirectly by the grower paying an ’end point royalty’ to the breeder based on the value of production generated by the seed of the new variety.

Other commercialisation costs may be incurred by the state agencies e.g. preparing promotional material for new varieties.

Measurement of Benefits

The benefits valued in the quantitative analysis are:

- The yield increase from the releases (or expected releases) of the new varieties of lentils to which the investment in the three projects has contributed.
- The quality improvement from some of the new varieties, including attributes valued by consumers, reduced weather damage from a faster harvest, and avoiding a price drop where the crop is not harvested on time.
- The reduced cost of fungicides due to the increased resistance to AB and BGM of some of the new varieties.
- Reduced weed control costs.
- The increase in rotational benefits due to the role of the new varieties in contributing to the increased area of lentils to date and predicted into the future (or in contributing to the avoidance of a decline in the existing area of lentils).

The benefits identified but not valued include:

- The reduced costs of harvesting (e.g. labour, fuel) due to faster harvesting of the more erect varieties; some of the benefit from faster harvesting is already accounted for in the quality benefit.
- The environmental benefits on farm or in the wider community due to the reduced use of chemicals.
- The potential wellbeing benefits to farmers and the wider community from reduced chemical use and potentially lowered export of chemicals to waterways.
- Any increase in the capital value of unexploited germplasm between 2000 and 2016.
- Increased regional investment and employment.

The principal reason for not valuing the reduced cost of harvesting is that the overall magnitude is likely to be small as the harvesting speed increase is only from about 5% to 20% and applies only to five of the sixteen new varieties. The difficulties in collecting evidence to support the linkage between the new varieties and the potential benefits identified in dot points 2 and 3, are exacerbated by the associated difficulty of placing a dollar value on these benefits. The fourth benefit is not valued due to the difficulty of valuing the improved capital value of the germplasm. The fifth benefit is not valued in the following cost benefit analysis (CBA) as such analyses are usually carried out on an Australia wide basis. A general principle is to exclude such benefits from any CBA on the basis of the opportunity cost and multiplier effects of alternative investments. If required, such benefits are best reported separately and qualitatively as social outcomes or impacts for the particular subject region.

Counterfactual

The only release from overseas lines during the period was Tiara and its release was not successful. Also, Canadian varieties are late maturing and ICARDA lines are generally susceptible to disease. Quarantine is required and the slow speed of seed increase means varieties must be proven to be better than existing before they will be grown by farmers.

Furthermore, if the GRDC investment in the three breeding projects had not been made, it is assumed there would not have been any significant breeding investment by the private sector or state agencies over this period. Variety evaluation is a major cost of breeding, and if not funded by GRDC, state governments would probably not invest due to the restricted size of the lentil industry. Also, it is assumed that private breeding investment would not have occurred without the GRDC investment.

It is concluded that without the investment in the National Lentil Breeding Program, there would have been insignificant genetic improvement of lentil undertaken and Nugget, Northfield and Aldinga would probably have remained as the major varieties. Further, it is assumed that if the lentil breeding investment had not been made, the area of lentils would not have increased from the year 2000 onwards to the extent observed.

In order to allow for a small genetic improvement without the breeding program, it is assumed that only 5% of the improvement estimated for the program would have occurred without the investment.

Actual and Expected Variety Releases

The assumption in this evaluation is that the investment has contributed to nine new varieties released up until November 2012. These exclude Tiara (128/85) and niche varieties on the grounds that the areas grown were small.

In addition, a further five or six new varieties are expected to be released between 2012 and the end of the current project in 2016. The breeding of all 14-15 varieties has been attributed to a greater or lesser degree by the specific period of investment being evaluated. These varieties and their expected characteristics are listed in Table 11.

Table 11: Actual and Expected Variety Releases and Variety Characteristics

Variety	Variety Characteristics
ALREADY RELEASED	
Nipper (CIPAL0203)	Released 2008; BGM and AB resistant, mid maturing, small red lentil with improved salt tolerance for more favourable lentil growing areas.
Boomer (CIPAL0402)	Released 2008; Large seeded green lentil with good disease resistance for major lentil growing regions.
PBA Flash (CIPAL0411)	Released 2010; suitable to all current lentil areas especially shorter season areas; high yields but susceptible to BGM, earlier maturing, erect, improved salt tolerance, good harvestability and suited to medium red lentil markets; also, improved crop topping.
PBA Bounty (CIPAL0415)	Released 2010; small seeded red lentil and highest yielding, mid maturing, broadly adapted and suited to all lentil areas, improved salt tolerance; 5% yield advantage over Nugget; seed is 10% larger than Nipper and Northfield but addresses similar markets.
PBA Blitz (CIPAL0610)	Released 2011; high yielding and early maturing with good disease resistance so good in disease prone areas; also suited to drier areas with minimal disease risk; medium large red lentil; also improved crop topping.
PBA Jumbo (CIPAL0605)	Released 2010; high yield and large seeded red lentil that can command higher prices.
PBA Herald XT (CIPAL0702)	Released 2011; Improved tolerance to herbicides imidazilinone and flumetsulam herbicides; good disease resistance and direct replacement for Nipper in medium to higher rainfall areas; strength is disease resistance and herbicide tolerance where weeds are a problem; lower yielding than other new varieties.
PBA Bolt (CIPAL0801)	Released 2012; early maturing; erect; PBA Flash replacement for the Mallee areas.
PBA Ace (CIPAL0803)	Released 2012; potential nugget replacement; high yielding medium maturity lentil with good disease resistance for mid north, Wimmera and southern NSW.
POTENTIALLY TO BE RELEASED	
CIPAL0901	Large seeded, very early drought tolerant lentil for low rainfall non traditional lentil areas.
CIPAL0902	High yielding early maturity lentil for all areas, particularly the Yorke Peninsula.
CIPAL1001	Early mid maturing lentil with most reliable yield of any lentil but not "showy" and lodges more than newer varieties.
CIPAL1101	High yielding, disease resistant imidazolinone tolerant lentil to replace PBA Herald.
CIPAL1104	High yielding, disease resistant medium green lentil with improved resistance to shattering to replace Boomer and expand green production.
CIPAL1207	High yielding large seeded green lentil to replace Boomer but will not be released if CIPAL 1104 released.

Seed for new varieties is assumed to be available to commercial growers in the year after the year of release; initial adoption is therefore assumed in the year after the year of release. Maximum adoption is assumed to occur in the third year of growing.

Baseline Area

In order to value the benefits from the new varieties some baseline estimates of the existing lentil area is required to measure the improvement. Estimates of areas used in assessing varietal improvements are reported in Table 12. The assumed total area of 160,000 ha is based on the average Australian area of lentils over the past five years, 2008-2012.

Any regional breakdown was not accommodated in this analysis due to the increased number of assumptons that would have been required. The assumptions regarding maximum adoption for each variety are used to accommodate both regional suitability and competition with existing varieties in the same region.

Baseline Yields

The percentage increase in yield has been estimated relative to the yield of the variety replaced. The average lentil yield for the past five years has been 1.13 tonnes per ha. As estimating the yield of the variety replaced would have required further significant data, the average lentil yield for the past five years was taken as the baseline yield to which any percentage increase attributed to new varieties was applied.

Release Probabilities and Years

The release year and first growing year for each variety are summarised in Table 12. Also shown in Table 12 is whether the variety has been released as of November 2012 and, if not, the expected year of release.

Table 12: Expected Variety Releases: Probabilities and Timing

Variety released/to be released	**Released or Probability of Release**	**Year of Release or Expected Release (Year ending June)**	**Year of First Commercial Production (Year ending June)**
Nipper (CIPAL0203)	Released	2008	2009
Boomer (CIPAL0402)	Released	2008	2009
PBA Flash(CIPAL0411)	Released	2010	2011
PBA Bounty(CIPAL0415)	Released	2010	2011
PBA Blitz (CIPAL0610)	Released	2011	2012
PBA Jumbo (CIPAL0605	Released	2010	2011
PBA Herald XT (CIPAL0702)	Released	2011	2012
PBA Bolt (CIPAL0801)	Released	2012	2013
PBA Ace (CIPAL0803)	Released	2012	2013
CIPAL0901	60%	2013	2014
CIPAL0902	20%	2015	2016
CIPAL1001	75%	2013	2014
CIPAL1101	90%	2013	2014
CIPAL1104	80%	2013	2014
CIPAL 1207	Assumed not released if CIPAL 1104 released		

Improvements in New Varieties

The principal characteristics valued from the new varieties are yield gains, quality improvements and fungicide cost reductions. Assumptions for the applicability of these benefits and their magnitude for each new variety are provided in Table 13.

Table 13: Varietal Gains Assumed

Variety to be Released	**Yield Gain Assumed (%)**	**Quality Gain Assumed (% price gain)**	**Reduction in number of fungicide sprays**	**Weed control cost reduction (%)**	**Harvest speed increase (%)**
Nipper (CIPAL0203)	5	No	2	0	10
Boomer (CIPAL0402)	5	10	1	0	0
PBA Flash(CIPAL0411)	5	No	0	10	20
PBA Bounty(CIPAL0415)	10	10	0	0	0
PBA Blitz (CIPAL0610)	5	No	2	5	10
PBA Jumbo (CIPAL0605	10	5	1	0	0
PBA Herald XT (CIPAL0702)	0	No	2	10	0
PBA Bolt (CIPAL0801)	5	No	1	5	5
PBA Ace (CIPAL0803)	5	No	1.5	0	0
CIPAL0901	5	No	0	5	0
CIPAL0902	5	No	0	0	0
CIPAL1001	5	No	0	0	0

CIPAL1101	10	10	0	0	5
CIPAL1104	5	No	0	0	0

Note: Harvest speed increases have not been valued
Source: Agtrans Research, after input and discussions with Michael Materne

Adoption of New Varieties

The assumptions regarding the adoption profile of the new varieties are shown in Table 14.

Table 14: Adoption Assumptions for Variety Releases

Variety Released/to be Released	First year grown	Year of maximum adoption	Maximum adoption level (%) (a)	Adoption in Year 2016 (b)
Nipper (CIPAL0203)	2009	2012	20	5
Boomer (CIPAL0402)	2009	2012	5	0
PBA Flash(CIPAL0411)	2011	2014	40	0
PBA Bounty(CIPAL0415)	2011	2014	5	0
PBA Blitz (CIPAL0610)	2012	2015	15	5
PBA Jumbo (CIPAL0605	2011	2014	15	5
PBA Herald XT (CIPAL0702)	2012	2015	20	0
PBA Bolt (CIPAL0801)	2013	2016	20	15
PBA Ace (CIPAL0803)	2013	2016	30	20
CIPAL0901	2014	2017	10	5
CIPAL0902	2016	2019	0	0
CIPAL1001	2014	2017	10	5
CIPAL1101	2013	2016	40	35
CIPAL1104	2013	2016	5	5

a) Linear increase assumed from first year of adoption to maximum level assumed in third year of production; linear decrease from maximum level to zero over 4 years assumed
b) Comparing the estimated adoption level in 2016 with the liner trend estimate showed that on average the linear decline assumption is reasonably robust.

Matching Genetic Gain from New Varietal Benefits to the Investment Being Evaluated

As breeding programs are usually long-term investments, attributing benefits to specific investment periods can be difficult. For this analysis, some attribution of benefits from these releases to the period of investment (years ending June 2001 to 2016) can be made.

The breeding investment being evaluated commenced in the year ending June 2001. It is assumed that lentil varieties are produced from a 10 year breeding cycle from initial cross to variety release. The first variety releases after the commencement of investment were in 2008. Hence, the influence of the investment on the varieties released in 2008 would have been significant, as the benefit for any release in 2008 would be attributable to investment in the year ending 2008 and the previous nine years breeding activity. Hence, it could be argued that approximately 80% of the benefit from that variety could be attributed to the investment; any varieties released in 2009 could be attributed 90% and so on.

Releases in the period 2009/10 to 2015/16 could be attributed 100% of the benefits from the released varieties as all ten years of the breeding cycle would fall within the investment period. However, releases after the end of the investment period would gradually decline in the proportion of benefits that could be attributed to the investment. Varieties released in 2025/26 or after will not have any benefits attributed to the current (2001 to 2016) investment period.

Details on the attribution of benefits for each of the varieties to the three projects being evaluated are provided in Table 15.

Table 15: Estimated Attribution of the Benefit of a Variety Release to the Investment Being Evaluated

Year of release	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Relevant Investment period															
2001			I	I	I										
2002			I	I	I	I									
2003			I	I	I	I	I								
2004			I	I	I	I	I	I							
2005			I	I	I	I	I	I	I						
2006			I	I	I	I	I	I	I	I					
2007			I	I	I	I	I	I	I	I	I				
2008			I	I	I	I	I	I	I	I	I	I			
2009				1	I	I	I	I	I	I	I	I	I		
2010					I	I	I	I	I	I	I	I	I	I	
2011						I	I	I	I	I	I	I	I	I	I
2012							I	I	I	I	I	I	I	I	I
2013								I	I	I	I	I	I	I	I
2014									I	I	I	I	I	I	I
2015										I	I	I	I	I	I
2016											I	I	I	I	I
2017															
2018															
2019															
2020															
% Attribution	60	70	80	90	100	100	100	100	100	100	100	90	80	70	60

Notes:
“I” indicates a year of investment between 2001 and 2016 that is relevant to a variety released in a particular year
Shading indicates the ten year period before the variety is released

Impact on Rotations

The area of lentils grown in Australia has been increasing since the year 2000 as shown previously in Figure 1. This increase is statistically significant with the average increase from 2000 to 2012 around 7,200 ha per annum.

There may be a number of reasons for this area increase, but it should be noted that the increase from 2008 to 2012 coincides with the release of seven new varieties of lentils. It can be assumed with some confidence that the new varieties played a significant role in the area increase. Other factors such as low cereal prices and the high lentil prices in the early 2000s would also have had an impact. Agronomic and management improvements would also have played a role.

Without the breeding program and the release of the new varieties, it is likely that the area increase would have been less. It is conservatively estimated that the varieties have been responsible for 25% of the increase (25% of the 7,200 ha per annum). Further, it is assumed this area increase and attribution will continue until 2020, after which the new releases assumed will have no further impact on the lentil area.

Of the new area of lentils since 2008, it is assumed 50% has been grown in rotation with other crops (e.g. wheat) and this 50% of the new area has not replaced other legumes grown in the crop rotation. It is assumed the other 50% of the new area of lentils has not been introduced into a cereal rotation.

The value of introducing lentils in a rotation will depend on a range of factors including the existing rotation sequence, seasonal conditions, relative crop prices, and how the lentil planting influences the benefits from the following (usually cereal) crop.

A conservative estimate of $60 per ha per annum average is attributed to the lentil crop impact (see Table 16).

Summary of Assumptions

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

Table 16: Summary of Assumptions

Variable	Assumption	Source
Baseline Performance		
Baseline average area of lentils in five years ending June 2012	160,600 ha	Table 1
Average yields for lentils in five years ending June 2012	1.13 tonnes per ha	Table 1
Average value of lentils	$450 per tonne	Rural Solutions (2012)
Counterfactual	5% of gains from the breeding program made in absence of the program	Agtrans Research
Cost saving for reduction of 1 fungicide application	$15 per ha	Based on Project DAV0434
Weed control costs	$72 per ha	Rural Solutions (2012)
VARIETAL RELEASES		
Variety Nipper		
First year of production	2009	Table 12
Reduced number of fungicide sprays	2	Table 13
Yield increase	5% of 1.13 tonnes per ha	Table 13
Maximum adoption level	20%	Table 14
Years to maximum adoption	3	Table 14
Attribution to investment	80%	Table 15
Variety Boomer		
First year of production	2009	Table 12
Reduced number of fungicide sprays	1	Table 13
Yield increase	5% of 1.13 tonnes per ha	Table 13
Price increase	10%	Table 13
Maximum adoption level	5%	Table 14
Years to maximum adoption	3	Table 14
Attribution to investment	80%	Table 15
Variety Flash		
First year of production	2011	Table 12
Yield increase	5% of 1.13 tonnes per ha	Table 13
Reduction in weed control costs	10%	Table 13
Maximum adoption level	40%	Table 14
Years to maximum adoption	3	Table 14
Attribution to investment	90%	Table 15
Variety Bounty		
First year of production	2011	Table 12
Yield increase	10% of 1.13 tonnes per ha	Table 13
Price increase	10%	Table 13
Maximum adoption level	5%	Table 14
Years to maximum adoption	3	Table 14
Attribution to investment	100%	Table 15
Variety Blitz		
First year of production	2012	Table 12
Yield increase	5% of 1.13 tonnes per ha	Table 13
Reduced number of fungicide sprays	2	Table 13
Reduction in weed control costs	5%	Table 13
Maximum adoption level	15%	Table 14
Years to maximum adoption	3	Table 14
Attribution to investment	100%	Table 15
Variety Jumbo		
First year of production	2011	Table 12
Yield increase	10% of 1.13 tonnes per ha	Table 13
Price increase	5% price increase	Table 13
Reduced number of fungicide sprays	1	Table 13
Maximum adoption level	15%	Table 14
Years to maximum adoption	3	Table 14
Attribution to investment	100%	Table 15

Variety Herald XT		
First year of production	2012	Table 12
Yield increase	0% of 1.13 tonnes per ha	Table 13
Reduced number of fungicide sprays	2	Table 13
Reduction in weed control costs	10%	Table 13
Maximum adoption level	20%	Table 14
Years to maximum adoption	3	Table 14
Attribution to investment	100%	Table 15
Variety Bolt		
First year of production	2013	Table 12
Yield increase	5% of 1.13 tonnes per ha	Table 13
Reduced number of fungicide sprays	1	Table 13
Reduction in weed control costs	5%	Table 13
Maximum adoption level	20%	Table 14
Years to maximum adoption	3	Table 14
Attribution to investment	100%	Table 15
Variety ACE		
First year of production	2013	Table 12
Yield increase	5% of 1.13 tonnes per ha	Table 13
Reduced number of fungicide sprays	1.5	Table 13
Maximum adoption level	30%	Table 14
Years to maximum adoption	3	Table 14
Attribution to investment	100%	Table 15
CIPAL 9001		
Probability of release	60%	Table 12
First year of production	2014	Table 12
Yield increase	5% of 1.13 tonnes per ha	Table 13
Reduction in weed control costs	5%	Table 13
Maximum adoption level	10%	Table 14
Years to maximum adoption	3	Table 14
Attribution to investment	100%	Table 15
CIPAL 9002		
Probability of release	20%	Table 12
First year of production	2016	Table 12
Yield increase	5% of 1.13 tonnes per ha	Table 13
Maximum adoption level	0%	Table 14
Years to maximum adoption	3	Table 14
Attribution to investment	100%	Table 15
CIPAL 1001		
Probability of release	75%	Table 12
First year of production	2014	Table 12
Yield increase	5% of 1.13 tonnes per ha	Table 13
Maximum adoption level	10%	Table 14
Years to maximum adoption	3	Table 14
Attribution to investment	100%	Table 15
CIPAL 1101		
Probability of release	90%	Table 12
First year of production	2014	Table 12
Yield increase	10% of 1.13 tonnes per ha	Table 13
Price increase	10%	Table 13
Maximum adoption level	40%	Table 14
Years to maximum adoption	3	Table 14
Attribution to investment	100%	Table 15
CIPAL 1104		
Probability of release	80%	Table 12
First year of production	2014	Table 12
Yield increase	5% of 1.13 tonnes per ha	Table 13
Maximum adoption level	5%	Table 14
Years to maximum adoption	3	Table 14
Attribution to investment	100%	Table 15
CIPAL1207		

Not valued as assumed not released due to the release of CIPAL 1104		
Attribution of Varietal Benefits to Breeding Program		
Assumed length of breeding cycle	10 years from first cross to release	Agtrans Research
Attribution to investment in the ten years before variety released	100%	Agtrans Research
Attribution of varietal benefits to the investment being evaluated (years ending June 2001 to 2016)	Number of the ten years before variety released that are included in the investment period, divided by ten	Agtrans Research (see Table 15)
INCREASE IN ROTATIONAL AREA		
Increased area of lentils since 2000	7,200 ha per annum	Based on linear statistical trend 2000 to 2012
Proportion of increased area due to new varieties released	25% from 2008 to 2016 and then declines linearly to zero over the next ten years	Agtrans Research
Proportion of new lentil area grown in rotation with cereals	50%	Agtrans Research
Increase in average gross margin in a cereal rotation when lentils are included	$60 per ha	Agtrans Research based on average gross margin increase for including chickpeas in a cereal rotation (NSW DPI, 2012)

Results

All costs and benefits were expressed in 2011/12 dollar terms using the CPI. All costs and benefits were discounted to 2011/12 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 (2015/16).

The present value of benefits (PVB) from each source of benefits 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 was 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**	**15 years**	**20 years**	**25 years**	**30 years**
Present value of benefits (m$)	47.89	56.68	57.97	58.98	59.77	60.39	60.88
Present value of costs (m$)	20.21	20.21	20.21	20.21	20.21	20.21	20.21
Net present value (m$)	27.68	36.47	37.76	38.77	39.56	40.18	40.67
Benefit-cost Ratio	2.37	2.80	2.87	2.92	2.96	2.99	3.01
Internal rate of return (%)	20.2	21.7	21.8	21.8	21.8	21.8	21.8

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**	**15 years**	**20 years**	**25 years**	**30 years**
Present value of benefits (m$)	23.35	25.60	27.77	28.37	28.84	29.21	29.49
Present value of costs (m$)	9.91	9.91	9.91	9.91	9.91	9.91	9.91
Net present value (m$)	13.43	15.68	17.86	18.46	18.92	19.29	19.58
Benefit-cost Ratio	2.36	2.58	2.80	2.86	2.91	2.95	2.97
Internal rate of return (%)	20.1	21.0	21.6	21.7	21.7	21.7	21.7

There are fifteen sources of benefits valued in the analysis. Table 19 shows the relative estimates of the contribution from each source. The highest contributors to the PVB were the prospective variety CIPAL 1101 (15%) and the rotational benefit from new areas of lentils (13%), followed by three varieties all contributing over 10% of the PVB (PBA Flash, PBA Jumbo, and PBA Ace).

Table 19: Contribution of Source of Benefits to Present Value of Benefits (30 years)

Source of Benefit	Present Value of Benefits ($ million)	% PVB
Nipper (CIPAL0203)	5.50	9.0
Boomer (CIPAL0402)	2.12	3.5
PBA Flash(CIPAL0411)	6.52	10.7
PBA Bounty(CIPAL0415)	2.40	3.9
PBA Blitz (CIPAL0610)	4.22	6.9
PBA Jumbo (CIPAL0605	6.63	10.9
PBA Herald XT (CIPAL0702)	3.54	5.8
PBA Bolt (CIPAL0801)	3.99	6.6
PBA Ace (CIPAL0803)	6.52	10.7
CIPAL0901	0.75	1.2
CIPAL0902	0.00	0.0
CIPAL1001	0.82	1.4
CIPAL1101	9.46	15.5
CIPAL1104	0.39	0.6
Rotational	8.02	13.2
Total	60.88	100.0

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
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 last investment are shown in Figure 2.

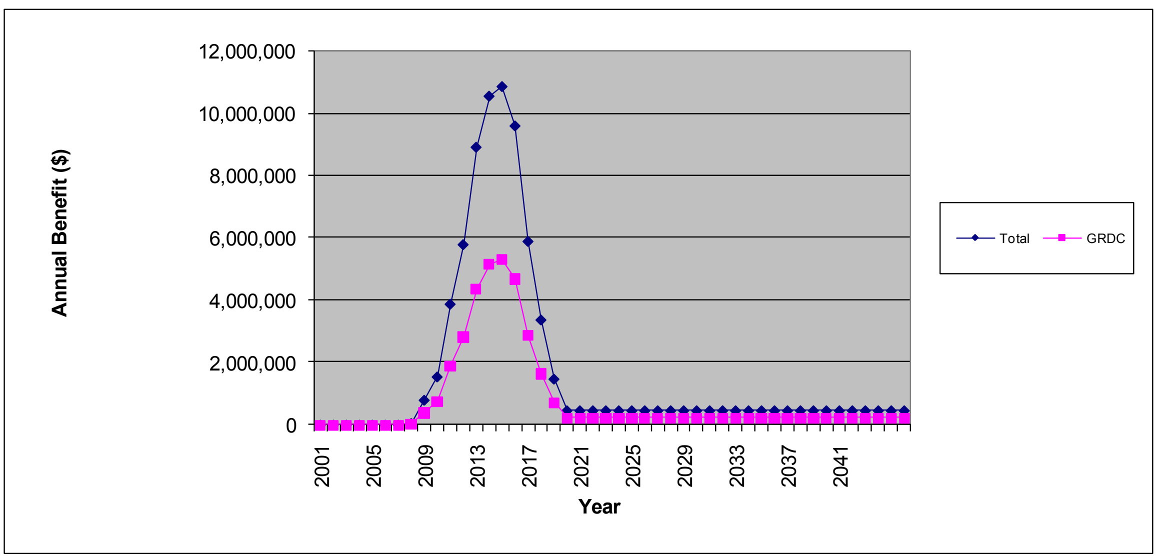

Figure 2: Annual Benefit Cash Flow

Sensitivity Analyses

Sensitivity analyses were carried out on several variables and results are reported in Tables 21 to 23. The sensitivity analyses were performed on the GRDC investment results 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 discount rate. The results show that the criteria are not particularly sensitive to the discount rate.

Table 21: Sensitivity of Investment Criteria to Discount Rate (GRDC investment, 30 years)

Criterion	**Discount Rate**		
	0%	**5% (Base)**	**10%**
Present value of benefits (m$)	35.76	29.49	25.85
Present value of costs (m$)	8.54	9.91	11.99
Net present value (m$)	27.22	19.58	13.86
Benefit cost ratio	4.19	2.97	2.16

Table 22 shows the sensitivity of changing the assumptions for the individual sources of varietal benefits including the yield gain, the price gain, the number of fungicide sprays avoided, the weed control cost reduction and the maximum adoption.

Table 22: Sensitivity of Investment Criteria to Changes in the Level of Varietal Parameters Assumed (GRDC investment, 5% discount rate, 30 years)

Criterion	**Base results**	**Assumed yield gain halved**	**Assumed price gain halved**	**Assumed fungicide spray reductions halved**	**Assumed weed control costs halved**	**Assumed maximum adoption halved**
Present value of benefits (m$)	29.49	22.01	28.54	26.11	28.81	16.61
Present value of costs (m$)	9.91	9.91	9.91	9.91	9.91	9.91
Net present value (m$)	19.58	12.01	18.62	16.19	18.90	9.69
Benefit cost ratio	2.97	2.22	2.88	2.63	2.91	1.68
Internal rate of return (%)	21.7	17.2	21.1	19.7	21.4	12.4

Table 22 shows that the key drivers of the benefits are the level of maximum adoption assumed and the yield gain, followed by disease resistance. However, the maximum adoption halving does not completely capture reality as no allowance has been made for some varieties released by the program continuing to deliver benefits when the adoption of the improved variety that is assumed to replace them is reduced. The quality gains and the weed control cost reductions have lesser impacts as they only are relevant to a restricted number of varieties; however, they could have been important contributors in the level of adoption.

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 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 Lentil Breeding Investment

Coverage of Benefits	Confidence in Assumptions
High	Medium

Conclusions

During the investment period (years ending June 2001 to 2016), a number of improved lentil varieties have been released from the breeding program with high adoption levels. Improvements have varied with the variety and have included higher yield potentials, greater resistance to AB and BGM, as well as improved quality and harvestability. As Project DAV00151 is ongoing until 2016, there are some further releases expected.

The principal direct benefit that has been delivered and captured by lentil producers is an increase in the lentil gross margins from the improvements in new variety performance.

The area of lentils grown in Australia has been increasing in the past decade. Some of this increase has been assumed due to the advances made in lentil varietal performance. In turn this new area of lentils has provided additional benefits such as fixation of nitrogen and acting as a disease break.

The benefits identified from the investment are predominantly private benefits for lentil growers in the southern region where most lentils are grown.

Private spillover benefits are likely to be captured by cereal growers who have started growing lentils or have expanded their area of lentils. There are likely to be some public benefits produced, mainly environmental in nature from lowered chemical and nitrogen fertiliser usage with potential implications for water quality off-farm.

The investment in the three projects has produced a number of benefits most of which have been valued. The total investment of $20 million (present value terms) has been estimated to produce total gross benefits of $60 million (present value terms) providing a net present value of $40 million, a benefit-cost ratio of 3 to 1 (over 30 years, using a 5% discount rate) and an internal rate of return of over 21%.

Acknowledgments

Vince Fernandes, Impact and Business Analyst, Grains Research and Development Corporation.

Kate Light, Project Manager, Breeding Programs, Grains Research and Development Corporation.

Brondwen MacLean, Senior Manager, Breeding Programs, Grains Research and Development Corporation.

Michael Materne, former leader of the Australian Lentil Breeding Program (currently Global Grain Genetics).

References

ABARES (various years) Australian Crop Report, various issues

Brennan J, Aw-Hassan A, Quade K and Nordblom T (2002) "Impact of ICARDA Research on Australian Agriculture", Economic Research Report No. 11, NSW Agriculture. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/146461/err-11-Impact-of-ICARDA-Research-on-Australian-Agriculture.pdf

NSW DPI (2012) "Farm Budgets and Costs-Winter crop gross margin budgets, Department of Primary Industries, NSW.

GRDC (undated) "Pulse Project Summary for DAV373" http://www.pulseaus.com.au/pdf/DAV373.pdf

GRDC (2012) "Pulse Breeding Australia" http://www.grdc.com.au/Research-and-Development/Major-Initiatives/PBA

Pulse Australia (2010) "Snapshot of Australian Pulses", Reprints of pulse industry and market posters displayed at CICILS/IPTIC Convention, Brisbane, Australia 2010 http://www.pulseaus.com.au/pdf/CICILS-IPTIC%202010%20Poster%20Booklet.pdf

Pulse Australia (2012) Web page Pulse Australia Limited http://www.pulseaus.com.au/about_us.aspx

Pulse Breeding Australia (2012) http://www.pulseaus.com.au/industry_links.aspx

Victoria No–Till Farmers Association (2012) “Rotations”. http://vicnotill.com.au/wp-content/uploads/2012/08/Rotations.pdf

Rural Solutions (2012) “Farm Gross Margin Guide 2012”, published by GRDC. http://www.grdc.com.au/uploads/documents/GRDC-Farm-Gross-Margin-and-Enterprise-Planning-Guide-2012.pdf