Impact of ICARDA Research on Australian Agriculture

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Economic Research Report No. 11

January 2002

NSW Agriculture

ICARDA

ISSN 1442-9764

ISBN **0 7347 1338 X**

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Citation:

Brennan, J.P., Aw-Hassan, A., Quade, K.J. and Nordblom, T.L. (2002), *Impact of ICARDA Research on Australian Agriculture*, Economic Research Report No. 11, NSW Agriculture, Wagga Wagga.

Available on the web at: http://www.agric.nsw.gov.au/reader/10550

Impact of ICARDA Research on Australian Agriculture

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Acronyms and Abbreviations Used in the Report

A$	Australian dollar
ABARE	Australian Bureau of Agricultural and Resource Economics (Canberra)
ACIAR	Australian Centre for International Agricultural Research (Canberra)
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Centre
CIPAL	Coordinated Improvement Program for Australian Lentils
CLIMA	Centre for Legumes in Mediterranean Agriculture (Perth)
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Canberra)
CWANA	Central and West Asia and North Africa
FAO	Food and Agriculture Organisation of the United Nations
GRDC	Grains Research and Development Corporation (Canberra)
DREAM	Dynamic Research Evaluation Model
ha	hectares
ICARDA	International Centre for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
NARS	National Agricultural Research Systems
NSW	New South Wales
Qld	Queensland
ROW	Rest of the World (other than Australia)
SA	South Australia
t	tonnes (= 1000 kilograms)
Tas	Tasmania
UNDP	United Nations Development Program
Vic	Victoria
WA	Western Australia
WANA	West Asia and North Africa
WA	Western Australia

Acknowledgments

A large number of people must be acknowledged for their contributions to this study. First, we wish to thank those from ICARDA. We are grateful to:

1. Those who have contributed by providing data and insights into the development of germplasm improvement at ICARDA:
    a. Salvatore Ceccarelli (Barley Breeder),
    b. Ashutosh Sarker (Lentil Breeder),
    c. Miloudi Nachit (Durum Wheat Breeder, CIMMYT),
    d. S. Rajinder Malhotra (Chickpea Breeder),
    e. William Erskine (Assistant Director General, Research),
    f. Habib Ketata (Iran-ICARDA Project Coordinator),
    g. Shaaban Khalil (Consultant, Faba Bean Breeder),
    h. Stefania Grando (Barley Breeder),
    i. Bruno Ocampo (Research Associate responsible for International Trials)
    j. Larry Robertson (former ICARDA faba bean breeder)
2. Hala Khawam (Research Assistant) for helping in compiling and analysing the data.
3. Many scientists from the national programs, although we are not able to list them all, for their help in getting data on variety adoption. These scientists are from the commodity improvement programs of the crops considered in this study in the national agricultural research programs of Algeria, Egypt, Ethiopia, Jordan, Morocco, Pakistan, Sudan, Syria, Tunisia, Turkey and Yemen.
4. Liz Bailey, Project Officer, and Sam Kugbei, Seed Economist, for their valuable comments on the draft report.
5. Professor Dr Adel El-Beltagy and Dr Mohan Saxena for their valuable support to this study.

Second, we are also grateful to all those who generously responded to our survey of Australian scientists on their involvement with ICARDA. A full list of the respondents is provided in Appendix B. Further, we want to acknowledge specifically the contribution of Ted Knights, Ray Hare, Barbara Read, Jeff Paull, Andrew Barr, Joop van Leur, Harry Marcellos, Michael Materne, David Moody, Jan-Bert Brouwer, Clive Francis and KHM Siddique. They generously provided time, information and comments on drafts for our report, and/or responded to a stream of queries. Without their input there could have been no such report.

Finally, we would like to acknowledge the role of the Australian Centre for International Agricultural Research (ACIAR) for their support of the project. In particular, Deborah Templeton played a key role in establishing the project and ensuring support funding was provided. Throughout the project, she has provided continuing guidance, and we thank her sincerely. Another who provided key support and helpful suggestions and comments was Ian Bevedge.

Of course, none of these people bear any responsibility for the interpretations, errors or omissions in this report.

Executive Summary

The project, "Impact of ICARDA Research on Australian Agriculture", was developed with the Australian Centre for International Agricultural Research (ACIAR), the International Center for Agricultural Research in the Dry Areas (ICARDA) and NSW Agriculture. The aim of the project was to investigate and document the impact of ICARDA's plant genetic research on Australian agricultural productivity and to evaluate those gains in relation to the world market price impacts of ICARDA's research.

The first task in the analysis was to identify the links between ICARDA and the relevant Australian research programs for each of the mandate crops (barley, durum wheat, chickpeas, faba beans and lentils). The linkages differed for each crop, but there are indications of good collaboration between the Australian programs and their ICARDA counterparts. There was regular exchange of germplasm between Australia and ICARDA, and there has also been a regular interchange of personnel between Australia and ICARDA since ICARDA's inception.

A large amount of ICARDA material either has been used in the past or is being used at present in Australian breeding programs. In addition, there have been some direct acquisitions of material from countries in Central and West Asia and North Africa (CWANA), often made available via the ICARDA germplasm exchange distribution system. Because the impact of this material is likely to occur over the next 20 years, the analysis is based on future benefits to these crops.

There were relatively strong links with ICARDA for the five main mandate crops. In barley, durum wheat, kabuli chickpea, faba bean and lentil there are both strong links and a substantial Australian industry to provide the necessary conditions for a significant benefit flowing back to Australia from germplasm obtained from ICARDA. In particular, the Australian faba bean and lentil industries have relied heavily on germplasm from ICARDA. However, for forage legumes, while there was evidence of interactions between Australia and ICARDA, the data available were insufficient to enable a quantitative analysis to be carried out for the impacts of those interactions on Australia.

In addition, there are benefits to Australia other than those obtained through germplasm. The collaborative arrangements, including screening for pests and disease resistances, training, regular visits and the availability of regular reports and evaluations, were all of value to Australia. However, while these benefits are recognised in this study, we do not attempt to place an economic value on the benefits of each of the strands of cooperation and collaboration involved. Only the benefits from germplasm flows were valued in this analysis. In addition, the flow of benefits from Australia to ICARDA from both the flow of genetic material from Australia and the other collaborative arrangements are not incorporated into the analysis.

For barley, the benefits are expected to come from higher yields in the drier regions of South Australia and Victoria with alkaline soils, as a result of the improved drought tolerance obtained from ICARDA germplasm. The benefits are valued at A$4.91 per tonne, but are likely to be slow to impact fully, because the materials need to be adapted to Australian conditions and to malting quality varieties. At the same time, ICARDA's research is estimated to bring about a cost reduction in the Rest of the World of A$1.45 per tonne. The increase in

production causes a world price fall of A$0.55 per tonne. The net result for Australia is the equivalent of an average annual benefit of A$2.4 million over the next 20 years.

For durum wheat, the contribution of ICARDA has been to provide a range of genetic materials that are incorporated into the Australian durum program, and which are likely to contribute to improved varieties released over the next 10-12 years. The impact of that ICARDA contribution is estimated as a cost reduction of A$2.04 per tonne, while for the Rest of the World the cost reduction from ICARDA in durum is projected at A$10.47 per tonne, resulting in a A$6.20 per tonne reduction in price. The net effect for Australia is a small net loss of welfare averaging A$0.9 million per year, as the negative world price effects outweigh the value of the productivity increases.

For chickpeas, the main benefit of the germplasm obtained from the ICARDA program is the incorporation of ascochyta blight resistance into Australian kabuli chickpeas. For kabuli chickpeas, the cost reduction in Australia is estimated to be 27%, or A$189 per tonne. However, the kabuli chickpea industry is very small, with only 22,000 tonnes produced in 2001. Globally, ICARDA is estimated to reduce costs in the Rest of the World for kabuli chickpeas by 8.7%, and world prices are estimated to fall by A$28 per tonne. The net effect for Australia is an estimated average welfare gain of A$1.2 million per year from ICARDA's chickpea research over the next 20 years.

For faba beans, the major benefits likely to be obtained from ICARDA germplasm are expected to come from a saving in spray costs for fungal diseases such as chocolate spot. At present, repeated applications of fungicide are necessary for faba beans, and the resistance being obtained from ICARDA will lead to a reduction in the use of fungicides. The value of that saving is equivalent to a cost reduction in Australia of A$54 per tonne. ICARDA is estimated to have made only small gains for the Rest of the World to date, with an estimated cost reduction is A$8.17 per tonne. The increases in production lead to an estimated world price reduction of A$7.00 per tonne. The net effect for Australia is equivalent to a gain of A$6.1 million per year, on average, for the next 20 years.

For lentils, the entire Australian industry is based on materials obtained from ICARDA. As a result, the value of the lentil program is the additional income that Australian farmers receive over and above that which they would have received if lentils had not been available in the Wimmera and Mallee regions of Victoria and South Australia, where lentils are grown. The estimated increase in gross margins of lentils over the crops that it has replaced is equivalent to a cost reduction of A$61 per tonne for lentils. In the Rest of the World, ICARDA is estimated to have led to a yield increase of 2.1%, equivalent to a cost reduction of A$7.71 per tonne. As a result of these productivity gains, the world price is estimated to fall by A$6.82 per tonne. The net effect for the Australian lentil industry is a gain of A$4.9 million per year from using the material provided from ICARDA.

As mentioned in the discussion of each crop, the economic analysis assesses the impact on Australia of ICARDA's research in terms of the impacts on world prices as well as on the costs of production. To the extent that ICARDA's research has increased world production, there will be a downward impact on price. Given finite supply and demand elasticities, any increase in production will mean a decline in price within the traded goods sector. Recent work at ICARDA has led to development of estimates of the likely impacts in the future of ICARDA's research. The increases in the world's production of each of the mandate crops are likely to have a downward impact on prices for the related predominantly export-oriented industries in Australia.

On that basis, the Australian industry faces lower prices as a result of ICARDA's research, at the same time as they were experiencing yield gains from the germplasm obtained from ICARDA. The economic analysis of those spillover impacts in an economic welfare framework revealed that the overall aggregate net effect for Australia was a small negative impact from lower prices that was more than offset by the increased productivity. Only in durum wheat was the estimated increase in productivity too small to outweigh the price decline. For durum, these losses occur because Australian producers are unable to make use of the productivity gains from ICARDA research to the same extent as producers in the Rest of the World, and hence cost reductions gained by other producers are larger than those gained by Australian producers. For the other crops, Australian producers are obtaining productivity gains from ICARDA large enough to increase their incomes, in spite of the lower world prices.

It should be noted that Australian producers are enjoying productivity gains from domestic research programs unrelated to ICARDA that have not been considered in this study. No attempt has been made to assess whether Australian producers are becoming more or less efficient than producers in the Rest of the World.

The average estimated net gain to Australia as a result of the overall research effort at ICARDA is A$13.7 million per year (in 2001 Australian dollars) over the period to 2022 (see Table). Most of those gains are achieved in the faba bean and lentil industries. Producers receive most of the welfare gains in Australia, amounting to A$12.6 million of the total. On the other hand, Australian consumers of these crops will make gains of approximately A$1.1 million per year. Consumer gains in Australia are relatively small because domestic consumption of several of the ICARDA mandate crops is modest.

Summary of Benefits to Australia from ICARDA Research
(Average annual benefits for 2001 to 2022)

	Barley *(A$m)*	**Durum** *(A$m)*	**Chickpea** *(A$m)*	**Faba bean** *(A$m)*	**Lentil** *(A$m)*	**Total** *(A$m)*
Producers	1.8	-1.2	1.1	6.0	4.9	**12.6**
Consumers	0.6	0.3	0.1	0.1	0.0	**1.1**
- Total	***2.4***	***-0.9***	***1.2***	***6.1***	***4.9***	***13.7***

a: Discounted to 2001 Australian dollars at 5% per annum

This study has produced significant findings at two levels. The first level has been the identification of anticipated spillover benefits in terms of cost reduction for producers of ICARDA mandate crops, barley, durum wheat, kabuli chickpeas, faba beans and lentils. Those cost reductions are expected to result from yield increases attributable to germplasm developed at ICARDA or collected by passing through ICARDA and incorporated into genotypes that will be grown in Australia.

The second level at which significant findings have emerged is in the incorporation of the price effects of international agricultural research for these crops. In several industries, the price effects resulting from successful ICARDA research were found to be significant. The lower world prices for Australian producers were generally more than offset by the increased yields or cost savings from improved germplasm. The gains for Australian consumers were less than the losses from price effects for Australian producers, because the significance of exports meant that consumption in Australia is less than production. In most cases, the price effects for producers are offset by lower costs of production

These findings have some important implications for Australian agriculture:

(a) International Centres such as ICARDA remain a source of materials for potential yield gains for Australian crops, even those crops grown in systems and environments significantly different from those targeted by the international centres.
(b) Australian producers will be affected by the price implications of the successful research that is undertaken by the international centres such as ICARDA, whether or not they take advantage of the possible yield gains spilling over.
(c) Consumers are likely to be significant beneficiaries of any research advances in the grains industries, although where Australia exports a large proportion of production, most of those consumers are overseas.
(d) Australia's gains from international spillovers are likely to be greatest for those industries where there are significant links between Australian researchers and the researchers and programs being undertaken in the international research centres.
(e) Australian researchers need to maintain their vigilance over international agricultural research developments. Because of the contributions of the international centres, producers throughout the world are becoming more efficient and prices are falling below what they would otherwise have been. There is a need for a strong domestic research program, partly to maximise benefits from international spillovers, to ensure that Australian producers achieve gains similar to those of their competitors.

Recognition of these factors can assist in leading to better-informed decision-making for research resources, and is likely to lead to a more efficient and more cooperative research system worldwide. That improved system will provide improvements in the efficiency of production and in the delivery of appropriate food cheaply to the consumers most in need.

1. Introduction

1.1 International Centre for Agricultural Research in the Dry Areas

ICARDA (International Centre for Agricultural Research in the Dry Areas) was established in 1977 by the Consultative Group on International Agricultural Research (CGIAR). Based at Aleppo, Syria, ICARDA is one of 16 non-profit, research and training centres funded through the CGIAR. The CGIAR is an informal association of approximately 50 public and private sector donors. It is co-sponsored by the World Bank, the United Nations Development Program (UNDP), the Food and Agriculture Organisation (FAO), and the International Fund for Agricultural Development (IFAD) of the United Nations.

ICARDA's mission is to improve the welfare of people in non-tropical dry areas of the developing world through research and training, by increasing the production, productivity and nutritional quality of food, while preserving and enhancing the natural resource base.

The geographic scope of ICARDA's research covers the countries of Central and West Asia and North Africa (CWANA), as well as developing countries with subtropical and temperate dry areas. ICARDA has global responsibility for the improvement of lentil, barley and faba bean. It also has responsibility in dry areas for the on-farm management of water, the improvement of small ruminant nutrition and productivity, and the rehabilitation and management of rangelands. In addition, ICARDA has responsibility in the CWANA region for the enhancement of the productivity of bread and durum wheat, chickpea, forage legumes and their associated farming systems, and for ensuring the conservation and management of the natural resource base of water, land and biodiversity. As a result of plant improvement research at ICARDA since its foundation in 1977, improved cultivars of these commodities have now had a major impact within the CWANA region.

Not only do target areas of research in CWANA have a common climatic and edaphic environment with parts of eastern and western mainland Australia, but also the ICARDA mandate crops are of key importance to Australian agriculture. As a consequence there has been spillover to Australian farmers of some benefits from ICARDA's research aimed at poverty alleviation in CWANA.

1.2 Project on ICARDA's Impact in Australia

Although ICARDA aims to improve the production of its mandate crops for developing countries, its germplasm and other technologies have also been made freely available to developed countries. Australia has been regularly testing material from ICARDA, and ICARDA germplasm has been incorporated into a number of varieties released in Australia. However, the economic impacts of the utilisation of ICARDA's plant genetic research in Australia have not been assessed until now.

A project was developed with the Australian Centre for International Agricultural Research (ACIAR), ICARDA and NSW Agriculture to investigate and document the impact of ICARDA's research on Australian agriculture. The project "Impact of ICARDA Research on Australian Agriculture" is funded jointly by ACIAR and NSW Agriculture.

The study aims to:

(a) Investigate and document the spillover impacts of ICARDA research on Australian agricultural productivity; and
(b) Evaluate those gains in productivity in relation to the price impacts of ICARDA's research in other parts of the world.

The principal objective of the project is a better understanding of the role of ICARDA's germplasm in varietal development in developed countries such as Australia. An appreciation of the spillover impacts on Australia would also lead to an improved understanding of the constraints and limitations of ICARDA's products for Australian conditions. While it would not be expected that ICARDA would necessarily change their approach to enable Australia to obtain larger spillover benefits, there may be valuable information for ICARDA from the findings of the analysis. A further outcome of the project would be the identification of any implications for Australia's investment in ICARDA through foreign aid payments, particularly whether there is evidence that it would be appropriate to increase Australia's contribution to the CGIAR system.

ICARDA makes contributions in a wide range of areas, including a number of collaborative research projects with Australia (see Appendix D), and will have made some critical contributions that are not captured in this report. In particular, ICARDA has the unique role of collecting, evaluating and distributing germplasm to breeding programs for its mandate crops around the world. While the analysis in this report does not identify the value of those activities, it is acknowledged that ICARDA plays a critical role as a source of diversity in some Australian breeding programs.

1.3 Outline of This Report

In section 2 of this report the identification of ICARDA's impact on Australia is discussed. In section 3, the methodology used for assessing the impacts is developed. In sections 4 to 9, the impacts of ICARDA's research in each of the mandate crops (barley, durum wheat, chickpeas, faba beans, lentils and forage legumes) are assessed. In section 10, the implications of the results are discussed, and the outcomes of this report are summarised. Appendices are attached with additional data and details of aspects of ICARDA's impacts on Australia.

2. Identifying ICARDA's Impact in Australia

2.1 Survey of Australian Crop Improvement Programs

In early 2001, a survey was conducted of the crop improvement programs in Australia known to be working on ICARDA's mandate crops. In all, 41 Australian scientists responded to the survey. A list of the respondents is provided in Appendix B, as well as a list of the questions included in the survey.

The aim of the survey was to identify the key personnel involved, so that further discussions could be held with them. Further aims were to discover the benefits that those involved in the research programs perceived for their programs from ICARDA, to identify the key materials involved and the strengths and weaknesses of that material, and to document which ICARDA lines are currently being used by Australian breeders.

It is apparent from the information obtained in the survey that ICARDA material is currently being widely used for a number of the crops. The breadth of the reliance on ICARDA as a source of breeding materials and methodologies varies widely between crops. The information obtained from the survey is used in the following sections of this report in identifying the impacts of ICARDA germplasm on Australian breeding programs.

2.2 Germplasm Flows from ICARDA to Australia

There has been an on-going flow of genetic materials from ICARDA to Australia for the different crops involved. In some cases, that flow is an organised regular flow of seed each year. In other cases, it is irregular, often sparked by a visit from an Australian researcher to ICARDA or by a specific issue arising. ICARDA has also organised joint collections with Australians of new genetic materials from the Central Asia/Caucasus region.

On the basis of data supplied by ICARDA, there have been a total of 553 sets of lines for testing and 21,472 individual lines of germplasm imported from ICARDA into Australia since 1983 (Table 2.1). The average number of lines per set in the past ten years has been 33, with 50 lines per set imported over the period 1983-1991. The trend in germplasm flows from ICARDA appears to be declining, as indicated by a fall in lines per set from 50 to 33 over the last two decades. This decline is likely to reflect an increasing awareness of the specific characteristics in ICARDA genetic materials that are likely to be of importance in Australia.

It should be noted that in some instances, lines sent directly from ICARDA breeders to Australian breeders might not be included in these data. That has been found to be particularly so for faba beans. An examination of the Australian faba bean collection shows that there have been a total of 821 accessions from ICARDA up to the end of 2000, more than are reflected in Table 2.1 (see section 7.5 for more details).

Table 2.1: Number of Lines Sent from ICARDA to Australian Programs[a]

Year	Barley	Wheat	Durum	Faba beans	Chickpeas	Lentils	Lathyrus	Vetch	*Total*
1983		0	0	0	0	240	0	0	***240***
1984	0	0	0	50	0	0	0	0	***50***
1985	0	0	0	0	0	113	0	0	***113***
1986	0	0	0	0	23	366	0	0	***389***
1987	537	230	0	0	281	531	0	0	***1579***
1988	477	941	0	13	218	403	0	0	***2052***
1989	387	626	222	0	341	659	0	0	***2235***
1990	132	317	0	0	0	0	0	0	***449***
1991	368	580	48	0	187	283	0	0	***1466***
1992	238	181	0	0	287	486	0	0	***1192***
1993	0	0	0	0	254	280	23	69	***626***
1994	0	0	0	0	427	474	4	90	***995***
1995	159	40	0	0	404	579	0	60	***1242***
1996	0	0	0	0	400	703	3	60	***1166***
1997	776	498	0	0	384	793	0	30	***2481***
1998	0	0	0	0	618	336	0	30	***984***
1999	144	0	209	0	490	432	0	30	***1111***
2000	100	0	131	0	249	449	0	30	***852***
2001	1244	462	89	0	356	188	0	0	***2250***
-Total	*4562*	*3875*	*308*	*63*	*4919*	*7315*	*30*	*399*	***21472***

a: In some instances, lines sent directly from ICARDA breeders to Australian breeders may not be included in these data, particularly for faba beans.

Source: Compiled by the authors from data supplied by ICARDA scientists.

2.3 Scope of This Study

Bread wheat has specifically been excluded from this study, on the basis that the bread wheat work is too closely integrated with CIMMYT to make the separation of ICARDA worthwhile. Similarly, we have made relatively arbitrary decisions on the extent to which durum wheats are included in this study (see section 5), to focus on the contribution of ICARDA. Those decisions were to make it feasible to undertake the study, but they remain essentially arbitrary, given the joint nature of the CIMMYT/ICARDA work on bread and durum wheat. Therefore, by excluding bread wheat and arbitrarily allocating durum wheat benefits to ICARDA and CIMMYT, this study is only providing a limited assessment of the total contribution of the wheat research work being undertaken at ICARDA. The results should be interpreted in the light of those limitations to the scope of the benefits included[1].

Further, it is apparent that for several ICARDA mandate crops there are complex, elaborate collaborative arrangements in operation. In some of the smaller crops (from Australia's point of view), the Australian breeders have few colleagues in Australia with similar interests and

[1] The apparent disparities between the impact of CIMMYT (Brennan and Fox 1995) and ICARDA on the Australian wheat industry (see section 5 below) raise a new question. A separate study to analyse the joint benefits to Australia from the wheat programs at CIMMYT and ICARDA would be valuable. Such a study would enable the CGIAR efforts to be assessed without any arbitrary divisions regarding the attribution between the different agencies.

aims, so that the possibility of international collaboration is especially important. This is particularly evident in lentils and durum wheat, where the collaboration is especially strong, but also applies to chickpeas and faba beans. For barley, the collaboration is also important because of the similarity of many of the production environments in Australia to some of those in ICARDA’s CWANA region and in Latin America where ICARDA operates a barley breeding program in conjunction with CIMMYT.

The collaboration and cooperation that occurs means that there is a level of integration between the Australian and ICARDA programs in some cases, and leads to a sharing of ideas, a free exchange of germplasm and extensive cooperation in access to trial and evaluation data. In addition, the role that ICARDA plays in training Australian scientists in these crops has been invaluable. The visits to each other’s programs have enhanced both the ICARDA and the Australian programs. For example, in the durum breeding programs, there are clearly two-way benefits from the degree of cooperation that occurs. The Australian breeder is able to get many of the lines evaluated in the presence of various exotic pests and diseases not (yet) present in Australia, while the ICARDA breeder is able to utilise the quality evaluation and other screening that is carried out in Australia. These activities are to the mutual benefit of both programs. The benefits of collaboration are especially important for the smaller crops that are still developing, such as faba beans and lentils. The number of researchers working in Australia on these crops is small, and might be below the critical mass needed to make sustained advances in variety improvement without international collaboration.

Another area where there are clear benefits, but which can not be quantified in a study such as this, is the access to the germplasm bank for the mandate crops at ICARDA. While the genetic material may not always be used in Australian varieties, information provided from the gene bank to the Australian breeders can provide them with important background on the crosses that they make and the materials that they use. In addition, knowing that there is access to the gene bank is in itself a source of security for the breeders and a saving in terms of the materials that they would otherwise have to store and manage. It is also valuable to the breeders to know that it is possible to screen populations for information as required. That access enables a degree of genetic diversity and confidence in the future genetic integrity of the varieties released that cannot be measured but is nevertheless very important.

The flow of germplasm in some crops is very much a two-way process. For example, as well as the ICARDA durum program providing substantial germplasm to Australia, the Australian program provides significant input into the lines being used in the ICARDA crossing program.

Given the limited time and resources available for this study, we do not attempt to place an economic value on the benefits of each of the strands of cooperation and collaboration involved. Indeed, there are many such activities that may be impossible to value. As a result, it has been necessary to limit the extent to which the benefits from ICARDA to Australia are quantified in this study. The only benefits evaluated in this study are those flowing from the germplasm introduced from ICARDA to Australia for each of the main mandate crops. It must be recognised that this approach omits many other potentially valuable avenues for benefits to flow to Australia from the relationship with ICARDA. In addition, the flow of benefits from Australia to ICARDA from both the flow of genetic material from Australia and the other collaborative arrangements are not incorporated into the analysis in this study. That is not to indicate that those elements are not important, merely that they are too difficult to identify with the resources and the time available.

3. Economic Analysis of Impacts

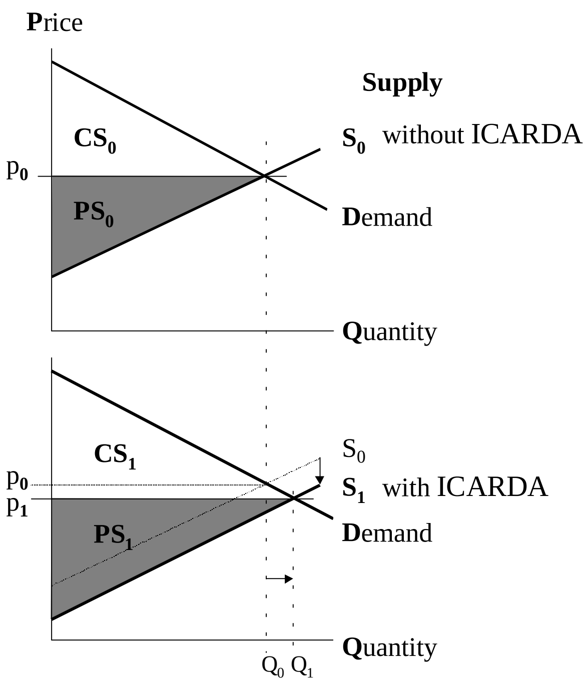
3.1 Economic Analysis of Productivity Increases

A genetic improvement in yield means an increase in productivity, in the sense that there is higher output for each level of input. In economic terms, the yield-increasing effects of a new variety result in a shift of the supply curve (Lindner and Jarrett 1978; Norton and Davis 1981; Edwards and Freebairn 1984).

As in Brennan and Bantilan (1999), the increase in productivity is defined as a parallel vertical (downward) shift in the supply curve through a lowering of the production costs per tonne (Edwards and Freebairn 1984). Assuming that new varieties do not interact with changes in other inputs (see Brennan and Fox 1995), the economic benefits can be estimated directly from these cost reductions.

The benefits that are measured are changes in the "Producer surplus" and the "Consumer surplus", which are measures of the economic welfare of each of the two industry groups. The analysis aims to measure the difference between the producer and consumer surpluses with the ICARDA contribution and the surpluses that would apply if there were no impact from ICARDA. This is illustrated in Figure 3.1, where the situation *without* ICARDA is shown with producer surplus = PS_0, and consumer surplus = CS_0, and the situation *with* ICARDA is shown with producer surplus = PS_1, and consumer surplus = CS_1. The change in producer surplus is the difference between PS_1 and PS_0, while the change in consumer surplus is the difference between CS_1 and CS_0.

Figure 3.1: Definition of Changes in Producer and Consumer Surpluses



Change in producer surplus = $\mathbf{PS_1 - PS_0}$

Change in consumer surplus = $\mathbf{CS_1 - CS_0}$

3.2 Framework for Analysis of Spillover Impacts

The net benefits of agricultural research in a tradeable commodity for its target region are influenced by the spillover of the effects of that research to other producing regions with which the target region competes for a share of the world market, as well as by the productivity changes in the target region. Edwards and Freebairn (1984) showed that the greater the extent to which the research innovations are adopted in other competing regions, the lower the producer benefits for the target region. Davis *et al.* (1987) further developed the incorporation of spillover effects into an analytical framework for the evaluation of research.

In this study, the spillover effects of research at ICARDA on crop production in Australia are identified. An attempt is made to quantify the extent of those spillover effects from the ICARDA program, largely through their influence on Australian yields and/or production costs.

The shifts in world supply attributed to research emanating from ICARDA are likely to have an impact on the world price for the relevant crops. It is likely, therefore, that the increased supply resulting from the increased productivity in CWANA obtained through ICARDA material has affected (even if only slightly) the prices received for Australia's production of the mandate crops. Since the demand is less than perfectly elastic, the increased supply in other countries will have reduced the price, so that the gains to producers indicated by this analysis are lower than if the assumption of perfect elasticity (as in Brennan and Fox 1995) had been maintained. As a result, these price effects are likely to have produced reductions in welfare for Australian producers of those crops, while at the same time producing benefits for Australian consumers (Brennan and Bantilan 1999).

While a large proportion of production in some of the crops analysed is not traded, the simplifying assumption of a single world price applying to all production is a practical means of allowing us to assess the impacts on Australia, which is the main objective of the study.

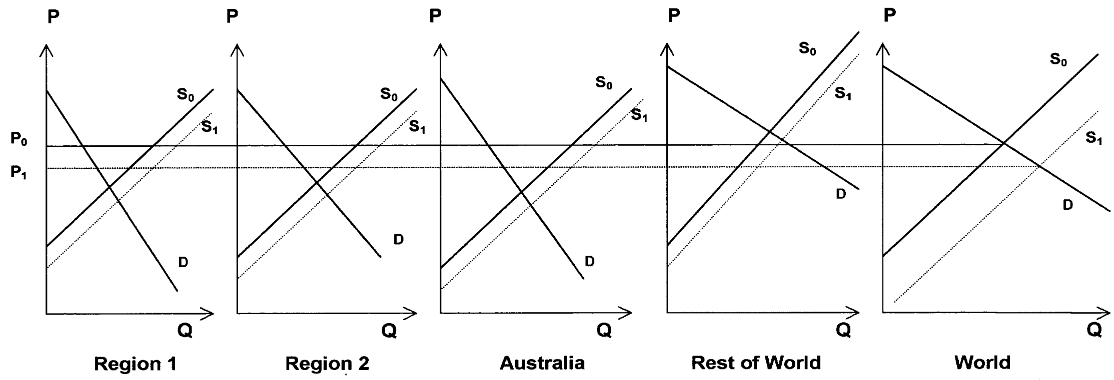
The framework used in this analysis is based on Edwards and Freebairn (1984). The world markets for each crop are disaggregated into two major component regions, namely Australia and the Rest of the World (ROW). Australia is further sub-divided into regions, as appropriate.

The following assumptions are made for the analysis of the impact of spillovers in Australia:

- (a) Elasticities of demand and supply are the same throughout Australia;
- (b) All countries other than Australia are grouped into the Rest of the World;
- (c) The total production costs per tonne equal the equilibrium price (see section 3.5);
- (d) All supply and demand curves are linear, and
- (e) All shifts in supply are defined as parallel vertical shifts (ie, cost reductions).

The framework used is illustrated in Figure 3.2, where P is price and Q is the quantity supplied or demanded. ICARDA research leads to a shift in supply curves for each region from S_0 to S_1. Direct shifts are obtained in the Rest of the World (the “target” region for that research), with spillovers impacting on Australia. For simplicity in this analysis, the impacts on developed countries other than Australia are incorporated with the Rest of the World.

Figure 3.2: Spillover Framework Used in Analysis



The shifts in supply in the Rest of the World and regions within Australia lead to a shift in the aggregate supply curve for the World. The shift in the world supply leads to a price fall from P_0 to P_1, given that there has been no change in the demand curve. The lower price feeds back to each region, so that each region faces a changed equilibrium price as well as the shift in the supply curve. The resultant welfare gains are measured as changes in producer and consumer surpluses for each of the regions (as illustrated in Figure 3.1). Regions that do not obtain a supply shift still face the price effect of the supply shifts in the other regions, and can have a change in producer or consumer surplus.

One of the consequences of a static analysis such as this one is that a number of simplifications are made. One such simplification is the lack of dynamic aspects such as second-round impacts on demand or supply of other commodities as a result of an increase in yields, and therefore income.

A further simplification is that demand is assumed to remain static. Consequently, an increase in productivity leading to a downward shift of the supply curve means that the price falls. However, it is likely that in the time period used in this analysis, increases in world population and income are likely to lead to an upward or outward shift in the demand curve, so that the price may not actually fall over the period of the analysis. Nevertheless, ignoring the demand-changing factors has little impact on the outcome of the analysis, since the welfare analysis measures the difference between the with- and the without-ICARDA scenarios. Therefore, the results would be similar whether the demand curve shifts out over time or not.

In reporting the results, figures for the Rest of the World are provided in this report for completeness, but they do not reflect the impact on individual countries. As the focus of this report is on Australia, all other countries are grouped together in the analysis. In some countries, there will be impacts significantly different from the overall aggregate for the Rest of the World, so the results of this study should not imply any particular impact for countries other than Australia.

3.3 DREAM Evaluation Model

The analysis outlined in Figure 3.2 was carried out using the DREAM (Dynamic Research Evaluation Model) evaluation model (Alston *et al.* 1995, Appendix A5.1.2). The model has been developed by the International Food Policy Research Institute (IFPRI)[2], and is becoming the standard for economic analysis of ACIAR projects. It provides a useful and reliable means of analysing the economic impact of research .

For each of the crops, the data were used in DREAM, run as a horizontal multi-market to provide analysis of the spillovers from ICARDA to Australia (and in some cases regions within Australia). While the parameters for the different crops varied in each case, common parameters used were:

(a) Linear adoption;
(b) The estimated supply shift was entered as having 100% probability of success;
(c) Benefits were measured for the period from 2001 to 2022;
(d) Two groups were used, namely Australia and the Rest of the World, with Australia being subdivided into regions as appropriate for each crop;
(e) Disadoption was assumed to occur immediately after 2021.

3.4 Level of Disaggregation in Analysis

Two levels of disaggregation are considered for the analysis of impacts in Australia. The first is the state level, for the main grain-producing states (Queensland, New South Wales, Victoria, South Australia and Western Australia). Some data are only available at the state level and it is administratively useful to know the distribution of impacts and benefits at this level.

In addition, the Grains Research and Development Corporation (GRDC) has defined 16 agro-ecological zones for the Australian grains industry (ABARE 1999), which can be combined into GRDC's three regions[3] (Northern, Southern, and Western) (Figure 3.3). Those zones provide a convenient analytical basis for our analysis. Where appropriate, the analysis is carried out for each crop at the zone level and the results are then aggregated to the region level. Because data since 1997 are only available at the state level, zone data has had to be extrapolated from state data for more recent years. Therefore, the results at the zone level are subject to some additional error resulting from the lack of available data. Where the impacts are the same across all states and regions, the analysis is carried out for Australia as a whole, without disaggregation.

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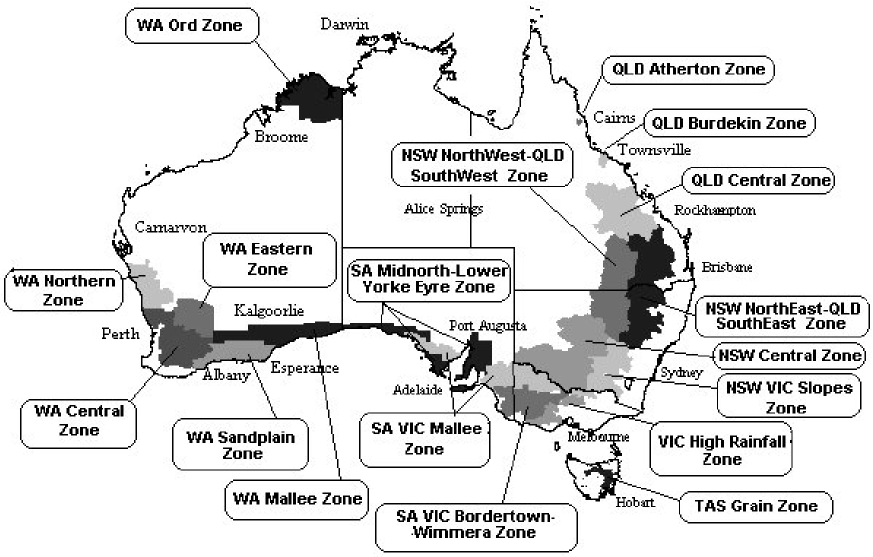
[2] The model and its documentation is publicly available from IFPRI on www.ifpri.org/dream/

[3] The Northern region comprises Queensland Atherton, Queensland Burdekin and Queensland central zones, plus North-West NSW - South-West Queensland and North-East NSW - South-East Queensland. The Western region comprises all the WA zones (Ord, Northern, Eastern, Central, Sandplain and Mallee). The Southern region comprises all the remaining zones.

Figure 3.3: Agro-ecological Zones Used in Analysis in This Study



3.5 Estimation of Cost Reduction from Limited Data

Following Rose (1980) and Alston *et al.* (1995, p. 64), supply shifts from research are treated as vertical shifts in parallel supply curves, given that there is no strong evidence to the contrary. For the analysis in this study, the supply shifts are assumed to be parallel shifts, and are entered in the analysis as vertical shifts, or cost reductions (as in Figures 3.1 and 3.2).

In some of the cases analysed in this study, the cost reductions are estimated directly from available data. However, in estimates of supply shifts in the Rest of the World and in some cases for the supply shifts in Australia, the technological impact of ICARDA is expressed as a percentage yield gain. To convert a percentage yield gain to an equivalent cost reduction, either data are needed for the total costs of production for the relevant region, or a simplifying assumption is required. For example, producers whose yields are 2.0 t/ha and whose total costs are $200 per ha have a total cost of $100 per tonne. A (costless) 10% yield gain for those producers means that their costs fall to $200/2.2 = $90.90 per tonne, a fall of $9.10 per tonne. On the other hand, producers who have the same yields but whose costs are $300/ha would have costs of $150 per tonne, which would fall to $136 per tonne with a 10% yield increase, a fall in costs of $14 per tonne. Therefore, the level of total costs is important in determining the extent of the fall in the supply curve.

Total cost data are not available for any of the crops analysed here, either in Australia or in the Rest of the World. While data are available in some cases on variable costs, there are no reliable data on fixed and overhead costs associated with the production. Following GRDC (1992) and the way in which the Alston *et al.* (1995) formulae have been incorporated into the DREAM analytical model, the simplifying assumption adopted here is that the world price represents an equilibrium at which the total cost of production equals the price. On the basis of that assumption, we use the world price as a proxy for the total costs per tonne without the ICARDA technology. Increases in yield due to ICARDA lead to a reduction in costs, which measures the downward shift in the supply curve.

The methods used are illustrated in Table 3.1. In this example, the expected yield gain from ICARDA is 20%. Given current yields of 2.00 t/ha, that will increase yields to 2.40 t/ha. If the price is $300 per tonne, then the estimated total costs per ha (without ICARDA's impact) is $600 per ha (=2.00 x 300), so that total costs per tonne are $600/2.00 = $300. With the 20% increase in yields, the total costs per ha are unchanged at $600 per ha. Therefore, the costs per tonne are now $250 (=600/2.40). The cost has fallen from $300 per tonne to $250 per tonne, a fall of $50 per tonne. Thus the supply shift used in the analysis is a downward shift of $50 per tonne, which is equivalent to a downward shift in the supply curve of 16.7% (=50/300) at the initial equilibrium.

Table 3.1: Illustration of Estimation of Cost Reduction from Percentage Yield Increase

	Unit	*Amount*
Impact of ICARDA		
Estimated yield impact due to ICARDA	%	20%
Estimation of cost reduction		
Yield without ICARDA	t/ha	2.00
Estimated yield with ICARDA	t/ha	2.40
Price	$/t	$300
Gross income per ha without ICARDA	$/ha	$600
= Total cost per ha	$/ha	$600
Cost per tonne without ICARDA impact	$/t	$300[a]
Cost per tonne with ICARDA impact	$/t	$250[b]
Cost reduction from ICARDA impact	$/t	$50
Percentage supply shift from ICARDA impact	%	16.7%[c]

a: = 600/2.00 = 300
b: = 600/2.40 = 250
c: = 50/300 = 16.7%

3.6 Data Sources for Empirical Analysis

The data used for the empirical analysis were derived from a number of sources. The data on area, yield and production in Australia for each of the mandate crops for recent years are shown in Appendix A. These were based on data from the Australian Bureau of Agricultural and Resource Economics (ABARE 2001), where they were available. For parts of the industry such as kabuli chickpeas and durum wheat, where separate data were not available from those sources, estimates of the relative importance of these components of the entire chickpea and wheat industries had to be estimated from industry sources. For kabuli chickpeas, faba beans and lentils, information was obtained from Pulse Australia (Pulse Australia 2001). World area, yield, production and trade data were obtained from FAO statistics (FAO 2001).

The prices used in the analysis were also derived from a combination of projections and estimates from ABARE (2001) and from industry sources. For durum wheat, the payments for durum were obtained from AWB Ltd, formerly the Australian Wheat Board (AWB 2001).

The supply and demand elasticities used in the analysis were derived from elasticities obtained from ACIAR (Table 3.2). Where individual elasticities were not available for the crops being analysed, estimates for "Pulses" were used for individual grains such as kabuli chickpeas and faba beans. In the absence of alternative estimates, elasticities for barley were taken to be the same as for sorghum, which is also used as both a food and a feed grain.

The determination of the impact of ICARDA research on Australia was the result of a broad-ranging search for information and data. The first step was a survey of crop improvement programs for the relevant crops in Australia (see section 2.1), which provided the initial information. Subsequently, key players identified in that survey were then approached for more detailed discussions and data on the impacts.

Table 3.2: Elasticities[a] of Supply and Demand Used in Analysis

	Supply		Demand	
	Australia	**Rest of World**	**Australia**	**Rest of World**
Barley	0.30	0.13	-0.35	-0.23
Durum wheat	0.25	0.30	-0.20	-0.20
Kabuli chickpeas	1.70	0.52	-0.79	-0.75
Lentils	0.80	0.60	-0.80	-0.41
Faba beans	1.70	0.52	-0.79	-0.75

a: Elasticity = $(\Delta Q/Q)/(\Delta P/P)$
Source: ACIAR spillover model (D. Templeton, personal communication)

Data on the ICARDA varieties of the different crops that have been released in Australia have been obtained from ICARDA (see Appendix C). That list has been supplemented by information from the Australian breeders on the lines with ICARDA germplasm in their programs but not yet released as varieties, as well as other lines and varieties with some ICARDA connections.

The estimated impacts of ICARDA on the Rest of the World were derived from information obtained from ICARDA. In each case, an estimate of the impact as at 2001 was made, as well as an estimate of the impact in 2006, the time at which most of the Australian impacts would be reaching their peak. These estimates for the Rest of the World took into account known use of ICARDA germplasm in individual countries as well as assessments on a country by country basis of the degree of use of that genetic material.

The countries in which varieties have been released with a contribution of ICARDA (ICARDA 2001) were identified, and the ICARDA contribution to those varieties estimated by ICARDA scientists from knowledge of the pedigrees of the varieties. In some cases, ICARDA lines have been released directly by national programs. In other cases, ICARDA lines were parents in crosses with ½, ¼ and lower contributions. The yield gain from those varieties was also estimated, along with the current level of adoption of those varieties. The estimated current impact in each country was then determined, along with the predicted impact in 2006, based on estimated changes in adoption of ICARDA varieties in each country over the next five years. Results were aggregated for the Rest of the World, weighting ICARDA's contribution to each country by recent average production. The expected increase in production attributable to ICARDA was then expressed as a percentage of total production in the Rest of the World, and that was used as the estimate of the yield increase expected to be attributable to ICARDA in 2006. These detailed calculations for the Rest of the World are voluminous. Therefore, only the results of the calculations rather than the details are shown in this report.

4. Impact in Australia of ICARDA's Barley Research

4.1 Background

Barley (*Hordeum vulgare*) is one of the major cereal crops in the world. Barley is widely grown in more hostile environments than wheat (ICARDA 2001), and it is often the crop grown in the most marginal areas. Barley is the most common crop in the driest rain-fed farming areas of the CWANA region.

World production of barley has averaged approximately 150 million tonnes in recent years. The main producing countries are Germany, Canada, Russian Federation, France, Spain and Turkey. Of the annual average barley production of 25 million tonnes in the developing world, about 72% is grown in West Asia and North Africa, 19% in Central Asian countries, and about 6% is grown in Latin America. In the WANA region, the major producers are Turkey, Morocco, Syria, Iran, Iraq, Algeria and Ethiopia. Most of the barley (88%) in Central Asia is grown in Kazakstan. Saudi Arabia is the main importing country, with the European Union and Australia being the source of most barley exports.

Barley grain is used for animal feed, malt and food for human consumption. Archeological evidence shows that barley was used in human food several thousand years ago (Bhatty 1992). Although replaced by wheat and rice in modern times, barley still remains an important food grain in some developing countries, particularly in marginal areas where it may be the only viable crop (FAO 2001). The most important use of barley grain is for animal feed. Barley straw is used as animal feed in many countries. Barley stubble is grazed in summer in large areas of West Asia and North Africa. Barley is also used as animal feed at the vegetative stage (green grazing) or is cut before maturity and either directly fed to the animals or used for silage. Barley straw is also used for animal bedding and as cover material for hut roofs. Malting barley for the production of beer is the second largest use after feed. Malting barley is especially important in Western countries, but is also grown as a cash crop in a number of developing countries. Typically, little of the barley grown in CWANA countries is used for malting for alcohol production, honouring their cultural and religious traditions.

4.2 ICARDA's Research on Barley

ICARDA has a mandate to improve barley germplasm for all developing countries, and has been breeding for improved barley varieties since its inception in 1977. ICARDA and the International Maize and Wheat Improvement Center (CIMMYT) in Mexico have a joint program in barley improvement in Latin America, while ICARDA focuses on the drier areas in the CWANA region.

Initially the main emphasis of ICARDA's barley improvement program was on the centralised development of varieties. Centralised breeding was largely conducted either in good environments or in well-managed experiment stations where growing conditions are optimum or near-optimum, and, generally, produced genetically uniform cultivars selected almost exclusively for grain yield and disease resistance (Valkoun, Ceccarelli and Konopka 1997). This promoted widely adapted cultivars that can be grown over large areas. The result of the barley-breeding program in that early phase was the production of varieties that were more adapted to the more favourable rainfall conditions. However, most of the barley in CWANA is grown in the harsh drier environments with no chemical inputs and with fluctuating weather conditions. Decentralisation of selection and farmer participatory research, which enables development of cultivars for specific adaptation, are now considered as the best strategies to tackle the challenge of breeding for less favourable environments.

Thus, ICARDA's mandate for barley improvement is currently being implemented through a process of decentralised breeding, involving scientists from national programs as equal partners in the entire breeding program (ICARDA 2001). ICARDA maintains the responsibility for generating a continuous flow of genetic variability, while selection in the target environments is carried out in the national programs. A major recent direction is the participation of farmers in early selection of segregating populations, to enable increased exploitation of specific adaptation (Ceccarelli *et al.* 2000). The result has been the development of varieties more attuned to the needs of farmers and to the particular environments in which they are grown.

The main goals of the ICARDA breeding program are yield potential, disease resistance and wide adaptation. ICARDA places little emphasis in its breeding program on malting quality for the reasons mentioned above. The barley-breeding program has established collaborative research work with many national agricultural research systems (NARS) in the developing countries and advanced institutions in developed countries. Some 166 new varieties have been released over the past 20 years in 34 countries that have collaboration with ICARDA's barley breeding program. ICARDA's contribution of these new varieties in terms of the content of the genetic material was estimated at about 70% (Aw-Hassan *et al.* 2001). ICARDA's barley breeding program has increased NARS access to germplasm through its international nurseries and germplasm exchange programs. ICARDA also contributes to NARS capacity building through training, collaborative research projects, and various exchanges.

4.3 Australian Barley Industry

In Australia, the area sown to barley over the past five years has averaged 2.96 million hectares (see Appendix Table A.1). Barley yields have averaged 1.98 t/ha, giving average production of 5.85 million tonnes in the five years to 2001-02. South Australia is the leading state in barley production, although New South Wales, Victoria and Western Australia have each produced over 1 million tonnes in recent years. Prices have varied considerably from year to year, but averaged A$194 per tonne in recent years.

Malting barley has generally been considered the more favourable option in Australia as it attracts a higher price premium over feed barley. However, even though approximately 80% of the area is sown to malting varieties each year, only approximately 70% of the crop sown to malting varieties achieves malting quality, which is characterised by low protein. Therefore, the proportion of the crop marketed as malting quality is only around 56%, with the other 44% being sold as feed barley.

Barley has traditionally been the second most important crop in the areas where wheat is grown. However, in recent years there has been a shift from the more traditional barley crop to other crops such as canola, which receive higher prices without the tight climatic requirements that must be met to achieve malting barley price premiums. As a result, the area sown to barley in most states in the most recent years has been lower than it was in the early to mid-1990s.

4.4 Australian Barley Improvement Program

Barley evaluation and breeding in Australia is a coordinated effort among the breeders in each state. The programs are coordinated on a regional basis for each of the GRDC's three regions (Northern, Southern, and Western). Collaborating breeders are located in each of the main barley-producing states. The Australian barley breeding programs have released a flow of improved varieties over the past decades.

The Australian programs have concentrated on the development of malting varieties, and the Australian breeders report that germplasm selected at ICARDA for grazing value as well as feed grain is generally not advantageous to malting quality. Ironically, the strict criteria for the release of new malting varieties acceptable to the malting industry has meant that the rate of change in malting varieties has been much slower than the rate of release and varietal change in feed barley varieties.

4.5 Use of ICARDA Barley Material in Australia

ICARDA has been a continuing important source of supply of germplasm for the Australian Barley Improvement Program. In the past five years, an average of 453 lines has been brought into Australia from ICARDA each year (see section 2.2 above). However, the flow of material has been relatively irregular between years since the early 1990's. For example, in 1997 and 2001, there were 776 lines and 1,244 lines imported, respectively. In the remaining years there were an average of 134 lines imported over three years, with nil lines imported in the other years.

A number of lines originating from the CWANA region are found in the pedigrees of Australian barley varieties such as Franklin and Arapiles. However, these lines were introduced into Australia prior to the establishment of ICARDA. For example, the variety Arapiles, released by the Victorian breeding program, has the line CI3576 from Egypt in its pedigree, with its contribution estimated to be less than 5% to the final cross.

No barley cultivars from ICARDA have been released directly in Australia. However, varieties have been released from the ICARDA/CIMMYT program, which include Kaputar, a semi-dwarf feed grain for northern NSW, Namoi, a hulless barley, of which very little is grown, and Yagan, a special purpose barley suited to late sowing in low-rainfall areas (Garlinge 1996). Yagan has subsequently been used as a parent of the variety Mundah, released in WA in 1995.

Some of the parental materials used in recent crosses made in the Australian breeding programs have been derived from ICARDA. For example, some of the ICARDA accessions being used in crosses include: derivates of SHYRI, an ICARDA/CIMMYT stripe rust resistant line and derivates of Q21972, which was a CIMMYT line with rust and other disease resistances. The SHYRI derivatives were introduced into Australia through the Victorian Institute for Dryland Agriculture at Horsham, primarily as sources of barley stripe rust resistance, and have been used extensively in the crossing programs in recent years. Other lines have been used in crossing programs for potential sources of improved adaptation to low rainfall environments. A range of barley lines including Weeah11/WI2291//Bgs, Roho//WI2198/Harmal-02, and Harmal are being used[4]. Sources of resistance to scald in barley are also being used in the Australian breeding programs.

The characteristics of most interest in ICARDA materials that are being tested for are resistance to diseases and pests, high yielding semi-dwarfs with large grain size and early maturity, potential malting quality, drought stress tolerance, and scald (*Rhynchosporium*) resistance.

Australian breeders focus on 2-row malting varieties, while ICARDA works with both 2-row and 6-row barley types. That restricts the extent to which some of the materials from ICARDA are of interest to Australian breeders, particularly the ICARDA nurseries where both types are included.

ICARDA materials have been found to perform best in alkaline soils, where boron tolerance is important, and they also provide some useful early-maturity. Another feature being obtained from some ICARDA materials is resistance to cereal cyst nematode, which has been incorporated into the feed variety Keel, but not yet into malting varieties.

The ICARDA germplasm collection for barley is an important resource for Australian breeders. The collaboration with ICARDA also allows Australian breeders access to Chinese materials that can be a valuable genetic resource in the future. In addition, the capacity to have screening for pests and diseases carried out at ICARDA allows selective use of materials rather than importing large number of lines to Australia. Of particular importance for breeders is information on sources of resistance to exotic pests of barley not present in Australia, such as stripe rust and Russian Wheat Aphid.

In addition to the use of genetic material from ICARDA in the Australian breeding program, data from ongoing ICARDA field trials and disease screening nurseries, and molecular maps and molecular markers, have been important inputs into the barley breeding program. Regular visits to ICARDA, and other regular written electronic contact with ICARDA's barley breeders, have also been important contributions. In addition, visits to Australia by ICARDA staff were seen as an important means of contact. Recent visits by Drs Ceccarelli, Grando and Yahyaoui, have been particularly valuable. The value of these collaborative arrangements is not quantified in this study, which concentrates only on estimating the economic impact of the genetic materials from ICARDA on the Australian barley industry.

4.6 Analysis of ICARDA's Impact on Australian Barley Production

4.6.1 Cost reduction in Australia attributable to ICARDA research

In measuring the impact of ICARDA on Australian barley, there are clearly regional differences in the usage of the materials from ICARDA. In the higher-rainfall production zones of NSW, where the emphasis is on malting barley production, the ICARDA material has been used only sparingly in the program, and there is likely to be no direct impact of the germplasm in the foreseeable future (B. Read, personal communication). The impact is likely to be similar in WA, where the soils are also acidic, and hence the materials drawn from ICARDA's mandate region with its mainly alkaline soils are not so directly relevant. As a

[4] Note that the WI lines in these crosses are Australian lines from the Waite Institute.

result, the impact in WA is also not likely to be important over the near term. Nevertheless, multiple resistance lines from the ICARDA/CIMMYT program are being used in the breeding programs in these areas, and are likely to have some impact eventually.

In SA and Victoria, the situation is different. The recent GRDC project on international collaboration between ICARDA and Australian breeders has generated materials that have been identified as being particularly useful for drought tolerance, for use in the drier, more marginal areas of SA. The areas of similarity between the CWANA region and Australia are the Upper North and Eyre Peninsula regions of SA and the Mallee areas of SA and Victoria. To a lesser extent, the sandy soils of WA and the drier areas of southern NSW also show some similarities with parts of the CWANA region. On that basis, it is expected that in the future there will be some further usage of materials from ICARDA in Australian varieties. The extent of the impact of that material is unknown at this stage, but we have made the following assumptions about the future impact:

(a) ICARDA materials will be used as parents for varieties for these regions;
(b) The first of those varieties will be released in 2012;
(c) Those varieties will be grown in the drier regions of SA and the mallee areas of SA and Victoria;
(d) The yield gain due to the contribution of the ICARDA lines will be 5% for feed barley and 2% for malting varieties.

From those assumptions, the implied benefits of the ICARDA materials for the barley program are as shown in Table 4.1. The yield gains are concentrated on the two regions SA-Victoria Mallee and SA Mid-North / Lower Yorke Peninsula, where the cost reduction is A$4.91 per tonne. There are expected to be no yield gains for the rest of Australia. The yield gains are equivalent to a weighted average cost reduction of A$2.41 per tonne across Australia.

4.6.2 Cost reduction in the Rest of the World attributable to ICARDA research

The extent to which ICARDA's research on barley has affected the costs of production in the rest of the world will determine the supply shift in those countries. In the analysis presented here, all impacts on the Rest of the World are aggregated for the analysis, since the emphasis is on the net impacts on Australia. Given that the impacts relevant to the analysis are those that are likely to occur over the next 10 years or so, precisely estimating the impact is very difficult. As a simplification, the expected impact for 2006 was used in the analysis as a proxy for the supply shift in the Rest of the World from the current level of technology.

In assessing the ICARDA impact, the ICARDA contribution to varieties has been estimated. ICARDA contribution is an estimate based on the pedigree of the varieties. In those assessments, 100% contribution means it is an ICARDA cross with only materials from ICARDA germplasm collection and lines. The contribution will be less than 100% if the cross contains non-ICARDA lines.

Table 4.1: Australian Cost Reductions for Barley from ICARDA Research

	SA-Vic. Mallee	SA Mid-N / Lower Yorke	Rest of Australia	Australia
% production of malting barley varieties	80%	80%	80%	80%
- % malting barley achieving malting	70%	70%	70%	70%
% barley production achieving malting quality	56%	56%	56%	56%
% barley production sold as feed	44%	44%	44%	44%
Total barley area ('000 ha)	690	541	1730	2961
Feed varieties' area ('000 ha)	138	108	346	592
Malting varieties' area ('000 ha)	552	433	1384	2369
Total barley production ('000 t)	1103	1267	3484	5853
Feed barley production ('000 t)	485	558	1533	2576
Malting barley production ('000 t)	618	710	1951	3278
Feed barley price (A$/t)	173	173	173	173
Malting barley price (A$/t)	210	210	210	210
Weighted average price (A$/t)	194	194	194	194
Impact of Yield Increases				
Yield increase from ICARDA: Malting (%)	2.0%	2.0%	0.0%	1.0%
Yield increase from ICARDA: Feed (%)	5.0%	5.0%	0.0%	2.5%
Yield increase from ICARDA: All barley (%)	2.6%	2.6%	0.0%	1.3%
Average yield with ICARDA (t/ha)	1.60	2.34	2.01	1.98
Average yield without ICARDA (t/ha)	1.64	2.40	2.01	1.00
Cost reduction				
Price/Total cost without ICARDA (A$/t)	193.72	193.72	193.72	193.72
Total cost per ha (A$)	309.62	453.41	390.18	382.97
Cost per tonne with ICARDA (A$/t)	188.81	188.81	193.72	191.65
- Cost reduction per tonne (A$/t)	4.91	4.91	0.00	2.07
- % supply shift	2.53%	2.53%	0.00%	1.07%

On the basis of expected impacts on yields, the contribution of ICARDA to those increases and the likely adoption of those improved varieties by 2006, an estimate has been made of the likely impact of ICARDA in the Rest of the World (Table 4.2). With a yield advantage of 2.8% from the varieties, an ICARDA contribution averaging 22% and adoption in 2006 estimated at 6.0%, the expected yield gain for the Rest of the World in 2006 is estimated at 0.8%. That is equivalent to a cost reduction of A$1.45 per tonne (or 0.75%) at recent world prices (see section 3.3).

Table 4.2: Impact of ICARDA on Barley in the Rest of the World

Impact of ICARDA		
Expected ICARDA yield impact in ROW by 2006	%	0.8
Estimation of cost reduction		
Estimated yield without ICARDA in 2006	t/ha	1.04
Estimated yield with ICARDA in 2006	t/ha	1.05
Price/Total cost without ICARDA	A$/t	193.72
New cost with ICARDA	A$/t	192.27
Cost reduction in ROW from improvement	***A$/t***	***1.45***
% supply shift	***%***	***0.75***

ROW: Rest of the World
Source: Estimates prepared by the authors from information supplied by ICARDA.

4.6.3 Welfare effects of ICARDA's barley research

In assessing the impact of ICARDA's spillover to Australia in barley research, the following data (based on the average of the five years to 2000) were used in the analysis:

a) The world market price for barley is A$193.72 per tonne;
b) The supply elasticity is 0.30, and the demand elasticity is -0.35 in each of the regions in Australia (Table 3.2);
c) The supply elasticity is 0.13, and the demand elasticity is -0.23 for the Rest of the World (Table 3.2);
d) World barley production is 141 million tonnes;
e) ICARDA research will have increased barley yields by 0.8% in the Rest of the World by 2006, equivalent to a cost reduction of A$1.45/t (Table 4.2);
f) The area sown to barley in Australia is 2.96 million hectares, yields are 1.98t/ha, so that total production is 5.85 million tonnes;
g) ICARDA research will have increased barley yields in the two regions by 2.6%, equivalent to a cost reduction of A$4.91/t, by 2006 (Table 4.1);
h) ICARDA research has no impact on yields in the other parts of Australia.

There are two direct research impacts. The first is a cost reduction in the Rest of the World of A$1.45/t. Second, there are spillover benefits in the form of a cost reduction of A$4.91/t for South Australia/Victoria Mallee, A$4.91/t for South Australia-Mid-North/Lower Yorke, but no cost reduction for the Rest of Australia (for a weighted average of A$2.44/t for Australia). While these cost reductions result in savings for producers, the resultant increased production leads to a fall in world price of A$0.55, or 0.28%. That leads to benefits for consumers of barley, while producers simultaneously achieve yield increases and face price falls. Their net position depends on the balance between the yield gains and the price fall.

Using the data in the analytical framework (section 3), the annual welfare changes at peak adoption are shown in Table 4.3. The cost reduction provides benefits to producers in each region in excess of the effects of the world price reduction. The net welfare gains for producers in Australia as a whole are approximately A$8.4 million per year. Australian consumers gain A$1.2 million per year from the lower prices, so that the overall result is a net gain for Australia of A$9.6 million per year. For producers in the Rest of the World, there is a welfare gain of A$121 million per year, with the yield increase offsetting the lower price. For the Rest of the World consumers, there are gains from lower prices of A$78 million per year. The Australian impacts are necessarily small compared to the overall global benefits from ICARDA.

Table 4.3: Annual Welfare Changes for Barley (at peak adoption)

	Producer surplus ***(A$m)***	**Consumer surplus** ***(A$m)***	***Total surplus*** ***(A$m)***
SA-Victoria Mallee	4.8	0.1	4.9
SA Mid-North/Lower Yorke	5.5	0.1	*5.6*
Rest of Australia	-1.9	1.0	*-0.9*
Australia	**8.4**	**1.2**	***9.6***
Rest of the World	**121.3**	**77.6**	***198.9***
World	**129.7**	**78.8**	***208.5***

These (Table 4.3) are the annual benefits that are expected at full adoption of the higher-yielding varieties. The flow of those benefits over time, and the total benefits likely to be received, depend on the rate of adoption by farmers of those varieties with ICARDA's germplasm. While the feed barley varieties incorporating the ICARDA material will be released in time for commercial production in 2004, malting barley varieties will not be available until 2012, since the material being developed will need to be incorporated into suitable Australian malting variety background before it can be used commercially.

The following adoption assumptions were made:

a) Adoption in the Rest of the World is measured from 2001 to the level estimated in 2006, increasing linearly in that time;
b) Adoption in Australia begins in 2004 with the release of improved feed barley varieties, but is not completed until 2016 because of the delay in the release and adoption of the improved malting barley varieties;
c) The yield increases estimated in the two regions relate to 100% of the area of barley in those regions;
d) Benefits are measured for both Australia and the Rest of the World until 2022.

On the basis of these assumptions, the future gross benefits of the cost reductions through ICARDA's germplasm are estimated from 2001 to 2022, as shown in Table 4.4. The annual discounted gross benefits for Australia (discounted at a real rate of 5% per annum) in 2001 values over the period 2001 to 2022 average A$2.4 million per year. Overwhelmingly, Australian barley producers capture those benefits, rather than consumers. In the Rest of the

World, the estimated annual benefits average A$109.4 million per year, shared between producers and consumers.

Table 4.4: Discounted Benefits for Barley

	Average Annual[a] Discounted Benefits *(A$m)*
Australia	
Producer surplus	1.8
Consumer surplus	0.6
Total surplus	*2.4*
Rest of the World	
Producer surplus	69.1
Consumer surplus	40.3
Total surplus	*109.4*
World Total	
Producer surplus	70.8
Consumer surplus	41.0
Total surplus	*111.8*

a Net Present Value of benefits over the period from 2001 to 2021, divided by 21.

4.6.4 Sensitivity of barley results to changes in parameter values

To examine the extent to which the chosen values for the parameters of the analysis for barley have an impact on the findings of the study, the sensitivity of the results (measured as the aggregate gains for Australia) was examined (Table 4.5). Selected parameters were varied by ±20% and the effect on the gains for Australia estimated. For elasticities, a test was made of considerably larger elasticities (a five-fold increase in magnitude) to represent longer-term elasticity estimates.

The indications are that the results of the analysis are sensitive to the average cost reduction in the Australian regions, the price used and the discount rate used. The higher the cost reduction or the price, the greater the benefits for Australia, while the greater the discount rate the lower the returns for Australia. However, within the range of values considered in this analysis, the overall outcome is not very sensitive to the yield increase in the Rest of the World or the elasticities of demand and supply (although the distribution of benefits between producers and consumers will be sensitive to these elasticities).

Table 4.5: Sensitivity of Barley Results to Changes in Parameters[a]

Parameter	Value	Average Gain for Australia (A$m per year)
Average cost reduction in Australian regions	**2.53%**	**2.39**
	2.02%	1.71
	3.04%	3.08
Average cost reduction in ROW by 2006	**0.75%**	**2.39**
	0.60%	2.59
	0.90%	2.18
Price (A$)	**A$194**	**2.39**
	A$155	1.91
	A$232	2.87
Elasticity of demand - ROW	**-0.23**	**2.39**
	-0.18	2.23
	-1.15	3.15
Elasticity of demand - Australia	**-0.35**	**2.39**
	-0.28	2.39
	-1.75	2.45
Elasticity of supply - ROW	**0.13**	**2.39**
	0.10	2.55
	0.65	1.32
Elasticity of supply - Australia	**0.30**	**2.39**
	0.24	2.40
	1.50	2.29
Discount rate	5**.0%**	**2.39**
	4.0%	2.75
	6.0%	2.09

a: Selected parameter values varied by -20% and +20% from values used in estimates, except elasticities varied by -20% and +500%.

5. Impact in Australia of ICARDA's Durum Wheat Research

5.1 Background

Durum wheat (*Triticum turgidum* L. var. *durum*) is a relatively small part of the world wheat industry, with approximately 5% of total wheat production being durum. World durum wheat production in recent years has been approximately 30 million tonnes, with the European Union, Canada and the United States accounting for nearly 60% of total production.

Durum wheat is one of the most important crops in the moderate rainfall areas of the CWANA region. That region produces about 13 million tonnes annually. Turkey, Syria, Morocco, Tunisia, Algeria and Iran account for 84% of that production. Durum wheat is produced predominantly under rain-fed conditions and it is generally grown under drier and more stressful conditions than bread wheat. Of the total annual area devoted to durum wheat in the developing countries, 80% is in West Asia and North Africa (ICARDA 1987).

Trade in durum wheat has averaged approximately 6 million tonnes in recent years. Canada and the USA are the main exporting countries, with Canada providing more than half of the world's durum wheat exports. Other exporters include Turkey, Mexico, Kazakstan and Syria. North African countries (particularly Morocco and Algeria) and Europe are the main importers, with Latin American countries (Venezuela, Chile and Peru) also significant. Australia has been a small exporter, but exports are currently growing very rapidly.

Durum wheat plays an important role in the diet of the people in the North Africa and the Middle East, particularly in the rural areas, where traditional dishes such as burghul, frike, couscous and other pasta products are made from grain of durum wheat. Wheat consumption is very high, ranging from 150 to 200 kg per person per year (ICARDA 1987).

In developed countries, durum wheat is mainly used for pasta, which requires a combination of very hard wheats and high protein levels. Durum wheat meeting the market specifications receives a higher price than bread wheat. In recent years, the premium for durum wheat has been increasing, providing incentive for increases in production and trade of durum wheat. In 2000-01, the price in Australia for the highest-quality durum wheat was approximately 30% above that for Australian Standard White wheat (AWB 2001).

5.2 ICARDA's Research on Durum Wheat

ICARDA's Durum Wheat Improvement Program is conducted in collaboration with the International Maize and Wheat Improvement Center (CIMMYT); a CIMMYT Durum Wheat Breeder is posted at ICARDA headquarters (ICARDA 2001). Dr Miloudi Nachit, Senior Durum Wheat Breeder, and his assistant are both members of CIMMYT's staff, but other positions in the joint program are provided by ICARDA.

The objective of durum wheat breeding undertaken at ICARDA is to assist CWANA countries to enhance durum wheat production by developing improved germplasm, improving crop management, upgrading manpower capabilities and developing efficient research methodologies (ICARDA 1988).

Durum wheat improvement at ICARDA has a strong emphasis on three elements. First, the landraces and wild relatives in the breeding program enable desirable traits for resistance to drought, cold, heat, disease, insects and viruses to be incorporated. Second, the program focuses on the development of breeding methodologies that are more efficient and better adapted to the environmental conditions of the Mediterranean dryland areas. Finally, the program fosters development of durum research networks in the Mediterranean region between Southern Europe, West Asia and North Africa (ICARDA 2001).

The jointness of the ICARDA/CIMMYT program makes the task of determining ICARDA's contribution, as separate from CIMMYT's, a very difficult one (see section 2.3). To make the task achievable, we have made the following simplifying assumptions:

- material obtained directly from ICARDA is designated as "ICARDA material"
- material obtained from Mexico through CIMMYT with no direct connection to ICARDA is not included in the analysis in this study.

These simplifications mean that the full extent of the impact of the joint ICARDA/CIMMYT durum wheat program on the Australian program is not identified, merely the direct impact of the materials obtained through ICARDA itself. The ICARDA/CIMMYT breeding activity in the Mediterranean region is the base for developing durum germplasm adapted to Mediterranean environments. The so-called "CIMMYT durum material" is screened in the Mediterranean environments before it is distributed worldwide. Therefore it is arguable that the analysis of the impact of ICARDA should include some element of the so-called "CIMMYT material". Nevertheless, in this study an arbitrary distinction has been made between materials obtained directly from CIMMYT and those obtained directly from ICARDA. These simplifications are not intended to imply that the benefits of the joint ICARDA/CIMMYT program are as limited as those estimated in this study. Some of the A$62 million per year increased productivity for all wheat gained by Australia from CIMMYT genetic materials in the early 1990s (Brennan and Fox 1995) will have included some degree of contribution from ICARDA. However, those benefits are not included in this study (see section 2.3).

5.3 Australian Durum Wheat Industry

The Australian durum wheat industry has undergone rapid expansion in recent years (see Appendix Table A.2). In the period since 1995, production has averaged approximately 400,000 tonnes, with production levels reaching over 900,000 tonnes in 1999. NSW has contributed to almost 80% of that production. Production of durum wheat has been concentrated mainly in northern NSW and Queensland. In recent years, durum wheat production has also developed in South Australia, especially in the central northern areas.

In the 1990s, the industry has made a transition from a purely domestic supplier to one servicing both the domestic and international markets. The quality of the Australian durum wheat meets the quality requirements in the world market. In recent years, approximately half of the total production has been exported. Both domestic and export sales are expected to continue to rise as the consumption of pasta increases. In addition, Australia has strong prospects for sales growth into East Asia in the form of grain, semolina and pasta (R. Hare, personal communication).

Production in 2001 is estimated at 650,000 tonnes, but the industry suggests that there is likely to be rapid growth in the coming years. Production has been predicted to increase to 1.2 million tonnes by 2006 (R. Hare, personal communication). Given the variability in the trends in recent years, it is difficult to be confident in the extent of the increases that can take place. Therefore, we have based our analysis on a more conservative assessment of trends in areas and yields. If the area sown were to increase as predicted, the figures from this study would understate the Australian production affected by the ICARDA contribution. The extent of that impact is shown in the sensitivity analysis presented for durum wheat (section 5.7.4 below).

5.4 Australian Durum Wheat Improvement Program

The National Durum Wheat Improvement Program is based at the Tamworth Centre for Crop Improvement, Tamworth, and is managed by Dr Ray Hare of NSW Agriculture. The program aims to develop durum wheat germplasm and varieties for Australian conditions.

The durum wheat-breeding program at Tamworth has been releasing improved durum wheat varieties since the 1980s. The varieties released include Yallaroi (released in 1987), Kamilaroi (1982), Wollaroi (1993), Tamaroi (1998), and Gundaroi (1999). Tamaroi and Gundaroi were developed for South Australia, where they have specific adaptational advantages. The other varieties were developed mainly for production in northern NSW and Queensland.

As the cultivation of durum wheat has expanded into a wider range of growing environments across Australia (from Central Queensland, Southern Queensland and New South Wales to South Australia and Western Australia), the number of production problems has escalated (*ie*, diseases, pests, nutrition and quality). The National Durum Wheat Improvement Program has an ongoing focus on the amelioration of these production problems. Access to key germplasm resources and prospective overseas screening technologies/services is important for finding a rapid and effective solution to these difficulties.

In the durum wheat program, Dr Hare introduces and tests germplasm from durum wheat programs around the world, particularly from ICARDA. Imported materials are tested for disease resistance, particularly to crown rot, leaf rust and fusarium head blight. Under the collaborative arrangements, ICARDA carries out tests on those materials for exotic pests such as Russian wheat aphid, hessian fly, sawfly and leaf beetle in Morocco, Syria and Lebanon. Some other accessions have been sourced from ICARDA via Morocco, because of their level of crown rot resistance. Dr Graham Wildermuth in Queensland provides pathology support to the National Durum Wheat Breeding Program. The collaboration between the Australian breeding program and ICARDA is especially important in relation to molecular markers. ICARDA's work on developing molecular markers and evaluating lines using the markers is valuable to Dr Hare in his breeding program.

5.5 Use of ICARDA Durum Wheat Material in Australia

The Australian Durum Wheat Improvement Program has a close bilateral relationship with the ICARDA/CIMMYT durum wheat program based in Syria. This collaboration has been enhanced by the GRDC-funded project DAN323, "National durum wheat improvement program", which provides funds for international collaboration with the ICARDA/CIMMYT program. The funds provided for this collaboration facilitate visits by the respective breeders to the other programs in alternate years, and provide other operating funds for the ICARDA/CIMMYT program. As a result, there is close collaboration between the programs, with regular cooperation and sharing of materials.

Dr Ray Hare uses lines obtained from ICARDA in his crosses. As this collaboration is a mutual exchange of interests, Dr Nachit also uses Australian materials in ICARDA crosses. In 1998, 24 of the over one thousand crosses made at ICARDA were made using Australian materials. In 2001, approximately 30% of crosses in the breeding program involved Australian materials as parents, due largely to their desirable quality characteristics. This represents a significant increase in ICARDA's interest in Australian lines.

At ICARDA, all of the ICARDA/CIMMYT material and the Australian lines are screened in various field and greenhouse assessments for a wide range of traits, including exotic pests and diseases (notably durum leaf rust), together with molecular probing at ICARDA. Some screening also takes place in other collaborating countries. The Australian breeding program then has access to those materials. According to Dr Hare, the full economic impact of this investment is not likely to be experienced in Australia until the next 5-10 years.

Germplasm has been imported to Australia from ICARDA since the 1980s (see Table 2.1 for details). The germplasm flow was most significant in 1989, when 222 lines were imported. During the early 1990s there was a much smaller flow of germplasm into the country. In more recent years, there has again been a regular inflow of lines, averaging nearly 100 lines per year from ICARDA. The lines imported into the Australian durum wheat breeding program range from early-generation breeding lines (F_3 to F_5 stage) to more advanced later-stage lines.

As part of the regular consultation and collaboration between Dr Hare and ICARDA, regular use is being made in the Australian breeding program of lines developed in the ICARDA/CIMMYT program. Imported lines are not released directly in Australia as finished varieties, because they need to be further adapted to Australian environments and Australian quality specifications. Therefore, all introductions are assessed in WANA and Australia for applicability as parents. That assessment considers whether they are sources of useful genes without introducing other less desirable genes.

5.6 Other Non-genetic Impacts

In addition to the direct germplasm exchange and screening of advanced lines, there are many other activities involved in the collaboration between ICARDA and the Australian Durum Wheat Improvement Program. These activities include:

- international testing of breeding lines
- exchange of data on quality, disease resistance, abiotic stress adaptation, molecular marker testing and agronomic characteristics (such as maturity, stature/lodging resistance and harvest index)
- screening and selection for resistance to exotic pests such as Russian Wheat Aphid and hessian fly, which are not yet present in Australia
- access to molecular markers
- exchange of ideas
- contact with international durum wheat researchers especially in the Mediterranean Basin
- funding of training at ICARDA (eg, for PhD student in durum wheat molecular markers)

The ability to employ molecular markers at ICARDA to assess the presence of particular genes in the early stage of the program provides the Australian program with access to important information. Naturally, it is difficult to quantify the benefit of such information in advance.

The benefits of these activities are not able to be quantified in this study, and we make no attempt to measure them. As a result, the estimated impact of this collaborative effort, which is based on the value of the genetic improvements resulting from the direct input of germplasm into the Australian program, will understate the true value of the collaboration.

5.7 Analysis of ICARDA's Impact on Australian Durum Wheat roduction

5.7.1 Cost reduction in Australia attributable to ICARDA research

There has been no direct contribution to the Australian durum wheat industry as a result of ICARDA's research into this mandate crop, since no germplasm obtained from ICARDA has been used in the commercially available varieties to date. However, material either developed from or incorporating ICARDA/CIMMYT background is currently being used in the Australian breeding program. It is therefore likely that there will be a measurable impact in the future. There is no unambiguous means of assessing the impact of yield advantages due to the use of the material obtained from ICARDA.

One means of estimating the future impact of germplasm obtained from ICARDA on yield improvement in Australia is through estimating the proportion of ICARDA's contribution to the germplasm used in the current breeding program. From the analysis used in Table 5.1, the weighted average contribution of ICARDA to the germplasm used in the Australian durum breeding program's crosses made in the period 1997-2000 was 7% (Table 5.2).

Table 5.1: Calculation of Contribution of ICARDA to Germplasm Used in Australian Durum Wheat Breeding Program, 1997-2000

		Number of crosses			
Cross	**Weight**	**1997**	**1998**	**1999**	**2000**
ICARDA line x ICARDA line	1.00	0	0	0	0
ICARDA line x ICARDA background[a]	0.75	0	0	0	0
ICARDA line x Other[a]	0.50	37	0	7	0
ICARDA background[a] x ICARDAbackground[a]	0.50	0	0	0	0
ICARDA background[a] x Other	0.25	0	0	10	3
Other[a] x Other[a]	0.00	73	93	68	57
- Total		**110**	**93**	**85**	**60**
Weighted average ICARDA contribution[b] (%)		***17%***	***0%***	***7%***	***1%***

a "ICARDA background" means lines whose parents are ICARDA lines. "Other" means material that is not from ICARDA.

b Number of crosses in each category weighted by ICARDA contribution, expressed as a percentage of total number of crosses

Table 5.2: Use of ICARDA/CIMMYT Durum Wheat Material in Australian Crosses

	1997	1998	1999	2000	Mean
At least one ICARDA/CIMMYT line	34%	0%	8%	0%	13%
At least 1 line with ICARDA/CIMMYT background	0%	0%	12%	5%	4%
No ICARDA/ICARDA material	66%	100%	80%	95%	84%
Weighted average of ICARDA contribution	17%	0%	7%	1%	**7%**

Future progress in the Australian durum wheat program was then estimated, on the basis of expected yield increases of 1% per year, or a cumulative 10.5% over the next ten years. Given the 7% contribution of the ICARDA/CIMMYT germplasm, the estimated yield gain due to ICARDA was 0.73% (7% of 10.5%) for Australia over the next ten years. The 0.73% yield increase due to ICARDA/CIMMYT is equivalent to a cost reduction of A$2.04 per tonne (Table 5.3).

Table 5.3: Estimating ICARDA's Contribution to Durum Wheat Improvement in Australia

	Australia
Base data[a]:	
Average durum wheat area (000 ha)	256
Average yields (t/ha)	2.04
Average production (000 t)	522
Yield Impact:	
Yield increase over 10 years (%)	10.5
Proportion of contribution by ICARDA	7%
Overall yield impact (%)	0.73
New yield (t/ha)	2.05
Cost reduction[b]:	
Price/Total cost (A$/t)	280.00
Gross income/Total cost per ha (A$/ha)	569.91
New cost per tonne (A$/t)	277.96
Cost reduction from improvement (A$/t)	2.04
% supply shift	0.73%

a: Average of five years to 2001-2002
b: Values are in 2001 Australian dollars

5.7.2 Cost reduction in the Rest of the World attributable to research at ICARDA

Research on durum wheat at ICARDA has also affected the costs of production in the rest of the world. In the analysis presented here, all impacts on supply shifts in the "Rest of the World" are aggregated for the analysis, since the emphasis is on the net impacts on Australia. Given that the impacts relevant to the analysis are those that are likely to occur over the next 10 years or so, estimating the impact is very difficult without simplifying the assumptions. The expected impact for 2006 was estimated as a proxy for the supply shift in the Rest of the World.

On the basis of expected impacts on yields, the contribution of ICARDA to those increases and the likely adoption of those improved varieties by 2006, an estimate has been made of the likely impact of ICARDA in the Rest of the World (Table 5.4). With a yield advantage of 6% from the varieties, an ICARDA contribution averaging 36% and adoption in 2006 estimated at 36%, the weighted expected yield gain for the Rest of the World in 2006 is estimated at 3.9%. That translates to a cost reduction of A$10.47 per tonne (or 3.74%) at recent world prices (see section 3.5).

Table 5.4: Rest of the World Yield Impact and Cost Reduction for Durum Wheat

Impact of ICARDA		
Expected ICARDA yield impact in ROW by 2006	%	3.9
Estimation of cost reduction		
Estimated yield without ICARDA in 2006	t/ha	1.91
Estimated yield with ICARDA in 2006	t/ha	1.98
Price/Total cost without ICARDA	A$/t	280.00
New cost with ICARDA	A$/t	269.53
Cost reduction in ROW from improvement	***A$/t***	***10.47***

ROW: Rest of the World
Source: Estimates prepared by the authors from information supplied by ICARDA.

5.7.3 Welfare effects of durum wheat research at ICARDA

In assessing the impact of spillovers to Australia in durum wheat research, the following data (based on the average of the five years to 2000) were used in the analysis:

a) The world market price for durum wheat is A$280/t;
b) The supply elasticity is 0.25, and the demand elasticity is –0.20 for Australia (Table 3.2);
c) The supply elasticity is 0.30, and the demand elasticity is –0.20 for the Rest of the World (Table 3.2);
d) Total world production of durum wheat is 30.0 million tonnes;
e) ICARDA research will have increased durum wheat yields by 3.9% in the Rest of the World by 2006, equivalent to a cost reduction of A$10.47/t (Table 5.4);
f) Australian durum wheat area is 256,000 hectares and yields are 2.04t/ha, so that production is 522,000 tonnes;

g) Research at ICARDA will have increased Australian durum wheat yields equivalent to a cost reduction of A$2.04/t (or 0.73%), by 2006 (Table 5.3).

The direct research impacts are a cost reduction in the Rest of the World of A$10.47/t, and spillover benefits in the form of a cost reduction of A$2.04/t for Australia. While these cost reductions result in savings for producers, the resultant increased production leads to a fall in price of A$6.20, or 2.21%. That leads to benefits for consumers of durum wheat, while producers simultaneously achieve yield increases and face price falls. Their net position depends on the balance between the yield gains and the price fall.

Using the data in the analytical framework (section 3), the annual welfare changes at peak adoption are shown in Table 5.5. The cost reduction provides benefits to Australian producers, but those benefits are more than outweighed by the negative effects of the research-induced world price reduction. The net welfare losses for producers in Australia as a whole are a loss of approximately A$2.2 million per year. Australian consumers gain A$0.6 million per year from the lower prices, so that the overall result is a net loss for Australia of A$1.5 million per year. The Rest of the World producers receive a welfare gain of A$126.5 million per year, with the yield increase offsetting the lower price. For the Rest of the World consumers, there are gains from lower prices of A$186.3 million per year. The Australian impacts are very small compared to the overall global benefits from research at ICARDA.

Table 5.5: Annual Welfare Changes for Durum Wheat (at peak adoption)

	Producer surplus *(A$m)*	**Consumer surplus** *(A$m)*	***Total surplus*** *(A$m)*
Australia	-2.2	0.6	*-1.5*
Rest of the World	126.5	186.3	*312.8*
World	124.3	187.0	*311.3*

These (Table 5.5) are the annual benefits that are expected at full adoption of the higher-yielding varieties. The flow of those benefits over time, and the total benefits likely to be received, depend on the rate of adoption by farmers of those varieties with germplasm from the ICARDA/CIMMYT program. The following adoption assumptions were made:

a) Adoption in the Rest of the World increases linearly from its level in 2002 to its estimated level in 2006;
b) The yield increases estimated for Australia relate to 100% of the area of durum wheat;
c) Varieties take ten years to reach peak adoption for Australia (beginning in 2002 and increasing linearly), because the material is at all stages of the breeding program and it will take several years for the varieties from the ICARDA/CIMMYT material to be released for commercial production;
d) Benefits are measured for both Australia and the Rest of the World until 2022.

On the basis of these assumptions, the future gross benefits of the cost reduction from the ICARDA/CIMMYT germplasm are estimated from 2001 to 2022, as shown in Table 5.6. The discounted gross benefits for Australia (discounted at a real rate of 5% per annum) in 2001 values, are estimated to average -A$0.9 million per year. In the Rest of the World, the estimated annual benefits average A$157.7 million per year.

Table 5.6: Discounted Benefits for Durum Wheat

	Average Annual[a] Discounted Benefits *(A$m)*
Australia	
Producer Surplus (A$m)	**-1.2**
Consumer surplus (A$m)	**0.3**
Total surplus (A$m)	***-0.9***
Rest of the World	
Producer Surplus (A$m)	**63.8**
Consumer surplus (A$m)	**93.9**
Total surplus (A$m)	***157.7***
World Total	
Producer Surplus (A$m)	**62.6**
Consumer surplus (A$m)	**94.2**
Total surplus (A$m)	***156.8***

a Net Present Value of benefits over the period from 2001 to 2021, divided by 21.

5.7.4 Sensitivity of durum wheat results to changes in parameter values

To examine the extent to which the chosen values for the parameters of the analysis for durum wheat have an impact on the findings of the study, the sensitivity of the results (measured as the aggregate gains for Australia) was examined (Table 5.7). Each selected parameter was varied by ±20% and the effect on the gains for Australia estimated. For elasticities, a test was made of considerably larger elasticities (a five-fold increase in magnitude) to represent longer-term elasticity estimates.

In addition, as discussed in section 5.3, the future levels of production are uncertain. The impact of different possible levels of production was examined by testing the Australian domestic production as 800,000 tonnes and 1.2 million tonnes as well as the base production of 522,000 tonnes.

Table 5.7: Sensitivity of Durum Wheat Results to Changes in Parameters[a]

Parameter	**Value**	**Aggregate Gain for Australia (A$m)**
Cost reduction in Australia by 2006	**0.73%**	**-0.88**
	0.58%	-0.96
	0.88%	-0.79
Cost reduction in ROW by 2006	**3.74%**	**-0.88**
	2.99%	-0.61
	4.49%	-1.14
Australian production (‘000 tonnes)	**522**	**-0.88**
	800	-1.49
	1200	-2.36
Price (A$)	**A$280**	**-0.88**
	A$224	-0.70
	A$336	-1.05
Elasticity of demand - ROW	**-0.20**	**-0.88**
	-0.16	-0.99
	-1.00	-0.07
Elasticity of demand - Australia	**-0.20**	**-0.88**
	-0.16	-0.88
	-1.00	-0.87
Elasticity of supply - ROW	**0.30**	**-0.88**
	0.24	-0.75
	1.50	-1.51
Elasticity of supply - Australia	**0.25**	**-0.88**
	0.20	-0.88
	1.50	-0.83
Discount rate	**5.0%**	**-0.88**
	4.0%	-0.97
	6.0%	-0.80

a: Selected parameter values varied by -20% and +20% from values used in estimates, except elasticities varied by -20% and +500% and production varied from 522,000 to 800,000 and 1,200,000 tonnes.

Across the range chosen for the possible values of the main parameters, none change the overall result that Australia suffers a net loss of welfare from the impact of ICARDA’s work on durum wheat. The estimated aggregate impacts for Australia for durum wheat are sensitive to the durum wheat price used. In addition, because the yield changes in the Rest of the World impact on the price, the impacts for Australia are also very sensitive to the values for those parameters. The cost reduction in the Rest of the World would have to be as low as 1.00% (rather than 3.74%) to give Australia a net gain in welfare.

Australian welfare impacts for durum are insensitive to a variation in the elasticity of demand and supply in Australia, though similar changes in the elasticity of demand and supply for the Rest of the World lead to changes in the aggregate Australian welfare. The results are also inversely sensitive to the discount rate used.

The level of Australian production is also important in determining the level of the economic impact in Australia, with higher production leading to greater welfare losses. While durum production in Australia is profitable and is tending to increase, this analysis shows that ICARDA’s research has reduced the returns to the Australian industry below what it would have been without ICARDA’s influence on world durum production. Given that those effects are transmitted to Australia through a lower world price for durum wheat, the larger the production in Australia, the greater the welfare reductions in Australia.

6. Impact in Australia of ICARDA's Chickpea Research

6.1 Background

Chickpea (*Cicer arietinum* L.) is the second most important pulse crop in the world. Chickpeas are grown in at least 33 countries in South Asia, the West Asia North Africa region, East Africa, Southern Europe, South America and Australia. India is the main producing country. In 2000, approximately 10 million hectares of chickpea were cultivated, with total world production of 8 million tonnes (FAO 2001). CWANA accounted for about 23% of the total world chickpea area and about 20% of the production in 2000 (FAO 2001). Only about 5% of total production is traded internationally each year.

There are two types of chickpea: desi, with small, dark brown seed, and kabuli, with larger beige-coloured seed. The desi type is primarily grown in South Asia, particularly India. The kabuli type predominates in the CWANA region.

Desi is mainly used for human consumption, but in some countries is also used as stockfeed. Kabuli is mainly used for human consumption, and commands a higher price in world markets. In developing countries, there is only very limited use of chickpea for livestock feeding (mainly screenings from milling, weather-damaged grain and crop residues for stock).

6.2 ICARDA's Research on Chickpea

With the establishment of ICARDA in 1977, a joint research program was started with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to enhance the productivity and yield stability of chickpea in the CWANA region. The crop is traditionally spring sown, and encounters heat and drought stresses towards maturity, which result in low and variable yields. Work under this program soon established that winter sowing could yield almost double that of spring sowing (Saxena 1984), though the winter-sown crop is prone to damage by ascochyta blight and cold, both of which can be avoided by spring sowing (Hawtin and Singh 1984).

A program to tackle the two main constraints to chickpea production; cold and ascochyta blight, was then launched. To identify a dependable resistance source, an effort was made to screen the world germplasm collection against known races of ascochyta blight. Resistant and moderately resistant kabuli and desi types were identified. Selection for cold tolerance was also undertaken to reduce the disadvantage of winter-sown over spring-sown chickpea in the abnormally cold years. A breeding program to combine ascochyta blight resistance and cold tolerance was established.

The chickpea program at ICARDA has carried out international yield trials since 1979, where different chickpea lines were tested in different countries in the Mediterranean region, in collaboration with NARS. On-farm trials were also conducted with different national programs.

Given the predominance of kabuli chickpeas in the CWANA region, ICARDA has concentrated on kabuli types, while ICRISAT has focused on desi chickpeas. The program established collaboration with the national research programs of those developing countries where kabuli chickpea is an economically important crop. As well, collaborative research projects were established with other CGIAR centres and with numerous advanced institutions in Australia, Germany, Italy, Spain and USA.

As a result of the ICARDA/ICRISAT program, 84 kabuli chickpea varieties have been released in 23 countries by 2001, with the ICARDA contribution estimated at approximately 80% of the genetic content of those varieties. The varieties released exhibit both the high levels of resistance to ascochyta blight and cold tolerance.

6.3 Australian Chickpea Industry

Chickpea production in Australia in recent years has averaged around 200,000 tonnes, from an area of over 210,000 ha. Although commercial yields of up to 3.5 tonnes per hectare have been achieved, Australian chickpea yields have averaged 0.89 t/ha over the past five years, considerably lower than in the previous five years.

Australia has exported most of its chickpea production, with exports estimated at 155,000 tonnes in 2001-02 (compared to estimated production of 175,000 tonnes), with an estimated value of A$88 million for this period (ABARE 2001). Domestic consumption of chickpeas is confined to specialty food uses and stockfeed.

After rapid expansion in the 1980s, the industry momentum was threatened by ascochyta blight (*Ascochyta rabiei*). This foliar disease, introduced into Australia in the 1970s, first caused significant yield losses in 1997. Its effects were most dramatic in Victoria and South Australia, where production declined by 90%. Victoria was the leading producer up until the mid-1990s, with production peaking at 170,000 tonnes in 1995-96. Production for the year 2000-01 was only 7,000 tonnes, due to a cutback in the area sown to chickpeas. After substantial yield losses in South Australia, the area sown was also cut back drastically, with production falling from 20,000 tonnes in 1996-97 to 2,000 tonnes in 2000-01 (Appendix Table A3). Ascochyta blight became widespread throughout northern NSW, southern Queensland and Western Australia, but for the short term at least, losses have been contained by the use of prophylactic fungicide sprays.

Desi chickpeas currently account for nearly all chickpeas grown in Australia. It is anticipated that the dominance of desi types will continue, but for some regions, particularly in the southern areas, there is likely to be a significant shift to the higher value kabuli types as production risks, particularly those attributable to disease, diminish (E.J. Knights, personal communication).

Production of kabuli chickpeas for 2001-02 is estimated at 22,000 tonnes for Australia, with the largest producing state for this period being Victoria (Table 6.1). Average yields are estimated to be 1.42 tonnes per hectare. In 2001-02, kabuli represents only 13% of the total chickpea production in Australia.

However, the industry suggests that there is likely to be rapid growth in the coming years with the release of new varieties with ascochyta blight resistance. Production has been predicted to increase to 100,000 tonnes by 2006 (C. Francis, personal communication). Given the variability in the trends in recent years, it is difficult to be confident in the extent of the increases that can take place. Therefore, we have based our analysis on a more conservative assessment of trends in areas and yields at current 2001-02 levels. If the area sown increases as predicted, the figures from this study would understate the Australian production affected by the ICARDA contribution. The extent of that impact is shown in the sensitivity analysis presented for kabuli chickpeas (section 6.6.4 below).

Table 6.1: Area, Yield and Production of Kabuli Chickpeas, 2001-02

Year	NSW	Vic.	Qld	WA	SA	Australia
Area Sown (000 ha)	1.0	12.0	1.0	1.0	0.5	**15.5**
Yield (t/ha)	1.00	1.50	1.00	1.50	1.00	**1.42**
Production (000 t)	1.0	18.0	1.0	1.5	0.5	**22.0**

Source: Pulse Australia (2001)

6.4 Australian Chickpea Improvement Program

Chickpea research in Australia began in earnest in the early 1970s. In 1974, a full-time chickpea breeder was appointed at the Agricultural Research Institute, Wagga Wagga, New South Wales. Subsequently, research and evaluation programs were begun in other states, although not until the late 1980s in Western Australia.

The research is now spread throughout Australia. The National Coordinated Chickpea Improvement Program is based at Tamworth, New South Wales, with Mr E. J. Knights as its coordinator. There are active breeding programs in both Victoria (Horsham) and Western Australia (Perth). There is at least one other full-time breeder and a number of part-time breeders.

Australia with its relatively new and growing industry, has had irregular demand for the ICARDA chickpea nurseries. Characteristics that are important to Australia are: (a) ascochyta blight resistance; (b) large seed size; (c) tall lodging-resistant lines; (d) increased yields; and (e) other disease resistance (particularly fusarium wilt and botrytis grey mould).

All varieties released since 1989 (Table 6.2) have been desi types, apart from Bumper, which is a kabuli variety. None of the varieties released have incorporated ICARDA germplasm. Although some of the varieties may have been represented in the ICARDA collection, they were obtained from another source pre-dating ICARDA's inception.

Table 6.2: List of Chickpea Varieties Released in Australia

Variety	Origin	Year	State of release
Desi Types			
Tyson	India	1978	Queensland
Amethyst	Aust.	1988	NSW
Dooen	USSR	1988	Victoria
Semsen	Aust.	1989	Queensland
Barwon	Aust.	1991	NSW/Qld
Norwin	Aust.	1992	Queensland
Desavic	India	1993	SA/Victoria
Lasseter	Iran	1996	Victoria
Sona	ICRISAT	1997	WA
Heera	ICRISAT	1997	WA
Gully	Iran	1997	NSW
Jimbour	Australia	2000	Queensland
Howzat	Australia	2001	NSW
Kabuli Types			
Opal	USSR	1980	NSW
Macareena	Mexico	1984	WA
Garnet	Turkey	1989	NSW
Kaniva	Spain	1989	Victoria
Narayen	USSR	1989	Queensland
Bumper	Australia	1997	NSW

Source: E.J. Knights, personal communication.

6.5 Use of ICARDA Chickpea Material in Australia

ICARDA has been a continuing important source of supply of germplasm for the Australian Coordinated Chickpea Improvement Program. In the past five years, on average 420 lines have been brought into Australia from ICARDA each year (see section 2.2 above). This trend has been relatively consistent since the late 1980s. A considerable amount of germplasm was sourced from ICARDA in 1998, when a total of 618 such lines entered the breeding program. The Australian chickpea breeding program has consistently imported large numbers of lines from ICARDA (Table 2.1).

In recent years, ICARDA material has been widely used in the Australian chickpea crosses carried out by the National Chickpea Breeding Program. For the crosses made for desi types in 1999, the vast majority involved no ICARDA-related parents, and none involved lines obtained directly from ICARDA (E.J. Knights, personal communication). On the other hand, 58 of the 60 kabuli crosses made in 1999 involved ICARDA-related parents. In 2000, more substantial use was made of ICARDA material as desi parent lines, but the majority of desi crosses still involved no ICARDA-related parent. For kabuli, 47 of the 48 crosses involved

ICARDA-related material in 2000. In the two years, over 27% of desi crosses and almost 97% of kabuli crosses involved at least one parent that had ICARDA material in its pedigree.

The main ICARDA lines involved in that material were for resistance to ascochyta blight; large seed size (FLIP 94-508C, FLIP 94-092C, FLIP 94-090C); increased plant height; and high yield potential. ICARDA kabuli chickpea breeding lines FLIP97-515; FLIP97-518; FLIP97-528; FLIP97-689; FLIP97-573; and FLIP97-642 have been used to transfer ascochyta blight resistance into Australian cultivars. Four ascochyta blight resistant Kabuli lines from ICARDA will be commercialised by Agriculture Victoria in 2002 (FLIP94-090C, FLIP94-092C, S95342 and S95362). These cultivars are expected to reduce fungicide costs and improve the reliability of growing kabuli chickpeas in south-eastern Australia (M. Materne, personal communication).

ICARDA has the largest ascochyta blight resistance-screening program for chickpeas in the world. Under a GRDC funded project, about 2,500 chickpea lines developed through hybridisation at ICARDA were screened in Turkey for ascochyta blight resistance. A total of 280 lines with resistance and good seed quality were selected for Australia. These lines are now being evaluated in Western Australia, South Australia, Victoria, and New South Wales. The Australian National Chickpea Program is making use of these superior ascochyta blight resistant lines in crossing programs. Another cycle of this process is continuing.

6.6 Analysis of ICARDA's Impact on Australian Chickpea Production

6.6.1 Cost reduction in Australia attributable to ICARDA research

In assessing the impact of ICARDA on Australian chickpea production, there has been no direct contribution to current production, since no ICARDA germplasm has been used commercially in Australia to date. However, material either developed from or incorporating ICARDA background is prevalent throughout the breeding materials currently in use in Australia. Therefore it is likely that there will be a measurable impact in the near future. Unfortunately, there is no simple, unambiguous means by which the future yield impact of the ICARDA material on Australia can be measured.

In this analysis, we consider that the major impact of ICARDA material will be in conferring valuable resistance to ascochyta blight in the future. In calculating the value of ascochyta blight resistance to the Australian chickpea industry, data were gathered from a number of sources. Data on the area and average yields of kabuli chickpeas were obtained from Pulse Australia (Table 6.1). Data on the percentage crop losses in the presence of the disease, the percentage of crop area prone to the disease, and the percentage of years favoured by the disease in each of three broad regions across Australia were obtained from Murray and Brennan (2001). The proportion of the losses controllable by the ICARDA resistance is estimated at 50% of the losses without resistance. The average price for kabuli chickpeas over the past 5 years (based on Pulse Australia 2001) was A$700 per tonne.

From these data, the expected value of the resistance obtained from ICARDA could be estimated (Table 6.3), on the basis of the GRDC's three production regions (North, South and West). For example, in the Northern Region, the loss expected in a year when ascochyta blight is present is 80%, and the area of kabuli chickpeas in this region that is suited to the disease is 89%. It is estimated that 78% of years favour this disease, or in other words, disease attributable to ascochyta blight may be expected approximately three in every four years. The expected loss without ascochyta blight resistance is then a product of these three assumptions. Hence, 55% losses are expected where the disease is not controlled.

Table 6.3: Estimation of the Value of Ascochyta Blight Resistance in Kabuli Chickpea

	North	South	West	Total
Kabuli area (000 ha)	2.00	12.50	1.00	15.50
% loss when present	80	80	80	80
% of region's crop prone to disease	89	100	67	96
% of years favoured by disease	78	100	67	95
= Expected loss without controls	55	80	36	74
% of losses controllable by resistance	50	50	50	50
= % annual value of ICARDA resistance	28	40	18	37
Average yield without ICARDA (t/ha)	1.00	1.48	1.50	1.42
Average yield with ICARDA (t/ha)	1.28	2.07	1.77	1.95
Price/Total cost (A$/t)	700	700	700	700
Total cost without ICARDA (A$/t)	700	1036	1050	994
Cost per tonne with ICARDA (A$/t)	548	500	594	511
Cost reduction per tonne (A$/t)	152	200	106	189
% shift in supply curve	21.7%	28.6%	15.1%	27.0%

Given the assumption that 50% of those losses may be controlled by resistance for ascochyta blight, the expected percentage annual value of this resistance is 28% (50% of 55%) for the North. In the other regions, the expected annual value of the resistance ranges from 18% in the West to 40% in the South, depending on the extent to which ascochyta blight is suited to those production areas. Across Australia, the average expected annual value of resistance is 37%. On the basis of a price of A$700 per tonne, that value translates to a benefit of A$152 per tonne from the resistance in the North at recent average yields. The equivalent cost reduction per tonne for the other regions ranges from A$106/t in the West to A$200/t in the South, which is particularly prone to the disease. At the national level, the value of resistance is equivalent to a cost reduction of A$189 per tonne.

It is likely that in the future the resistance to ascochyta blight in kabuli chickpeas can be transferred to desi chickpeas. However, given the extra research required, it is not possible to determine the extent of the value of that resistance, or of the likely time lags involved, so it has not been included in this study.

6.6.2 Cost reduction in the Rest of the World attributable to ICARDA research

ICARDA's research on kabuli chickpeas has also affected the costs of production in the rest of the world. In the analysis presented here, all impacts on supply shifts in the "Rest of the World" are aggregated for the analysis, since the emphasis is on the net impacts on Australia. Given that the impacts relevant to the analysis are those that are likely to occur over the next

10 years or so, estimating the impact is very difficult. As a simplification, the expected impact for 2006 was estimated as a proxy for the supply shift in the Rest of the World.

On the basis of expected impacts on yields, the contribution of ICARDA materials to those increases and the likely adoption of those improved varieties by 2006, an estimate has been made of the likely impact of ICARDA in the Rest of the World (Table 6.4). The expected yield gain for it is estimated at 9.6%[5], which translates to a cost reduction of A$61.05 per tonne (or 8.7%) at recent world prices. This is lower than the cost reduction on average for the Australian growers (see above) of A$189 per tonne.

Table 6.4: Impact of ICARDA on Kabuli Chickpea in the Rest of the World

Impact of ICARDA		
Expected ICARDA yield impact in ROW by 2006	%	9.6
Estimation of cost reduction		
Estimated yield without ICARDA in 2006	t/ha	1.19
Estimated yield with ICARDA in 2006	t/ha	1.31
Price/Total cost without ICARDA	A$/t	700.00
New cost with ICARDA	A$/t	638.95
Cost reduction in ROW from improvement	A$/t	61.05

ROW: Rest of the World
Source: Estimates prepared by the authors from information supplied by ICARDA.

6.6.3 Welfare effects of ICARDA kabuli chickpea research

In assessing the impact of ICARDA spillovers to Australia in kabuli chickpea research, the following data (based on the average of the five years to 2000) were used in the analysis:

a) The world price for kabuli chickpeas is A$700/t;
b) The supply elasticity is 1.70 and the demand elasticity is -0.79 in each of the regions in Australia;
c) The supply elasticity is 0.52 and the demand elasticity is -0.75 for the Rest of World;
d) World kabuli chickpea production is 1.52 million tonnes;
e) ICARDA research will have increased kabuli chickpea yields by 9.6% in the Rest of the World by 2006, equivalent to a cost reduction of A$61.05/t (Table 6.4);
f) In Australia[6], the area sown to kabuli chickpea is 15,500 ha, yields are 1.42t/ha, and total production is 22,000 tonnes;
g) ICARDA research will have increased Australian kabuli chickpea yields by 37.0%, equivalent to a cost reduction of A$189/t, by 2006 (Table 6.3).

[5] This estimate is based on ICARDA's projection of adoption of ICARDA's varieties increasing from 20% in 2001 to 35% in 2006. This figure also assumes that the benefits of new varieties, in terms of ascochyta blight resistance and cold tolerance, will remain intact until 2021.
[6] The Australian data are based on an average of the past two years, rather than the five years to 2000, because of the recent rapid growth in area.

The direct research impacts are a cost reduction in the Rest of the World of A$61.05/t, and spillover benefits in the form of a cost reduction of A$152/t for the North, A$200/t for the South, and A$106/t for the West (equivalent to A$189/t for Australia). While these cost reductions result in savings for producers, the resultant increased production leads to a fall in price of A$27.90, or 4.0%. That leads to benefits for consumers of kabuli chickpeas, while producers simultaneously achieve yield increases and face price falls. Their net position depends on the balance between the yield gains and the price fall.

Using the data in the analytical framework (section 3), the annual welfare changes at peak adoption are shown in Table 6.5. The cost reduction provides benefits to producers in each region in excess of the effects of the world price reduction. The net welfare gains for producers in Australia as a whole are approximately A$4.3 million per year. Australian consumers gain A$0.1 million per year from the lower prices, so that the overall result is a net gain for Australia of A$4.4 million per year. For the Rest of the World producers, there is a welfare gain of A$50.7 million per year, with the yield increase offsetting the lower price. For the Rest of the World consumers, there are gains from lower prices of A$43.3 million per year. The Australian impacts are small compared to the overall global benefits from ICARDA.

Table 6.5: Annual Welfare Changes for Kabuli Chickpea (at peak adoption)

	Producer surplus ***(A$m)***	**Consumer surplus** ***(A$m)***	***Total surplus (A$m)***
North	0.3	0.0	*0.3*
South	3.8	0.1	*4.0*
West	0.1	0.0	*0.1*
Australia	**4.3**	**0.1**	***4.4***
Rest of the World	**50.7**	**43.3**	***94.1***
World	**55.0**	**43.4**	***98.4***

The annual benefits shown in Table 6.5 are those expected at full adoption of the higher-yielding varieties. The flow of those benefits over time, and the total benefits likely to be received, depend on the rate of adoption by farmers of those varieties with ICARDA's germplasm. The following adoption assumptions were made:

a) Adoption begins in 2001 in the Rest of the World and 2003 in Australia (based on the expected release of varieties with ascochyta blight resistance);
b) The cost reductions are calculated to relate to 100% of the area of kabuli chickpeas;
c) The benefits are based on a linear increase to the estimated adoption in 2006;
d) The expected life of the ascochyta blight resistance is 7 years (G.M. Murray, personal communication), so that adoption in Australia ceases in 2014;
e) Benefits are measured for the Rest of the World until 2022.

On the basis of these assumptions, the future gross benefits of the cost reductions due to ICARDA's germplasm are estimated from 2001 to 2022, as shown in Table 6.6. The discounted gross benefits for Australia (discounted at a real rate of 5% per annum) in 2001 values, are estimated to average A$1.2 million per year over the period 2001 to 2022. The benefits are captured predominantly by producers. In the Rest of the World, the estimated annual benefits average A$51.7 million per year.

Table 6.6: Discounted Benefits for Kabuli Chickpea

	Average Annual[a] Discounted Benefits *(A$m)*
Australia	
Producer Surplus	**1.1**
Consumer surplus	**0.1**
Total surplus	***1.2***
Rest of the World	
Producer Surplus	**29.3**
Consumer surplus	**22.4**
Total surplus	***51.7***
World Total	
Producer Surplus	**30.4**
Consumer surplus	**22.4**
Total surplus	***52.9***

a Net Present Value of benefits over the period from 2001 to 2021, divided by 21.

6.6.4 Sensitivity of kabuli chickpea results to estimated parameter values

To examine the extent to which the chosen values for the parameters of the analysis for chickpeas have an impact on the findings of the study, the sensitivity of the results (measured as the aggregate gains for Australia) was examined (Table 6.7). Each selected parameter was varied by ±20% and the effect on the gains for Australia estimated. For elasticities, a test was made of considerably larger elasticities (a five-fold increase in magnitude) to represent longer-term elasticity estimates.

In addition, as discussed in section 6.3, the future levels of production are uncertain. The impact of different possible levels of production was examined by testing the Australian domestic production as 50,000 tonnes and 100,000 tonnes as well as the base production of 22,000 tonnes.

Table 6.7: Sensitivity of Kabuli Chickpea Results to Changes in Parameters[a]

Parameter	Value	Aggregate Gain for Australia (A$m)
Supply shift in Australia by 2006	**27.03%**	**1.15**
	21.62%	0.83
	32.43%	1.49
Supply shift in ROW by 2006	**8.72%**	**1.15**
	6.98%	1.21
	10.47%	1.09
Australian production (‘000 tonnes)	**22**	**1.15**
	50	2.31
	100	4.39
Price (A$)	**A$700**	**1.15**
	A$560	0.92
	A$840	1.38
Elasticity of demand - ROW	**-0.75**	**1.15**
	-0.60	1.11
	-3.75	1.38
Elasticity of demand - Australia	**-0.63**	**1.15**
	-0.51	1.15
	-3.15	1.15
Elasticity of supply - ROW	**0.52**	**1.15**
	0.42	1.19
	2.60	0.90
Elasticity of supply - Australia	**1.70**	**1.15**
	1.36	1.12
	8.50	1.72
Discount rate	**5.0%**	**1.15**
	4.0%	1.23
	6.0%	1.07

a: Selected parameter values varied by -20% and +20% from values used in estimates, except elasticities varied by -20% and +500% and Australian production varied from 22,000 to 50,000 and 100,000 tonnes.

The sensitivity analysis reveals that the outcome for Australia, in welfare terms, is generally not very sensitive to most of the key parameters used. Variations of 20% in the supply shift in the Rest of the World lead to only relatively small changes in the average annual benefits for Australia. Similarly, the values chosen for elasticities of demand and supply for Australia and the Rest of the World have only a small impact on the outcome for Australia. However, the results are directly sensitive to the price used for kabuli chickpeas, and inversely to the discount rate used in the analysis.

The results are also very sensitive to the size of the supply shift in the Australian regions. The level of Australian production is also critically important in determining the level of the economic impact in Australia, with higher production leading to greater welfare gains due to the price reduction from ICARDA's research. If production of kabuli chickpeas increases to 100,000 tonnes as predicted by industry experts, the average annual benefits will increase to over $4 million per year.

7. Impact in Australia of ICARDA's Faba Bean Research

7.1 Background

Faba beans (*Vicia faba L.*) are a valuable protein-rich food that sustains millions of people in developing countries, particularly those in low and middle-income brackets. World production of faba beans averages approximately 4.3 million tonnes each year, of which 3.38 million tonnes are harvested as dry beans and 0.97 million tonnes are harvested as green vegetables (FAO 2001). China, with almost half of the world's production, is the major producer. Other significant producing countries are Egypt, Ethiopia, Australia, Sudan, Morocco and some western European countries.

Faba beans are mainly used as human food in China and in the Middle East and North Africa region, while they also provide an alternative to soybeans for animal feed in developed countries. World trade in faba beans in 2000 was approximately 0.6 million tonnes, with the main exporting countries being China, Australia (the leading exporter) and the UK. The main importing countries are Egypt (with whom Australia has recently reached a trade agreement on faba beans), Italy, Spain and Saudi Arabia.

7.2 ICARDA's Research on Faba Bean

Faba bean improvement has been part of the ICARDA global mandate since its establishment in 1977. Research was carried out in Syria and Lebanon, and at sites in different countries of the region. In 1992, the breeding program was transferred to the Moroccan national program. However, in 1996 ICARDA resumed its role in faba bean improvement in a limited, targeted and decentralised mode, in close coordination with research activities in the countries of the region. ICARDA focuses on pre-breeding activities including identification of germplasm accessions resistant to biotic stresses such as major fungal diseases (ascochyta blight, chocolate spot, alternaria blight and root-rots), bacterial diseases (leaf spot, soft rots), viruses (bean leaf roll, bean yellow mosaic and broad bean stain), nematodes (stem nematode, root lesion nematodes), parasitic weeds (*orobanche* spp., *cuscuta* spp.) and insects, mainly aphids (Saxena, *et al.* 1993).

Research at the headquarters focuses on the development of early generation segregating populations, more efficient breeding methodologies, and improved screening techniques, whereas the production of finished cultivars has become the responsibility of the national agricultural research systems (NARS).

Research has concentrated on the alleviation of constraints imposed by diseases, mainly chocolate spot and ascochyta blight, and on the level and stability of faba bean productivity (Oram and Belaid 1989). Screening of inbred lines produced from the germplasm collection has revealed lines with resistance to chocolate spot and other diseases and pests. Intensive work carried out at ICARDA has resulted in lines with high yield potential, early maturity, disease resistance, and large, medium and small seed size, combined with determinance. Aphid screening work has also been carried out in Egypt.

In addition, ICARDA has provided training to many NARS scientists who pass through the program as trainees, visiting scientists and post doctorates. This has had a vital impact, as it has boosted the development of faba bean improvement programs in many developing countries.

Since the beginning of faba bean research at ICARDA, 21 modern cultivars have been released, mainly in Egypt, Iran, Portugal, Sudan and Syria. Most of these varieties have improved levels of resistance to various abiotic and biotic stresses, depending on the location where they were released.

7.3 Australian Faba Bean Industry

The Australian faba bean industry is relatively new, with the first variety released in 1980 (Paull 2001). The industry grew steadily until the mid-1990s, and has grown rapidly since that time. Production has been over 200,000 tonnes in recent years. Faba bean is a significant crop in South Australia (the leading producer), and Victoria (Appendix Table A4). Only small areas of faba beans have been grown in the other states, although production in NSW has been growing rapidly in recent years.

Faba bean varieties have narrow adaptability to differing climatic conditions. While faba beans can yield well under high rainfall conditions, high rainfall can lead to reduced quality and hence a lower price. Prices are affected by the percentage of seeds that are defective and have poor colour.

The major constraints to production of faba bean in Australia are poor adaptation of current varieties and susceptibility to foliar diseases and viruses (Paull 2001). In an industry expanding into newer areas, the narrow adaptation of faba beans to differing climatic conditions means that they are often not well adapted to the conditions in which they are grown. The main foliar diseases constraining production are ascochyta blight, chocolate spot and rust. Disease can cause serious losses in faba beans. Rust (*Uromyces viciae-fabae*), which is especially important in the northern production areas, has generally been held in check by resistance. Chocolate spot (*Botrytis fabae*), which generally occurs in intermittent years, can cause very heavy yield losses when the disease is present. Bean leaf roll virus (BLRV) can also cause important losses, especially in northern areas. Ascochyta blight (*Ascochyta fabae*), a problem particularly important in the southern production areas, causes spots on the seed that result in heavy price discounting.

The main market for Australian faba beans is the human consumption market in the Middle East and North Africa, with Egypt the main importer (Pulse Australia 2001). They are consumed whole or split as Foul medames (a porridge-like dish and a staple for many people), or crushed green and made in to felafel (Jeff Paull, personal communication). Both whole green and split beans are also canned. The preferred seed type for the Middle East is a medium-sized buff-coloured seed.

Australian farmers generally rotate wheat with faba beans. Faba bean, as a legume, is beneficial for use in rotational cropping, with benefits accruing to the following wheat crops. However, its full potential has not yet been reached because of the lack of locally adapted faba bean varieties.

7.4 Australian Faba Bean Improvement Program

In 1996, the National Faba Bean Improvement Program, funded by the Grains Research and Development Corporation, was established. The leader of the program is Dr Jeff Paull, based at the Waite Institute at the University of Adelaide, and breeding for the northern areas is led by NSW Agriculture’s Dr Ian Rose at Narrabri. Before that time, faba bean breeding had generally involved evaluations and selections from imported lines. The major source of those lines was the faba bean program established at ICARDA in the early 1980s. Since the establishment of the national program, crosses have been made using those materials to develop varieties with suitable disease resistances and with adaptation to Australia’s main production environments.

In faba beans, ICARDA is collaborating with the Australian Centre for International Agricultural Research (ACIAR) and the Grain Research and Development Corporation (GRDC). ACIAR is involved in research on faba bean with the Chinese national program, and GRDC supports the flow of germplasm between ICARDA and Australia.

A list of the faba bean varieties released in Australia is shown in Table 7.1. Apart from Fiord, which was selected from a landrace from Greece before ICARDA was established, the varieties have all been derived from or selected from ICARDA lines, some of which were obtained by ICARDA from Ecuador and Spain. Thus, to date, the varieties released have been selections from imported lines or varieties, with none developed from crosses made in Australia.

Table 7.1: List of Faba Bean Varieties Released in Australia

Variety	Origin	Year	Comments
Fiord	Greece	1980	Selection from Greek landrace
Icarus	ICARDA/Ecuador	1993	Derived from ICARDA line BPL710
Ascot VF		1995	Selection from Fiord
Fiesta VF	ICARDA/Spain	1998	Selected from ICARDA line
BPL1179			
Rossa	ICARDA/Ecuador		Selected from ICARDA line
BPL3025			
Manafest	ICARDA/Ecuador	1999	Selected from ICARDA line
BPL3026			
Barkool			Selection from Fiord
Aquadulce			

Source: Compiled by the authors from industry information.

More recently, since the establishment of the National Faba Bean Improvement Program, crosses have been made between some of these imported lines and selections. That material is currently at the F_3 and F_4 stage of the program, and is expected to be released for farmers in 3-4 years. Commercial production of the varieties based on those crosses is likely to be significant by 2006.

Characteristics that are important to the northern component of the program based at Narrabri are high yields; early maturity; biomass; non-lodging; frost resistance; and seed characteristics. The Northern faba bean breeding program is making progress in screening for disease resistance to chocolate spot.

7.5 Use of ICARDA Faba Bean Material in Australia

Germplasm flows from ICARDA in recent years have been generally direct transfers between breeders, and have not been shown in the data provided by ICARDA (see section 2.2 above). Earlier, 50 lines were imported in 1984, with a further 13 lines in 1988. Since the faba bean research program is still in its early stages of development, a continuing contribution in terms of germplasm flows from ICARDA may be expected in future years.

A rapid analysis of the data of the database of the Australian faba bean collection held at the Waite Institute in Adelaide shows that there have been 620 ICARDA germplasm accessions and 201 different ICARDA pure faba bean lines introduced up to the end of 2000 (J. van Leur, personal communication). In addition, a number of disease resistant selections (particularly for fungal diseases and viruses) have been imported in recent years from ICARDA. Further to the Waite collection, the Australian Temperate Pulse collection holds a number of ICARDA accessions that have not yet passed through quarantine Altogether, it is likely that Australia has received close to 1000 faba bean accessions from ICARDA (J. van Leur, personal communication).

All of the faba bean varieties that are commercially available in Australia have been identified at ICARDA, except Fiord.

7.6 Analysis of ICARDA's Impact on Australian Faba Bean Production

7.6.1 Cost reduction in Australia attributable to ICARDA research

The original Australian faba bean variety, Fiord, was selected from a landrace obtained from Greece prior to ICARDA's faba bean program. Subsequent varieties Ascot VF and Barkool have in turn been developed from Fiord. More recent lines have been selected from genetic materials obtained through ICARDA. The main characteristics of these later varieties is that they have allowed faba beans to be grown successfully in a broader range of environments, and the improved resistance to fungal diseases such as chocolate spot (Jeff Paull, personal communication). Thus the industry is strongly based on germplasm obtained from the Mediterranean region, but only the more recent varieties have been obtained from ICARDA.

However, the real impact of the ICARDA materials is likely to happen at the next stage, when the first lines developed from crosses made in Australia from the materials obtained from ICARDA are available to farmers. Those varieties will have vastly improved disease resistance, so that the current regime of 3 to 5 fungicide sprays that are necessary to grow faba beans will be able to be reduced to 2 or 3 (Jeff Paull, personal communication). Thus, the main benefit of the improved materials obtained from ICARDA will be a saving in fungicide costs. The present and anticipated costs of those fungicide sprays are estimated in Table 7.2.

Table 7.2: Fungicide Cost Savings from Varieties with Improved Resistance

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Current 4 applications
Fungicide 0.5 kg/ha @A$57.00/kg = A$28.50 per application
4 applications = A$114.00 per ha
Application costs: 2 x aerial @ A$9.50/ha + 2 x ground spray @ A$1.61/ha = A$22.22
Total costs of 4 sprays = A$136.22/ha

Expected 2 applications
Fungicide 0.5 kg/ha @A$57.00/kg = A$28.50 per application
2 applications = A$57.00 per ha
Application costs: 1 x aerial @ A$9.50/ha + 1 x ground spray @ A$1.61/ha = A$11.11
Total costs of 2 sprays = A$68.11/ha

Savings:
Saving in fungicide costs = A$68.11 per ha

Source: Costs of fungicides derived from data in Faour (2001) and NSW Agriculture Web site.

On that basis, the expected benefit from the ICARDA material is a saving of A$68.11 per ha, which is equivalent to a cost reduction of A$53.80 per tonne, at current average yield levels of 1.27 t/ha.

7.6.2 Cost reduction in the Rest of the World attributable to ICARDA research

ICARDA's research on faba beans has also affected the costs of production in the rest of the world. In the analysis presented here, all impacts on supply shifts in the "Rest of the World" are aggregated for the analysis, since the emphasis is on the net impacts on Australia. Given that the impacts relevant to the analysis are those that are likely to occur over the next 10 years or so, estimating the impact is very difficult. As a simplification, the expected impact for 2006 was estimated, as a proxy for the supply shift in the Rest of the World.

On the basis of expected impacts on yields, the contribution of ICARDA to those increases and the likely adoption of those improved varieties by 2006, an estimate has been made of the likely impact of ICARDA in the Rest of the World (Table 7.3). The expected yield gain for the Rest of the World is estimated at 3.0%, which translates to a cost reduction of A$8.17 per tonne (or 2.92%) at recent world prices.

Table 7.3: Impact of ICARDA on Faba Bean in the Rest of the World

Impact of ICARDA		
Expected ICARDA yield impact in ROW by 2006	%	3.01
Estimation of cost reduction		
Estimated yield without ICARDA in 2006	t/ha	1.00
Estimated yield with ICARDA in 2006	t/ha	1.03
Price/Total cost without ICARDA	A$/t	280.00
New cost with ICARDA	A$/t	271.83
Cost reduction in ROW from improvement	A$/t	8.17
% supply shift	%	2.92

ROW: Rest of the World
Source: Estimates prepared by the authors from information supplied by ICARDA.

7.6.3 Welfare effects of ICARDA faba bean research

In assessing the impact of ICARDA spillovers to Australia in faba bean research, the following data (based on the average of the five years to 2000) were used in the analysis:

a) The world price for faba bean is A$280/t;
b) In Australia, the supply elasticity is 1.70 and the demand elasticity is -0.79;
c) In the Rest of the World, the supply elasticity is 0.52 and the demand elasticity is -0.75;
d) Total world faba bean production is 4.35 million tonnes;
e) ICARDA research will have increased faba bean yields by 3.0% in the Rest of the World by 2006, equivalent to a cost reduction of A$8.17/t (Table 7.3);
f) The area sown to faba beans in Australia[7] is 213,000 ha, yields are 1.27 t/ha, so that production is 270,000 tonnes;
g) ICARDA research will have reduced costs of producing Australian faba beans by A$53.80/t by 2006, equivalent to a cost reduction of 19.2%.

The direct research impacts are a cost reduction in the Rest of the World of 2.92%, and spillover benefits in the form of a cost reduction of 19.22% for Australia. While these cost reductions result in savings for producers, the resultant increased production leads to a fall in world price of A$7.00, or 2.5%. That leads to benefits for consumers of faba beans, while producers simultaneously achieve yield increases and face price falls. Their net position depends on the balance between the yield gains and the price fall.

Using the data in the analytical framework (section 3), the annual welfare changes at peak adoption are shown in Table 7.4. The cost reduction provides benefits to Australian producers in excess of the effects of the world price reduction. The net welfare gains for producers in Australia as a whole are approximately A$14.4 million per year. Australian consumers gain A$0.2 million per year from the lower world prices, so that the overall result is a net gain for

[7] The Australian data are based on an average of the past two years, rather than the five years to 2000, because of the recent rapid growth in area.

Australia of A$14.6 million per year. For the Rest of the World producers, there is a welfare gain of A$5.1 million per year, with the yield increase offsetting the lower price. For the Rest of the World consumers, there are gains from lower prices of A$32.3 million per year. The estimated Australian producer benefits are greater than the estimated Rest of the World producer benefits. This extraordinary result is due to the advances made possible with ICARDA materials in Australia, where faba beans are a growing export-oriented industry, and where potential productivity gains are adopted rapidly. Overall, Australia obtains 28% of the total global benefits estimated in this analysis for faba beans.

Table 7.4: Annual Welfare Changes for Faba Bean (at peak adoption)

	Producer surplus ***(A$m)***	**Consumer surplus** ***(A$m)***	***Total surplus*** ***(A$m)***
Australia	14.4	0.2	*14.6*
Rest of the World	5.1	32.3	*37.3*
World	19.5	32.4	*51.9*

The annual benefits shown in Table 7.4 are those expected at full adoption of the higher-yielding varieties. The flow of those benefits over time, and the total benefits likely to be received, depend on the rate of adoption by farmers of those varieties with ICARDA's germplasm. The following adoption assumptions were made:

a) Adoption begins in 2001 in the Rest of the World and 2004 in Australia ;
b) The yield increases relate to 100% of the area of faba beans;
c) Varieties take five years to reach the peak adoption levels in Australia, increasing linearly;
d) Adoption in the Rest of the World increases linearly from current level (11%) to the estimated level in 2006 (27%);
e) Benefits are measured for both Australia and the Rest of the World until 2022.

On the basis of these assumptions, the future gross benefits of the cost reductions due to ICARDA's germplasm are estimated from 2001 to 2022, as shown in Table 7.5. The discounted gross benefits for Australia (discounted at a real rate of 5% per annum) in 2001 values, are estimated to average A$6.1 million per year over the period 2001 to 2022. The Australian benefits are captured overwhelmingly by producers. In the Rest of the World, the estimated annual benefits average A$20.4 million per year, and flow mainly to consumers.

Table 7.5: Discounted Benefits for Faba Bean

	Average Annual[a] Discounted Benefits *(A$m)*
Australia	
Producer Surplus (A$m)	**6.0**
Consumer surplus (A$m)	**0.1**
Total surplus (A$m)	***6.1***
Rest of the World	
Producer Surplus (A$m)	**4.9**
Consumer surplus (A$m)	**15.4**
Total surplus (A$m)	***20.4***
World Total	
Producer Surplus (A$m)	**10.9**
Consumer surplus (A$m)	**15.5**
Total surplus (A$m)	***26.5***

a Net Present Value of benefits over the period from 2001 to 2021, divided by 21.

7.6.4 Sensitivity of faba bean results to estimated parameter values

To examine the extent to which the chosen values for the parameters of the analysis for faba beans have an impact on the findings of the study, the sensitivity of the results (measured as the aggregate gains for Australia) were examined (Table 7.6). Each selected parameter was varied by ±20% and the effect on the gains for Australia estimated. For elasticities, a test was made of considerably larger elasticities (a five-fold increase in magnitude) to represent longer-term elasticity estimates.

Variations of 20% in the supply shift in the Rest of the World lead to only relatively small changes in the average annual benefits for Australia. However, the results are sensitive to supply shift in Australia and the price used for faba bean, and less so to the discount rate. As well, Australian gains for faba bean are generally insensitive even to large variations in the elasticity of supply in either market or the elasticity of demand in Australia. However, similar changes in the elasticity of demand for the Rest of the World lead to more significant changes in the aggregate gains.

Table 7.6: Sensitivity of Faba Bean Results to Changes in Parameters[a]

Parameter	Value	Aggregate Gain for Australia (A$m)
Supply shift in Australia by 2006	**19.22%**	**6.09**
	15.38%	4.66
	23.06%	7.57
Supply shift in ROW by 2006	**2.92%**	**6.09**
	2.34%	6.18
	3.50%	5.99
Price (A$)	**A$280**	**6.09**
	A$224	4.87
	A$336	7.21
Elasticity of demand - ROW	**-0.75**	**6.09**
	-0.60	5.96
	-3.75	6.81
Elasticity of demand - Australia	**-0.79**	**6.09**
	-0.63	6.09
	-3.95	6.10
Elasticity of supply - ROW	**0.52**	**6.09**
	0.42	6.11
	2.60	5.90
Elasticity of supply - Australia	**1.70**	**6.09**
	1.36	6.03
	8.50	6.38
Discount rate	**5.0%**	**6.09**
	4.0%	6.80
	6.0%	5.46

a: Selected parameter values varied by -20% and +20% from values used in estimates, except elasticities varied by -20% and +500%

8. Impact in Australia of ICARDA's Lentil Research

8.1 Background

Lentils (*Lens culinaris*) are one of humanity's oldest food crops (Webb and Hawtin 1981). As a food, lentils provide valuable protein and, unlike several other food legumes, few anti-nutritional or toxic factors have been reported in lentils. They also require a comparatively short cooking time and are one of the most easily digested of pulses. Lentils may be consumed whole, decorticated and split or ground into flour. Although lentils are mainly human food, they may occasionally be used to feed animals, particularly poultry. The straw and pod walls, residues from threshing, have a high feed value. The seed coats left after decortication are also considered a valuable feed and may contain up to 13% protein. Lentils are sometimes grown as a fodder with the whole plants being grazed green or cut and fed to livestock. They may also be ploughed in as a green manure. Although lentils are not a major food crop on a world scale, they are nevertheless important in certain countries. The wide range of uses of lentils and their by-products, coupled with their value in many farming systems, and ability to thrive on relatively poor soils and under adverse environmental conditions, has ensured their continued role as crop species.

On a global scale, lentil is a small but rapidly expanding crop, with total area in 2000 of 3.38 million hectares, of which 2.46 million hectares (73% of the total) was planted in developing countries. The annual average lentil production in developing countries was about 2.1 million tonnes. The main producers are India (approximately 1 million tonnes), Turkey and Canada (both approximately 0.5 million tonnes), with Bangladesh, Syria, Iran, Nepal, China and Australia producing smaller quantities. Lentil consumption is highest in India, Turkey, Bangladesh, Iran, Iraq and Syria.

Canada and Turkey are the leading exporting countries, accounting for three-quarters of world exports in 1997. While the importing countries vary from year to year with the levels of production in some of the main consuming countries, in 1997 Sri Lanka and India were the main importers. Several European countries also have significant annual lentil imports.

There are two main types of lentils, namely red and green lentils. In countries such as Turkey, India and Syria, production is mainly red lentils. In Canada, the main exporting country, mainly green lentils have been produced, but red lentil production is now expanding. Australia produces predominantly red lentils. There are other specialty types of lentils that have niche markets, including French green lentils (De Puy) and Spanish brown lentils.

8.2 ICARDA's Research on Lentils

ICARDA has a global mandate for the improvement of lentils. A concerted effort for lentil improvement started virtually from the time of ICARDA's establishment. The major focus has been the development and delivery to national programs of production technology, particularly genetic materials with appropriate combinations of increased biomass for food and feed, and resistance to key biotic and abiotic stresses. ICARDA's lentil research covers developing countries in South Asia (Bangladesh, India, Pakistan, Nepal), West and Central Asia and the Caucasus, North and East Africa (Ethiopia and Eritrea), and Latin America (Peru, Bolivia, Argentina, Colombia).

Many factors that affect lentil yields, such as diseases (vascular wilt, ascochyta blight, rust) and drought, have global importance. Some regionally important stresses, such as parasitic angiosperms (*orobanche, cuscuta*) and insect pests (sitona), pose a threat to lentil production in the Mediterranean region. Landraces are liable to lodging and are unsuitable for mechanical harvesting. Accordingly an integrated approach to lentil improvement has been pursued at ICARDA covering the development of both improved production technology and genetic stocks. A high priority has been placed on transferring to national programs the results of research on lentil harvest mechanisation systems to reduce the high cost of manual harvesting in the West Asia and North Africa region.

Lentils are generally considered to be one of the most cold tolerant of the food legume crops. However, they are unable to withstand the very severe winters of the higher elevations in the Mediterranean region, such as on the Anatolian plateau in Turkey or the high plateaux in the North African countries. In these areas the crop is normally sown during early spring. The Indian subcontinent is the largest lentil-producing region in the world. The crop is grown as a winter crop, and is normally sown after the end of the summer monsoon rains, from October to December, and raised on conserved soil moisture. If water is available, the crop may be given one or two irrigations. In the Nile Valley of Egypt and northern Sudan, lentils are sown in the early winter, but, under the extremely arid conditions of this region, almost the entire water requirement of the crop is met by irrigation. Thus, both cold tolerance and drought tolerance are desirable traits.

The breeding strategies used for lentil have evolved with time. At the early stages, development of high yield potential cultivars and development of appropriate agronomic packages were the major objectives. In this first stage, the variation in the ICARDA lentil germplasm collection was directly exploited with selection made among and within landraces. The particular combinations of characters required for specific regions were often not found "on the shelf" in the collection. Consequently, in the second stage, ICARDA started hybridisation and selections from segregating populations. Stable lines were then distributed to national programs for testing in their respective agro-climatic conditions. Research in this stage resulted in the release of a number of cultivars in different regions. However, lentil lines developed from selection at ICARDA are mostly limited in adaptation to West Asia. As a result, the breeding program has decentralised to work closely with national programs having different agro-ecological conditions. In this third stage of lentil improvement, potential crosses are identified with NARS partners and subsequently made at ICARDA's Tel Hadya station. Then country-specific segregating populations are shipped to national cooperators for local selection. More than 200 crosses are made annually at ICARDA, targeted to address different stresses in specific agro-ecological zones. Increasingly, national programs use ICARDA-derived material in their own hybridisation programs.

Separate programs target improvements for the diverse environments in which lentil is grown. Abiotic and biotic stresses affect lentil, and sources of resistance are being identified. In addition, multiple resistance is often needed, and several accessions have resistance to two or more diseases. Rust is the most important foliar disease. ICARDA screens for rust resistance through joint research with the national programs of Ethiopia, Morocco, and Pakistan. As a result of this effort, rust-resistant cultivars have been released in Chile, Ecuador, Ethiopia, Morocco and Pakistan. An international nursery for rust resistance was initiated with national programs in 1990 to clarify the host-pathogen relationships in different regions and to assist in identifying variation in the fungus. Vascular wilt is the most important soil-borne disease of lentil in the Mediterranean region and also causes major yield losses in the Indian subcontinent. ICARDA has developed an efficient screening method for vascular wilt in lentil and identified several useful sources of resistance. Ascochyta blight causes losses in productivity in the CWANA region, parts of the Indian subcontinent and Canada. Good sources of resistance to ascochyta blight have been identified in cooperation with NARS.

Since 1987, 73 lentil varieties have been released by national programs of 27 mainly developing countries around the globe of which ICARDA has contributed to about 77% of the genetic stock either selected from ICARDA's accessions or crosses from at least one ICARDA parent. These varieties are replacing the traditional landraces. The capacity of NARS scientists and technicians has been improved through visits, training, and exchange of ideas in meetings and workshops.

8.3 Australian Lentil Industry

The Australian lentil industry is small but rapidly growing. Because lentils are only 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. The other states have only minor areas of lentils. While lentils have some drought tolerance and have an ability to thrive where rainfall is low, they are especially intolerant to water-logged and acid soils as well as salinity and boron. In Victoria and South Australia, lentils are mainly concentrated in medium rainfall areas on alkaline well-drained soils.

Lentils have only a small market for domestic human consumption in Australia (estimated at 2,000 tonnes per year), so the industry aims to produce lentils mainly for export to the Middle East and South Asia.

In 2000, lentil area in Australia exceeded 100,000 ha for the first time, and is estimated to increase further to around 150,000 ha in 2001 (see Appendix Table A.5). Since the mid-1990s, lentil yields have averaged 1.2 t/ha. Production has increased rapidly and is estimated to exceed 180,000 tonnes in 2001. Considering that lentil area in 1992 was approximately only 300 ha, its growth in recent years has been very rapid.

Production has been predominantly of red lentils, with only small areas being sown to the green lentil variety Matilda. Red lentils generally have a yield advantage over green, while green lentils have a price advantage (of approximately A$100 per tonne) over red varieties.

Prices have varied considerably from year to year, but have averaged approximately A$400 per tonne in recent years. That is almost double the average prices for competing pulse crops such as field peas and lupins. The price advantage makes them an attractive enterprise for growers who can obtain good yields.

8.4 Australian Lentil Improvement Program

Lentil evaluation and breeding in Australia is a coordinated effort between collaborators in each state (Materne 1999). The Coordinated Improvement Program for Australian Lentils (CIPAL) is based at the Victorian Institute for Dryland Agriculture at Horsham, under the leadership of Michael Materne of Agriculture Victoria, with Victoria, South Australia, Western Australia, New South Wales and Tasmania as collaborating states. The program receives financial support from the GRDC. ICARDA is also part of CIPAL, and under that program funds are provided to the ICARDA breeding program to assist with technical support. The program also finances reciprocal visits between the ICARDA and Australian programs.

The objectives of the Australian breeding program are:

- improved yield
- marketability
- standing ability/erect habit for mechanical harvest
- disease resistance, particularly ascochyta blight and grey mould resistance
- harvestability
- tolerance to hostile soils (especially tolerance to boron and salinity)

Harvestability is particularly important, since lentils often do not grow very tall and they are difficult to harvest mechanically. In many of the world's production regions, lentils are harvested by hand. The Mediterranean types, particularly those grown in Turkey, are more suited to mechanical harvesting, and so provide a valuable genetic resource for the Australian program.

All of the Australian lentil varieties that have been released to date have been lines from ICARDA (see Table 8.1). All except Matilda have been red lentils. Varieties have been released in Western Australia, Victoria and South Australia. Apart from these varieties released directly in Australia, Ansak has been introduced from New Zealand, although it originally came from ICARDA.

Table 8.1: Lentil Varieties Released in Australia

Variety	Source	Synonym	Year of release	State of release
Red Lentils				
Aldinga	ICARDA		1993	SARDI, SA
Cobber	ICARDA	ILL5728	1993	Agriculture Victoria
Digger	ICARDA	ILL5722	1993	Agriculture Victoria
Northfield	ICARDA		1994	SARDI, SA
Cassab	ICARDA	ILL7200	1998	Agriculture WA
Cumra	ICARDA	ILL590	1998	Agriculture WA
Ansak	ICARDA[a]	ILL6243	1998	SGB (private)
Nugget	ICARDA	ILL7180	1999	Agriculture Victoria
Green Lentils				
Matilda	ICARDA	ILL5823	1993	Agriculture Victoria

a Introduced via New Zealand

Source: Compiled by the authors from industry information

Most of the parental materials used in crosses made in the Australian breeding program at VIDA at Horsham have also been derived from ICARDA. For example, some of the ICARDA accessions are being used in crosses to provide ascochyta blight resistance, earliness, resistance to grey mould, and high yield potential. Some lines introduced from Canada and the United States have also been used in crosses in recent years, though they originally also come from ICARDA. Australian lines were used as parents in the crossing program for the first time only in 2000.

In the breeding program, there are many advanced lines with ICARDA materials in their pedigree. For example, the ICARDA red lentil line ILL7220 is in advanced trials and is expected to be released in Western Australia in the near future. There are also a number of other ICARDA lines in the advanced stages of the Victorian breeding program. In addition, there are many ICARDA lines or lines based on ICARDA materials among the materials that are being tested in the earlier stages of the program.

The characteristics of interest in ICARDA materials that are being tested for are: resistance to ascochyta blight, botrytis resistance, harvestability (height, lodging resistance and reduced pod drop), yield, earliness, quality and boron tolerance. Anthracnose and fusarium wilt are exotic diseases for which Australian lines are being screened for resistance in Canada and ICARDA, respectively.

Apart from the genetic materials and breeding lines that are being used, ICARDA has provided significant support for the Australian lentil-breeding program in achieving industry funding through GRDC and ACIAR projects. ICARDA's support has ensured that Australia has access to the valuable genetic resources. ICARDA also plays a key role in international seed distribution. ACIAR projects in Central Asian republics are conducted jointly with ICARDA, and a collection mission, organised by ICARDA, was undertaken in that area in mid-2001. An ACIAR project in Nepal and Bangladesh has relied upon ICARDA lentil germplasm and technical support. Disease screening techniques and scoring systems, as well as pulse quality evaluation methods, have been other important outputs to breeders, in addition to breeding lines used in the program.

8.5 Use of ICARDA Lentil Material in Australia

ICARDA's target environments are similar to Australia's, and because of this ICARDA is an extremely important genetic resource for lentils. Materials from the breeding program at ICARDA, aimed at the Middle East region, generally have good adaptation to southern Australian conditions. ICARDA's lentil germplasm has been the basis for the rapid development of the lentil industry in Australia.

ICARDA has been a continuing important source of supply of germplasm for the Australian Lentil Improvement Program. In the past five years, an average of 440 lines has been brought into Australia from ICARDA each year (see section 2.2 above). This level has been relatively consistent since the late 1980s. Lentils have accounted for about one-third of all lines of all crops introduced into Australia from ICARDA since 1983.

In addition to the use of genetic material from ICARDA in the Australian breeding program, contact is regular between the Australian researchers and ICARDA, with visits to ICARDA, emails, joint projects, and publications. Dr Ken Street is based at ICARDA with the assistance of GRDC. Dr Materne received training at ICARDA before establishing the Australian Lentil Improvement Program. There are annual reciprocal visits, and the provision of in-service sabbatical leave between the Australian organisations and ICARDA has proven very successful. The value of these collaborative arrangements is not quantified in this study, which concentrates only on estimating the economic impact of the genetic materials from ICARDA on the Australian lentil industry.

8.6 Analysis of ICARDA's Impact on Australian Lentil Production

8.6.1 Cost reduction in Australia attributable to ICARDA research

It is clear that the lentil industry in Australia is based on material from ICARDA. The total value of that industry is expected to be approximately A$80 million in 2001, and is expected to increase further. However, the benefit to Australia is not the gross value of the industry. Wherever the increased areas of lentils have been grown they have replaced another crop or enterprise that would have produced some income. As a result, the development of a new crop such as lentils provides benefits that are measured by estimating the value of the lentils produced less the value of the crop(s) that they replaced.

The main areas in which lentils have been grown had previously been growing pulse crops in rotations with cereals, particularly wheat and barley, for many years. Originally, field peas were grown in many of these areas, subsequently replaced by chickpeas in areas such as the Victorian Wimmera. Lentils are also likely to have, to a smaller extent, replaced cereals in the rotations, either Australian Standard White wheat or barley.

A comparison of the relative returns from the different crops that are likely to have been grown if lentils were not available is shown in Table 8.2 for the Mallee and Wimmera areas in Victoria, the main lentil-producing state. The gross margin for lentils compared to the alternative crops is shown and, in all cases except chickpeas in the Wimmera, the gross margins are higher for lentils. Because of their higher profitability, lentils have replaced the less profitable alternative crops, thus leading to an increase in gross margins.

On the basis that the crops replaced by lentils were a balanced mix of pulse and cereal crops, the average advantage of lentils compared to an average of field peas, desi chickpeas, ASW wheat, and barley is estimated as A$56 per ha in the Wimmera and A$116 per ha in the Mallee. Averaging across the two regions, the average advantage of lentils is A$86 per ha. Given an average yield of 1.4 t/ha, that translates to a benefit from growing lentils equivalent to A$61 for each tonne of lentils produced. Since the analytical framework requires the technical advances to be translated into vertical shifts of the supply curve, this is equivalent in the economic analysis to a cost reduction of A$61 in the costs per tonne (or a downward shift in the supply curve) for lentils across those regions. For simplicity in this analysis, the A$61/t figure is used in the analysis across all regions.

Table 8.2: Comparison of Gross Margins for Lentils and Crops Replaced

	Red lentil	Field pea	Chickpea	Wheat	Barley	Mean of alternatives	Advantage of lentils
Wimmera:							
Gross income (A$/ha)	646	380	800	450	425		
Variable costs (A$/ha)	216	160	154	127	115		
Gross margin (A$/ha)	430	220	646	323	310	375	56
Mallee:							
Gross income (A$/ha)	418	209	280	270	340		
Variable costs (A$/ha)	168	167	179	107	110		
Gross margin (A$/ha)	250	42	101	163	230	134	116
Mean:							
Gross margin (A$/ha)	340	131	374	243	270	254	86
Equivalent cost reduction (A$) per tonne of lentil production							61
% cost reduction							16.1%

Source: O'Brien (1999) for Wimmera input data and Hall (2001) for Mallee input data. Prices and yield were taken as most recent 5-year averages.

The benefits measured in this analysis relate to the farm-level values. There have also been benefits to associated industries and communities, through employment and income generated by local processing plants, market traders, etc. However, no additional benefits are included in this analysis for those effects, as it is unclear from the limited data available that lentils provides measurably different "multiplier" benefits than the crops which it replaces.

8.6.2 Cost reduction in the Rest of the World attributable to ICARDA research

ICARDA's research on lentils has also affected the costs of production in the rest of the world. In the analysis presented here, all impacts on supply shifts in the "Rest of the World" are aggregated for the analysis, since the emphasis is on the net impacts on Australia. Given that the impacts relevant to the analysis are those that are likely to occur over the next 10 years or so, estimating the impact precisely is impossible. As a simplification, the expected impact for 2006 was estimated as a proxy for the supply shift in the Rest of the World.

On the basis of expected impacts on yields, the contribution of ICARDA to those increases and the likely adoption of those improved varieties by 2006, an estimate has been made of the likely impact of ICARDA in the Rest of the World (Table 8.3). The expected yield gain for the Rest of the World is estimated at 2.1%, which translates to a cost reduction of A$7.71 per tonne (or 2.03%) at recent world prices. This is considerably less than the A$61/t cost reduction estimated for Australia (see above).

Table 8.3: Impact of ICARDA on Lentils in the Rest of the World

Impact of ICARDA		
Expected ICARDA yield impact in ROW by 2006	%	2.1
Estimation of cost reduction		
Estimated yield without ICARDA in 2006	t/ha	0.81
Estimated yield with ICARDA in 2006	t/ha	0.83
Price/Total cost without ICARDA	A$/t	380.00
New costs per tonne with ICARDA	A$/t	372.29
Cost reduction in ROW from improvement	A$/t	7.71
% supply shift	%	2.03

ROW: Rest of the World
Source: Estimates prepared by the authors from information supplied by ICARDA.

8.6.3 Welfare effects of ICARDA lentil research

In assessing the impact of ICARDA spillovers to Australia in lentil research, the following data (based on averages for the five years to 2000) were used in the analysis:

a) The world lentil price is A$380/t;
b) In Australia, the supply elasticity is 0.80 and the demand elasticity is -0.80;
c) In the Rest of the World, the supply elasticity is 0.60 and the demand elasticity is -0.41 for the Rest of the World;
d) Total world lentil production is 2.96 million tonnes;
e) ICARDA research will have increased lentil yields by 2.1% in the Rest of the World by 2006, equivalent to a cost reduction of A$7.71/t, or 2.03% (Table 8.3);
f) The area of lentils in Australia[8] is 138,000 ha and yields are 1.13 t/ha, so that production is 156,000 tonnes;
g) ICARDA research impact will have increased returns from growing lentils rather than alternative crops by A$61.27/t, equivalent to reducing costs in Australia by 16.12%, by 2006.

The direct research impacts are a cost reduction in the Rest of the World of 2.03%, and spillover benefits in the form of a cost reduction of 16.12% for Australia. While these cost reductions result in savings for producers, the resultant increased production leads to a fall in the world price of A$6.82, or 1.8%. That leads to benefits for consumers of lentils, while producers simultaneously achieve yield increases and face price reductions. Their net position depends on the balance between the yield gains and the price fall. In both Australia and the Rest of the World, the benefits from yield increases are greater than the effect of the price falls, so that producers also have increases in welfare.

Using these data in the analytical framework from section 3, the annual welfare changes at peak adoption are shown in Table 8.4. The net welfare gains for producers in Australia are

[8] The Australian data are based on an average of the past two years, rather than the five years to 2000, because of the recent rapid growth in area.

estimated at A$9.0 million per year. Australian consumers gain less than A$0.1 million per year from the lower prices, so that the overall result is a net gain for Australia of about A$9.0 million per year. For the Rest of the World producers, there is a welfare gain of A$2.5 million per year, with the yield increase offsetting the lower price. For the Rest of the World consumers, there are gains from lower prices of A$20.3 million per year. Again, as for faba beans, the total Australian welfare impacts are a relatively significant proportion of the overall global benefits from ICARDA, especially the producers' share.

Table 8.4: Annual Welfare Changes for Lentils (at peak adoption)

	Producer surplus ***(A$m)***	**Consumer surplus** ***(A$m)***	***Total surplus*** ***(A$m)***
Australia	9.0	0.0	*9.0*
Rest of the World	2.5	20.3	*22.8*
World	11.5	20.3	*31.8*

The annual benefits shown in Table 8.4 are those that are expected at peak adoption of the higher-yielding varieties. The flow of those benefits over time, and the total benefits likely to be received, depend on the rate of adoption by farmers of those varieties with ICARDA's germplasm. The following adoption assumptions were made:

a) Adoption begins in 2001 in the Rest of the World and Australia;
b) The yield increases relate to 100% of the area of lentils in Australia, and 19.9% of lentil area in the Rest of the World;
c) Varieties take five years to reach peak adoption, increasing linearly;
d) Benefits are measured for both Australia and the Rest of the World until 2022.

On the basis of these assumptions, the future gross benefits of the cost reduction due to ICARDA's germplasm are estimated from 2001 to 2022, as shown in Table 8.5. The discounted gross benefits for Australia (discounted at a real rate of 5% per annum) in 2001 values, are estimated to average A$4.9 million per year over the period 2001 to 2022. Producers capture virtually all of those benefits. In the Rest of the World, the estimated annual benefits average A$22.8 million per year and are mainly captured by consumers.

Table 8.5: Discounted Benefits for Lentils

	Average Annual[a] Discounted Benefits *(A$m)*
Australia	
Producer Surplus (A$m)	**4.9**
Consumer surplus (A$m)	**0.0**
Total surplus (A$m)	***4.9***
Rest of the World	
Producer Surplus (A$m)	**1.4**
Consumer surplus (A$m)	**11.2**
Total surplus (A$m)	***12.5***
World Total	
Producer Surplus (A$m)	**6.3**
Consumer surplus (A$m)	**11.2**
Total surplus (A$m)	***17.5***

a Net Present Value of benefits over the period from 2001 to 2021, divided by 21.

8.6.4 Sensitivity of lentil results to estimated parameter values

To examine the extent to which the chosen values for the parameters of the analysis for lentils have an impact on the findings of the study, the sensitivity of the results (measured as the aggregate gains for Australia) was examined (Table 8.6). Each selected parameter was varied by ±20% and the effect on the gains for Australia estimated. For elasticities, a test was made of considerably larger elasticities (a five-fold increase in magnitude) to represent longer-term elasticity estimates.

The analysis shows that the results are very insensitive to elasticity changes, and only change a little in response to changes in yield gains for the Rest of the World or in discount rates. However, the results are directly proportional to changes in the supply shift for Australia. Most significantly, the effects are highly sensitive to the prices used for lentils, since the benefits are measured by a comparison of gross margins, and even small changes in price can lead to a magnified change in the relative gross margin. Any increase in price above the $380 per tonne used in the analysis leads to markedly higher gains for Australia, and correspondingly there are significantly lower returns if the price is lower than $380 per tonne.

Table 8.6: Sensitivity of Lentil Results to Changes in Parameters[a]

Parameter	Value	Aggregate Gain for Australia (A$m)
Supply shift in Australia by 2006	**16.12%**	**4.9**
	12.90%	3.8
	19.35%	6.1
Supply shift in Rest of the World by 2006	**2.03%**	**4.9**
	1.62%	5.0
	2.43%	4.9
Lentil price (A$/t)	**A$380**	**4.9**
	A$304	-1.5
	A$456	12.0
Elasticity of demand - ROW	**-0.41**	**4.9**
	-0.33	4.9
	-2.05	5.3
Elasticity of demand - Australia	**-0.80**	**4.9**
	-0.64	4.9
	-4.00	4.9
Elasticity of supply - ROW	**0.60**	**4.9**
	0.48	4.9
	3.00	4.9
Elasticity of supply - Australia	**0.80**	**4.9**
	0.64	4.9
	4.00	4.9
Discount rate	**5.0%**	**4.9**
	4.0%	5.4
	6.0%	4.5

a: Selected parameter values varied by -20% and +20% from values used in estimates, except elasticities varied by -20% and +500%

9. Impact in Australia of ICARDA's Forage Legume Research

9.1 ICARDA's Research on Forage Legumes

ICARDA's Forage Legume Germplasm Improvement program is directed at increasing the feed and food production of forage legumes, and the productivity of farming systems in the dry areas. The program is targeted at farm households and particularly livestock owners in marginal lands, where interruption of continuous cereal cropping with forage crops increases the feed supplies for livestock (ICARDA 2001). Feed resources can also be augmented through the use of suitable adapted self-regenerating forage legumes in rehabilitating non-arable grazing lands.

The goals of ICARDA's work on forage legumes are first to enhance production from mixed crop/livestock farming systems based on improved productivity and nutritional content of forage legumes (*Vicia* spp. and *Lathyrus* spp.) for livestock feed in the marginal low rainfall areas (ICARDA 2001). Second, the work aims to improve the source of dietary protein in areas where grasspea (*Lathyrus sativus*) is a major food crop, by developing germplasm with safe neurotoxin content that will reduce the incidence of neurolathyrism.

9.2 Use of ICARDA's Forage Legume Material in Australia

Australia's pasture legumes originate from the Mediterranean Basin (ICARDA 1997). ICARDA has a collection of pasture legume species that are well adapted to the regions of Australia with Mediterranean climate. The annual medicago species are suited to the soils in South Australia and Western Australia.

An active collection effort by Australians in the Mediterranean region prior to the establishment of ICARDA provided the foundation for medic pasture selection and production in Australia. Considerable Australian efforts to establish ley-farming systems of cereals in rotation with self-regenerating annual medics were carried out in Libya, Tunisia, Iraq, Syria and Jordan with mixed success (Christiansen *et al.* 1993, 2000; Petersen *et al.* 2002).

Australia uses only seven of the 26 annual medic species. The other species have important characteristics such as delayed germination and high hard-seededness. ICARDA scientists and their CWANA colleagues are working to incorporate those characteristics into the species of importance in their regions. In addition, they are developing new approaches to the selection of pasture legumes based on an understanding of their distribution and evolution (ICARDA 1997).

The lathyrus variety 'Chalus' *(Lathyrus cicera L.)* was developed by the Centre for Legumes in Mediterranean Agriculture (CLIMA) and the germplasm evaluation team in Agriculture WA. It is a high yielding and high quality *Lathyrus cicera* cultivar suitable for low and medium rainfall areas of Australia. It was jointly released by CLIMA and Agriculture Western Australia in August 1998. Chalus was selected for adaptation to Western Australian conditions from the line IFLA 1279 supplied by ICARDA.

Other lines based on ICARDA materials that are currently being tested in programs are subterranean vetch, *Vicia amphicarpa*, and Trifolium species, *Ornithopus compressus*, *Biserrula pelecinus*, and *Lotus ornithopioides*.
The characteristics in the ICARDA materials of most interest to Australia include agronomic traits such as flowering time and vigour, and morphological characteristics such as growth habit, leaf size, and seed size. Pasture breeders further test germplasm for characteristics such as hard seed levels, seed head shattering, dry matter production, seed production, and regeneration. Early maturity was also considered to be a characteristic of interest in ICARDA material being tested in one particular breeding program.

ICARDA outputs other than breeding lines have been an important resource to the Australian forage legumes breeding program. ICARDA and the University of Western Australia have collaborated on training programs. Several students have completed post-graduate degrees at the University of WA with the field work being conducted at ICARDA headquarters. Research findings on the ecology of annual legumes conducted by researchers at ICARDA have also been useful to Australian researchers.

It has not been possible in this study to develop a detailed analysis of the impact of ICARDA on the Australian forage legume industry. It is clear that there have been important contributions to the medic species grown in Australia. However, the lack of production and yield data and the difficulty of obtaining even basic statistics on the forage legume industry in Australia has made it an impossible task in the time and resources available in this study. In addition, there have been difficulties in determining the precise pedigrees and sources of germplasm included in many of the legume species and varieties involved. As a result, we have not been able to undertake detailed quantitative analysis, and the benefits estimated for Australia from ICARDA will understate the total benefits because it excludes the benefits that have been obtained for forage legumes.

Compared to the other materials, which flow into established or fast-growing commodity markets, ICARDA’s forage legume materials are at the earliest stage of use. Ultimately, these too can be expected to contribute positive impacts in Australia by marginally lowering the costs of feeding livestock. Perhaps more important, in terms of human impact, are ICARDA’s promising advances in low-neurotoxin legumes for domestic and export feed and food markets in the future. It is too early to confidently assess the future economic benefits of such advances for human health in the poorest countries. Therefore, we treat the question of forage legume impacts as we have the other intangible benefits such as those evident in the regular contacts of Australian scientists with ICARDA staff and associated national scientists in the CWANA region.

10. Discussion of Results and Implications

10.1 Aggregate Results

The aggregate annual benefits to Australia (in discounted 2001 dollars) over the period 2001 to 2022 are summarised in Table 10.1. Australia is estimated to benefit from the activities of ICARDA by an average of A$13.7 million per year, over the period to 2022. The most significant gains for Australia are made in faba beans and lentils, two smaller industries that are based strongly around germplasm from ICARDA. Smaller benefits are obtained for barley and chickpeas. For durum, the welfare gains from higher productivity are marginally outweighed by the effects of the lower world prices from ICARDA's success in its research, so that overall there is a loss of welfare in the Australian durum industry. In aggregate, however, the net effect is a significant gain for Australia from the work of ICARDA.

Table 10.1: Net Welfare Gains[a] for Australia from ICARDA
(Average annual benefits for 2001 to 2022)

	Barley (A$m)	Durum (A$m)	Chickpeas (A$m)	Faba beans (A$m)	Lentils (A$m)	Total (A$m)
Producers	1.8	-1.2	1.1	6.0	4.9	**12.6**
Consumers	0.6	0.3	0.1	0.1	0.0	**1.1**
Total	***2.4***	***-0.9***	***1.2***	***6.1***	***4.9***	***13.7***

a: Discounted to 2001 Australian dollars at 5% per annum

It is apparent from the figures in Table 10.1 that the benefits to Australia go predominantly to producers. The consumption of pulses such as kabuli chickpeas, lentils and faba beans in Australia is small, so there are likely to be few benefits from lower prices resulting from the increase in productivity. For durum wheat, where more of Australia's production is consumed domestically, consumers gain, but still receive gains of considerably less than A$1 million per year. For barley, as with the food legumes, producers obtained more of the gains than did consumers.

Thus, while each of the crops in Australia faced lower world prices as a result of the success of ICARDA in its mandate, all except durum received productivity gains from the germplasm obtained from ICARDA to more than counter the price reduction. Australian consumers of all crops gain from the lower level of prices, although those gains are generally small.

10.2 Reliability of Results

The sensitivity analysis carried out for each crop shows that the results are sensitive to the values of some of the parameters used in the analysis. In particular for the base data, all results are approximately proportional to the prices used in the analysis. For a price 20% higher, the net gains are generally approximately 20% higher as well. Similarly, the results are generally inversely proportional to changes in the discount rate. The results are generally insensitive, however, to the supply and demand elasticities used in the analysis. For the specific analysis, the findings are dependent on the estimated cost reductions for each of the crops. They are relatively sensitive to the estimated cost reductions used for Australia. As well, the impact on Australia is dependent on the future level of production in Australia.

Nevertheless, the parameter values are based on the best available data. As a result, we have confidence that the findings are the “best” estimates that could have been developed from the available information.

It is apparent that the outcomes are most sensitive to the yield gains in the Rest of World, since the price consequences can be very important for export-oriented countries such as Australia.

As expected, the aggregate results obtained are sensitive to the values of several of the parameters that have been used in the analysis. In addition, the relative gains of Australian producers and consumers vary with the values used. It is apparent that further success by ICARDA in its mandate areas will put further downward pressure on prices below what they would otherwise be, so that unless Australia continues to obtain productivity benefits from ICARDA, Australia will suffer loss of welfare from the lower prices. Of course, for consumers in developing countries the greater availability of these grains at lower prices is a boon, and this is one of the key aims of ICARDA and the other CGIAR centres.

10.3 Implications of Results

There are several implications of the findings of this study:

(a) International Centres such as ICARDA remain a source of materials for potential yield gains for Australian crops, even those crops grown in systems and environments significantly different from those targeted by the international centres.

(b) Australian producers will be affected by the price implications of the successful research that is undertaken by the international centres, whether or not they take advantage of the possible yield gains spilling over.

(c) Consumers of these grains are also likely to be significant beneficiaries of any research advances in the grains industries, although most of those consumers are overseas where Australia exports a large proportion of production.

(d) Australia’s gains are likely to be greatest for those industries where there are significant links between Australian researchers and the researchers and programs being undertaken in the international centres. As a result, personnel interchange and overseas visits by Australian researchers to those centres are likely to have significant pay-offs for Australian grains industries, since they are a principal means of developing those links. Funding to support international collaboration also has a key role to play. The subsequent reduced time lags for the exchange of research information are also likely to result in increasing the impacts.

(e) Australian researchers need to maintain their vigilance over international agricultural research developments. Only where Australian researchers can keep abreast of developments in other parts of the world can the benefits for Australian producers be maintained. Producers continually face the long-term decline in real prices that results from the ongoing success of agricultural research around the world, in both national and international institutes, to increase yield levels for so many significant crops. The long-term decline in real prices is likely to occur whether or not Australia contributes to the international agricultural research system, and Australia's best opportunity to glean spillover benefits from the system lies in being part of the system through financial support.

Declines in commodity prices can lead to significant benefits for Australian consumers of grains, whether in consuming grain products directly or in consuming livestock products that use lower-priced feed grains. As in Brennan and Bantilan (1998), those benefits to consumers in developed countries such as Australia have been found in this study to be significant in some industries. The findings of this study reinforce the importance of the price effects in evaluating the economic benefits spilling over from international agricultural research.

10.4 Conclusions

In conclusion, this study has identified anticipated spillover benefits in terms of cost reduction for producers in five of the ICARDA mandate crops, namely barley, durum wheat, kabuli chickpeas, faba beans and lentils. Those cost reductions are generally expected to result from yield increases attributable to germplasm developed at ICARDA or acquired through ICARDA's germplasm improvement program and incorporated into genotypes that will be grown in Australia, or from particular resistances in the germplasm. In addition, the price effects of international agricultural research for these crops were found to be significant. With four of the five ICARDA mandate crops analysed, Australian producers stand to gain more through their productivity improvements than they lose through lower world prices.

Overall, Australia is estimated to receive significant benefits from ICARDA's research over the next 20 years, at an average of A$13.6 million per year. Recognition of these impacts can assist in leading to better-informed decision-making for research resource allocation and is likely to lead to a more efficient, and more cooperative, research system worldwide. That improved system will deliver expected improvements in the efficiency of production and in the delivery of appropriate food cheaply to the consumers around the world most in need.

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Appendix A:
Australian Area, Yield and Production Data for ICARDA Mandate Crops

Appendix Table A.1: Barley Area, Yield and Production

Year	NSW	Vic.	Qld	WA	SA	Tas.	Australia
Area Sown (000 ha)							
1992-93	560	551	189	611	1023	12	2946
1993-94	623	639	232	799	1115	15	3423
1994-95	410	492	93	579	882	14	2470
1995-96	593	628	168	745	964	14	3112
1996-97	668	585	180	909	1009	15	3366
1997-98	701	618	135	1017	1036	13	3520
1998-99	560	550	120	825	1020	12	3087
1999-00	450	580	130	530	846	9	2545
2000-01	420	595	91	910	925	12	2953
2001-02	530	625	80	950	965	12	3162
Yield (t/ha)							
1992-93	1.86	2.03	1.51	1.74	1.81	2.92	1.83
1993-94	2.10	2.71	1.13	1.73	2.00	2.73	2.03
1994-95	0.71	0.91	0.78	1.58	1.31	1.93	1.18
1995-96	1.81	2.14	1.16	1.78	1.92	2.71	1.87
1996-97	2.22	2.03	2.38	1.80	1.91	2.33	1.99
1997-98	1.95	1.50	1.52	1.99	1.86	2.38	1.84
1998-99	2.05	1.45	1.67	1.76	2.01	2.50	1.84
1999-00	2.34	2.04	1.99	2.11	1.67	2.22	1.98
2000-01	2.07	2.10	1.16	1.27	2.31	2.50	1.88
2001-02	2.15	1.88	1.25	1.60	2.03	2.42	1.87
Production (000 t)							
1992-93	1044	1116	285	1061	1855	35	5396
1993-94	1310	1733	262	1381	2229	41	6956
1994-95	291	448	73	915	1159	27	2913
1995-96	1074	1342	195	1323	1851	38	5823
1996-97	1483	1189	429	1635	1923	35	6694
1997-98	1365	928	205	2027	1926	31	6482
1998-99	1150	800	200	1450	2050	30	5680
1999-00	1052	1181	259	1120	1410	20	5042
2000-01	870	1250	106	1160	2140	30	5556
2001-02	1140	1175	100	1520	1959	29	5923

Source: ABARE (2001) and earlier issues.

Appendix Table A.2: Durum Wheat Area, Yield and Production

Year	NSW	Qld	SA	Australia
Area Sown (000 ha)				
1992-93	28	2	10	39
1993-94	43	3	21	66
1994-95	102	3	14	119
1995-96	82	5	24	111
1996-97	66	3	34	103
1997-98	103	4	34	141
1998-99	130	5	46	180
1999-00	262	12	149	423
2000-01	92	4	43	139
2001-02	233	na	167	400
Yield (t/ha)				
1992-93	1.75	0.88	2.04	1.78
1993-94	2.62	1.00	2.17	2.41
1994-95	0.48	0.51	1.38	0.59
1995-96	1.72	0.76	2.31	1.80
1996-97	2.85	2.00	2.24	2.63
1997-98	1.97	1.49	2.42	2.06
1998-99	2.16	1.76	2.45	2.22
1999-00	2.54	1.55	1.79	2.25
2000-01	2.43	1.60	2.08	2.30
2001-02	1.50	na	1.80	1.63
Production (000 t)				
1992-93	49	1	20	70
1993-94	112	3	45	160
1994-95	49	1	20	70
1995-96	140	4	56	200
1996-97	189	5	76	270
1997-98	203	6	81	290
1998-99	280	8	112	400
1999-00	665	19	266	950
2000-01	224	6	90	320
2001-02	350	na	300	650

Source: Derived by the authors from industry estimates (R. Hare, personal communication).

Appendix Table A.3: Chickpea[a] Area, Yield and Production

Year	NSW	Vic.	Qld	WA	SA	Tas.	Australia
Area Sown (000 ha)							
1991-92	85	90	58	1	16	0	250
1992-93	28	78	33	1	12	0	152
1993-94	26	100	7	3	9	0	147
1994-95	20	144	19	13	13	0	209
1995-96	35	101	30	30	11	0	207
1996-97	34	144	20	45	12	0	255
1997-98	40	80	30	40	15	0	205
1998-99	60	80	56	54	15	0	265
1999-00	60	15	60	63	7	0	205
2000-01	90	6	85	50	2	0	233
2001-02	48	84	40	30	11	0	213
Yield (t/ha)							
1991-92	0.62	1.26	0.63	2.40	1.21		0.89
1992-93	0.88	1.63	0.44	1.60	0.76		1.17
1993-94	1.08	1.46	0.57	1.00	1.14		1.31
1994-95	0.38	0.26	0.41	0.60	0.61		0.33
1995-96	1.14	1.68	0.27	0.83	1.36		1.25
1996-97	0.88	0.97	2.00	1.07	1.67		1.09
1997-98	1.25	0.78	0.83	1.00	0.93		0.93
1998-99	0.67	0.25	0.89	0.74	0.67		0.60
1999-00	1.10	1.00	0.75	0.90	0.57		0.91
2000-01	1.00	1.17	0.88	0.80	1.00		0.92
2001-02	0.90	1.04	0.77	1.09	0.99		0.94
Production (000 t)							
1991-92	53	113	37	1	20	0	223
1992-93	25	128	14	2	9	0	177
1993-94	29	146	4	3	11	0	193
1994-95	8	38	8	8	8	0	69
1995-96	40	170	8	25	15	0	258
1996-97	30	140	40	48	20	0	278
1997-98	50	62	25	40	14	0	191
1998-99	40	20	50	40	10	0	160
1999-00	66	15	45	57	4	0	187
2000-01	90	7	75	40	2	0	214
2001-02	43	84	31	26	11	0	195

a Includes both desi and kabuli chickpeas.
Source: ABARE (2001) and earlier issues.

Appendix Table A.4: Faba Bean Area, Yield and Production

Year	NSW	Vic.	Qld	WA	SA	Tas.	Australia
Area Sown (000 ha)							
1991-92	8.8	30	0	0	19.4	0	58.2
1992-93	16	37	0	2	27	0	82
1993-94	16	45	0	4	22	0	87
1994-95	20	30	0	15	21	0	86
1995-96	16	26	0	20	20	0	82
1996-97	12	30	0	25	23	0	90
1997-98	30	30	3	40	30	0	133
1998-99	27	24	0	24	32	0	107
1999-00	22	40	0	10	53	0	125
2000-01	45	55	0	14	63	0	177
2001-02	21	35	0	15	31	0	103
Yield (t/ha)							
1991-92	1.25	0.83			1.46		1.11
1992-93	1.75	1.08		1.00	1.07		1.21
1993-94	2.50	1.22		1.25	1.59		1.55
1994-95	0.50	0.47		0.53	0.86		0.58
1995-96	1.31	1.54		1.20	1.70		1.45
1996-97	2.08	1.00		1.20	1.65		1.37
1997-98	0.67	1.00	0.67	0.45	2.17		1.02
1998-99	0.74	1.25		0.75	2.03		1.24
1999-00	1.09	1.45		1.00	1.40		1.33
2000-01	1.71	1.45		1.00	1.51		1.50
2001-02	1.36	1.13	0.67	0.93	1.54		1.24
Production (000 t)							
1991-92	11	25	0	0	28.4	0	64.4
1992-93	28	40	0	2	29	0	99
1993-94	40	55	0	5	35	0	135
1994-95	10	14	0	8	18	0	50
1995-96	21	40	0	24	34	0	119
1996-97	25	30	0	30	38	0	123
1997-98	20	30	2	18	65	0	135
1998-99	20	30	0	18	65	0	133
1999-00	24	58	0	10	74	0	166
2000-01	77	80	0	14	95	0	266
2001-02	28	40	0	13	48	0	129

Source: ABARE (2001) and earlier issues.

Appendix Table A.5: Lentil Area, Yield and Production

Year	NSW	Vic.	Qld	WA	SA	Tas.	Australia
Area Sown (000 ha)							
1991-92							
1992-93							
1993-94							
1994-95	0	5	0	0	0	0	6
1995-96	0	6	0	1	1	0	8
1996-97	1	15	0	0	2	0	18
1997-98	1	50	0	1	5	0	57
1998-99	1	70	0	2	9	0	82
1999-00	1	55	0	2	17	0	75
2000-01	2	78	0	6	25	0	111
2001-02	1	40	0	2	8	0	51
Yield (t/ha)							
1991-92							
1992-93							
1993-94							
1994-95		0.41		0.67	0.75		0.45
1995-96	0.50	2.50		0.80	1.30		2.18
1996-97	0.30	2.33		0.75	1.00		2.04
1997-98	1.00	0.56		1.00	1.20		0.63
1998-99	1.00	0.43		1.00	1.44		0.56
1999-00	1.00	1.40		1.00	1.35		1.37
2000-01	1.00	1.26		1.00	1.40		1.27
2001-02	0.80	1.27		0.89	1.21		1.22
Production (000 t)							
1991-92							
1992-93							
1993-94							
1994-95	0	2	0	0	0	0	3
1995-96	0	15	0	0	1	0	17
1996-97	0	35	0	0	2	0	38
1997-98	1	28	0	1	6	0	36
1998-99	1	30	0	2	13	0	46
1999-00	1	77	0	2	23	0	103
2000-01	2	98	0	6	35	0	141
2001-02	2	98	0	6	35	0	141

Source: ABARE (2001) and earlier issues.

Appendix B: Survey of Research Programs on Impact of ICARDA on Australian Agricultural Production

B.1 List of Respondents

Eric Armstrong, NSW Agriculture
Phil Banks, Queensland Department of Primary Industries
Andrew Barr, University of Adelaide
Philip Beale, University of Adelaide
Rodger Boyd, University of WA
Trevor Bretag, Agriculture Victoria
Bob Brinsmead, Queensland Department of Primary Industries
Jan Bert Brouwer, Agriculture Victoria
Tony Brown CSIRO-Plant Industry
Phil Cocks, University of WA
Brian Dear, NSW Agriculture
Russell Eastwood, Agriculture Victoria
Frank Ellison, University of Sydney
Clive Francis, Centre for Legumes in Mediterranean Agriculture
Ray Hare, NSW Agriculture
Rob Henry, Southern Cross University
T.J. Higgins, CSIRO-Plant Industry
Gil Hollamby, University of Adelaide
Steve Hughes, University of Adelaide
Paul Johnston, Queensland Department of Primary Industries
Akram Khan, NSW Agriculture
Ted Knights, NSW Agriculture
David Loyd, Queensland Department of Primary Industries
David Luckett, NSW Agriculture
Harry Marcellos, NSW Agriculture
Michael Materne, NSW Agriculture
David Moody, Agriculture Victoria
Blakely Paynter, Department of Agriculture WA
Mark Ramsey, SA Research and Development Institute
Barbara Read, NSW Agriculture
Greg Rebetzke, CSIRO-Plant Industry
Ian Rose, NSW Agriculture
John Sheppard, Queensland Department of Primary Industries
KHM Siddique, Department of Agriculture WA
Richard Snowball, Department of Agriculture WA
Neil Turner, CSIRO
Joop van Leur, NSW Agriculture
Hugh Wallwork, SA Research and Development Institute
Graham Wildermuth, Queensland Department of Primary Industries
Peter Wilson, SunPrime Seeds
Meixue Zhou, Tasmanian Institute of Agricultural Research

B.2 Questions in Survey

1. Have you or your organisation released cultivars that were developed by ICARDA? If so, please provide details.

2. Have you or your organisation released cultivars that have ICARDA materials in their pedigrees? If so, please provide details.

3. Are you currently using ICARDA material in your crossing program? If so, please specify the main lines that you are currently using and the characteristics you are seeking from them.

4. Are there ICARDA lines or lines based on ICARDA materials among your current advanced lines? If so, please identify the ICARDA materials, and provide details of the stage of the lines.

5. Are there ICARDA lines or lines based on ICARDA materials among the materials that are being tested in your trials? If so, please identify.

6. If you are using or testing ICARDA lines or lines based on ICARDA materials, what characteristics of those materials are of most interest to you?

7. Are there ICARDA outputs other than breeding lines that you have used or are using (eg, analytical techniques, screening methods, etc)? Please specify.

8. Do you have regular contact with ICARDA, such as regular visits?

9. Any other comments on the impact of ICARDA in Australia?

Appendix C: ICARDA Varieties Released by Australian Breeding Programs

Appendix Table C.1: ICARDA Varieties Released by Australian Breeding Programs

Barley	
1989	Yagan
1993	Kaputar
1993	Namoi
Lentil	
1989	Aldinga
1993	Digger
1993	Cobber
1993	Matilda
1995	Northfield
1998	Cumra
1998	Cassab
Forage Legumes	
1998	*Lathyrus cicera* Chalus

Source: http://www.icarda.cgiar.org/CVR/cvr.html

Appendix D: ICARDA's Collaboration in Research with Australia

Australian Winter Cereals Collection, Tamworth
- Development and conservation of plant genetic resources in the Central Asian Republics

Australian Temperate Field Crops Collection, Horsham
- Development and conservation of plant genetic resources in the Central Asian Republics

University of Adelaide, CRC for Molecular Plant Breeding, Waite Campus
- International collaboration in barley research

Charles Sturt University, NSW
- Soil physical characteristics in relation to infiltration and surface evaporation under conventional and no-till operations

CLIMA (Centre for Legumes in Mediterranean Agriculture)
- Improvement of drought and disease resistance in lentils in Nepal, Pakistan and Australia
- Faba bean germplasm multiplication
- Germplasm testing and assessment of anti-nutritional factors: *Lathyrus* spp. and *Vicia* spp.
- International selection, introduction and fast tracking of kabuli chickpea
- Development and conservation of plant genetic resources in the Central Asian Republics
- Preservation of the pulse and cereal genetic resources of the Vavilov Institute
- Pulse transformation technology transfer

La Trobe University
- Development and use of molecular genetic markers for enhancing the feeding value of cereal crop residues for ruminants

NSW Agriculture, Tamworth Centre for Crop Improvement
- Durum wheat improvement
- Selection of legume germplasm for virus disease resistance

Plant Breeding Institute, University of Sydney
- Near isogenic lines for the assessment of pathogenic variation in the wheat stripe (yellow) rust pathogen

Victorian Institute for Dryland Agriculture, Horsham
- Improvement of drought and disease resistance in lentils in Nepal, Pakistan and Australia
- Improvement of lentil and grasspea in Bangladesh
- Improvement of narbon vetch for low rainfall cropping zones in Australia

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Source: ICARDA Annual Report 2000, Appendix 5:
http://www.icarda.cgiar.org/publications/annualreport/2000/app%205/app5.html

NSW Agriculture

Economic Research Report series

Number

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