

## Synergies of public-private grower-based research in the Western Australian grains industry

Jeff Russell

Grain Industry Development Officer, Centre for Cropping Systems, PO Box 483, Northam.  
Email: jeff.russell@agric.wa.gov.au

**Abstract.** The Department of Agriculture and Food Western Australia (DAFWA) assisted the research activities of the Kellerberrin Farm Demonstration Group (KFDG) from January 2003 to July 2007. This assistance was delivered through the Northam Advisory District's Farming Systems Project (NAD-FSP) of the Central Agricultural Region (CAR) and the results of the research outcomes have been delivered to the wider grains industry over the last 6 years. The results of an evaluation into the effectiveness of this work are documented to: 1) quantify the extent of the value that this assistance has for those members of the KFDG, and 2) assess the potential value that the KFDG research has had for the wider farming community and state's grains industry. Data for the evaluation was collected through the use of an email survey of both the group members and research support providers. Estimates of the value of individual outcomes of some specific research activities are also provided. A Benefit/Cost analysis has been calculated on the quantified results of the research outcomes and the likely impact this has had on the wider grains industry. The conclusion formed is that this assistance with the KFDG research is likely to have been one of the most successfully orchestrated research activities ever conducted by DAFWA to influence the state's grains industry. The work achieved impact in 3 key DAFWA strategic plan strategies of Production Efficiency and Growth, Environmental Stewardship and Capacity. It also met 2 of DAFWA's service delivery strategy areas of Community and Client Perspective and People, Learning and Innovation Perspective. A key recommendation is for the continuance and expansion of similar services providing group support for innovative research regionally and state-wide within DAFWA's Farming Systems Project where practicable. Three key learnings: Growers can competently conduct broadscale research if appropriately supported with assistance for design and analysis. In the support model described, extension of the results can be widespread and have greater impact because it is grower driven. Government resources can be applied with high returns on investment.

**Keywords:** On-farm research, benefit-cost analysis, extension, evaluation

### Introduction

Since 1999, the Kellerberrin Farm Demonstration Group (KFDG) has been conducting a number of 'On Farm Research' (OFR) experiments to investigate numerous cropping issues that affect the profitability of a grower's cropping enterprise. The group was able to access funding from the Grains Research and Development Corporation (GRDC) DAW 599 project to assist with building a weigh trailer for these purposes in 2002. From early 2003 the Department of Agriculture and Food (DAFWA) invested resources to assist the group through the provision of a Farming Systems Development Officer to help with the design of experiments, the analysis of the results and in the writing up of these for extension to the broader community through the Agribusiness Crop Updates (Russell and Roe 2004a,b; Russell 2005; Russell and Roe 2005a,b,c; Russell et al. 2006a,b, 2007a,b,c), DAFWA AgMemos (2006, 2007), media releases (GRDC 2004; Countryman, 2004, 2005, 2006 and 2007) and National and International conferences and symposia (Russell and Roe, 2004c; Russell et al. 2006c,d, 2007d).

With the conclusion of a 5 year project cycle, an evaluation of DAFWA's work with the group was conducted in 2007 to review the value of this work and determine the outcomes from this activity being conducted through the Farming Systems Project (FSP) in the Central Agricultural Region (CAR) of Western Australia.

### Method

A survey questionnaire was emailed out to group members after discussions with the Agribusiness partners of the group – ConsultAg, Northam (formerly Farm Focus). This is in keeping with the group management protocols. Growers actively engaged in the research were contacted as they are the 'first users' of the services provided by the FSP's input. The survey sought information on the types of activities conducted, the resultant changes that were made and a quantified assessment of the value of these changes to the grower and the value of the support given to them by DAFWA. The information supplied by the growers and from the annual research reports of the group's OFR results as produced by the consultancy firm was then used to construct a 'Benefit/Cost analysis' (BCA).

The BCA was undertaken using only a number of high profile research findings that have been made by the group, these having been published in the annual Agribusiness Crop Updates of

2002 to 2007 and conferences (see references above) and reviewed by peers within the industry. In these, an economic analysis of the range of gross benefits and/or costs of the many different treatment practices in these reports had been calculated. The estimated scope of the potential physical area of impact that these results are likely to have some influence was made using the following assumptions for the respective areas of grain cropping within Western Australia based on Grains Industry Plans (February 2007, DAFWA internal document). Unlike more detailed BCAs in the grains industry (i.e. Tozer 2006, Evans 2006, or Blanchard 2007) discount rates and scales of adoption are not included here as the timeframe of this project and the delivery of the results to the wider industry is seen as being much shorter, within 5 years as opposed to 10 to 25 years in the examples mentioned. In fact a number of the practices evaluated and reported on are already now deemed mainstream in Western Australia. Key assumptions were:

4. Term of analysis: Immediate benefits over 5 years.
5. Scale of adoption:
  - Area of wheat applicable: 4 million ha. Estimated area of wheat on wheat: 2 million ha.
  - Area of barley applicable: 600 000 ha.
  - Area of canola applicable: 150 000 ha.
  - Area of lupins applicable: 350 000 ha.
6. Years of adoption: Varies from 2004 to 2008.
7. 5 year average commodity prices \$/t FOB GST exclusive as to 2006/07.

The cost component to the BCA was calculated on the DAFWA value of input allocated to this activity and was calculated from the PSA (Project Staff Allocation) and PAPDR (Performance Appraisal and Personnel Development Review) documentation from the individual financial years of 2002 to 2007. Overheads were included at 20% of salaries. Based on the range of the calculated benefits to the grains industry, an average was identified within this range. The average was calculated and an annual current estimate was derived from this. The BCA ratio was then calculated.

## Results

### 1. 'First users' survey

A majority of survey respondents (80%) had been with the KFDG since 1999. About 20% had come into the group since about 2005 while others dropped out. The KFDG is currently open to all local community members to attend and at the time of the survey, numbered 12 growers. The priority for this membership is to be active through the implementation of at least one OFR activity in each year. These activities are planned at the beginning of the season at the planning meeting which can be seen as the commencement of a new action learning cycle (Kolb, 1984). A list of some of the activities nominated to have been undertaken by the respondents during the period of 1999 to 2006 is seen in Table 1.

**Table 1. Research activities by KFDG survey respondents from 1999 to 2006\*.**

Activity	Years	Participants
Wide row spacing in lupins	2001, 2002, 2003	4
Manganese in wheat	2004, 2005	1
Manganese in lupins	2004, 2005	2
Lupin row orientation	2002, 2003	3
N and seeding rates of wheat	2005	1
Barley nutrition rates	2005, 2006	2
Potassium response cereals	2003, 2004, 2005	4
Seeding rates for barley	2003	1
Fungicides in barley	2003, 2004, 2005	1
Nutrition in cereals	2004, 2005	2
Renovation cropping	2005, 2006	2
Lime, ripping trials	2006	1
Disease management in wheat	2003, 2004, 2005	2
Row spacing in canola	2001	1
UAN v CAN in wheat	2005	1

\* Does not include all activities undertaken by the KFDG during the period 1999 to 2006.

All respondents indicated that they had applied a number of the outcomes from the research findings to their own cropping practices. All growers were able to give direct examples of changes they have made to their cropping program. These examples are seen in Table 2 below.

**Table 2. The changes made by growers of the KFDG due to the outcomes of research conducted by the group (1999 to 2006).**

Applied findings from research.	Resultant changes in cropping practices (Provided by growers).	Percentage of growers adopting practice.
Lupin yields on wide rows are often greater than on narrow rows especially in drier years.	Now sow lupins on wide rows. Adopted wide row spacing of lupins Lupins are easier to harvest as they are taller.	80%
Soil test for potassium is not a good indicator of the need for K fertiliser.	Have a more efficient application of K fertiliser. Band K with seed rather than top dress. From work done by the group it is obvious that in many cases we are not getting an economic response from Potassium in the year of application. This has made me be far more selective about K applications and invest more money in tissue testing in an effort to try and isolate problem paddocks.	60%
Fungicides applied at seeding in a wheat on wheat scenario are an advantage. Especially flutriafol.	Better fungicide application and timing. More confidence of extra input in returning investment and security in disease management. Use flutriafol in all wheat plantings - Pre. More tactical application of fungicides to cereal crops. More profit. 2008 and will see the adoption of Impact in furrow on the whole wheat program directly as a result of work done by this group.	80%
No advantage in late application of fungicide for stem rust in a dry year.	Will be more prudent about investing in money in late stem rust control in wheat.	20%
Fertiliser responses in cereals.	Apply Mn on sandy grit soils. UAN is far ahead of CAN on my farm in most seasons.	40%
Barley agronomy	Lowered the seeding rate for barley	40%
Establishing a low cost brown manure crop may not pay.	Brown manure is a expensive option that is unlikely to pay for itself	20%

Value of the research to the grower The ability to put an actual monetary value on the research findings by members of the KFDG was difficult to quantify. 60% indicated that they could not. Their responses were more descriptive than quantitative. Still they were able to give examples of the extent of the resultant changes to their cropping practices have had in improving production in the examples below.

*"Done as the results indicate. If no response, don't do it, if a response do it."*

*"As a result of work done by this group I have changed or implemented many practices."*

*"Using research done by the group, I felt as though I have access to independent information gathered on a local basis about what is likely to be economic on my own farm."*

*"Better yield and quality."*

*"More consistent lupin yields."*

*"More cost effective approach."*

*"Unknown – but gives us more confidence in what we are doing."*

*"Greater and more secure yields from fungicide work."*

*“Row spacing – wide rows consistently yielding greater in lower potential situations.”*

*“Probably led to better lupin crops.”*

*“Work done in conjunction with CSIRO and the group on the brown manure trial in 2006 gave me a far better understanding of the ability of different soil types to store water. With a significant amount of wheat still to sow in late June 2006 this information allowed me to make far more informed decision about what paddocks to sow and where I had the best chance of making a reasonable return in a very tight season.”*

Other statements given by the growers referred to the value gained from being involved in doing OFR through learning or knowledge gained from being involved.

*“Learning more of deep soil constraints (restraints)”.*

*“Better knowledge of soils.”*

*“The field walks help to do tissue testing and agronomy measurements.”*

*“CSIRO work on soil moisture in the soil profile.”*

*“Certainly let us be far more flexible with our lupin planting programme. Wide rows allow us handle far more stubble hence eliminate the need for residue management and decisions can be made as the season unfolds about what paddocks to plant. In the past all potential lupin paddocks would have been raked to remove straw to a manageable level and then seeded only if seasonal condition looked favourable. Wide rows have a number of other agronomic advantages from our point of view.”*

*“More knowledge – K in the system, where response is more likely.”*

*“Ongoing work will allow us to make better decision as to the most effective timing of fungicides sprays in our malt barley crops.”*

*“With potassium (K) – more confidence in balancing nutrient status.”*

The other 40% of members indicated that a value could be attributed but not as a ‘whole of cropping enterprise’ value, more so from what was obtained from the direct results of the work that was conducted. For instance, as a value of \$/ha, estimates were given with the following examples.

*“A possible saving of \$15/ha by not using MacroPro.”*

*“10% yield improvement in lupins with wider rowspacing (Representing \$20 - 25/ha)”*

*“100 – 200% return on fungicide investments.”*

When asked to then give an estimate of the value of the KFDG’s work to the wider grains industry it was harder to do. No respondent tried to quantify this in dollar (\$) terms. Of the 60% that tackled this question, the consensus was that it was perceived to be *“highly valuable for the central and eastern wheatbelt and associated areas”* of the state. The *“row spacing of lupins is seen now as an accepted practice within the industry”*. While gaining *“a better understanding of the moisture relationships in the soil profile was one for the future”*.

The key driver of this work having an impact on the wider community was seen as being the level of adoption by other growers in the wider grains industry. Additional to this, extension of the results arising from this research were provided through a network of Agribusiness agencies within the northern and central wheatbelt regions. ConsultAg, Northam had also been contracted by a private agribusiness network to deliver updates and fieldwalks throughout the years. This enabled transfer of information to a large number of growers estimated at over 400 annually in these regions at no cost to DAFWA.

Value of DAFWA involvement with the KFDG The department’s provision of a staff member to assist the group was overwhelmingly highly valued by 80% of the growers surveyed. The value of this support was ranked as 9 out of 10 for quality and valued by members as being able to validate the credibility of the group’s work at a scientific level that could otherwise not be given.

*“Brings professional credibility to trial sites”.*

*“Gives a different scientific rigour to the trials”*

*“Credibility of trials”.*

*“Essential in assisting with trial design and analysing the results”.*

The KDFG members considered the DAFWA staff member to be extremely suitable for the work involved. A gross ranking of 9.2 out of 10 for suitability to the task was returned by the group.

## **2. Benefit/cost analysis**

The value of investment by DAFWA into supporting the KDFG is shown in Table 3 for the five years from 2003 to 2006/07. Prior to this, a GRDC funded project DAW599 supported this work and a time allocation to the KDFG was not required to be allocated.

**Table 3. The value of DAFWA’s input from 2003 to June 30 2007 based on the time allocated within the FSP including overheads and operating.**

<b>Year</b>	<b>Value (\$)</b>
January 1 to June 30, 2003	3 873
2003/2004	7 496
2004/2005	15 024
2005/2006	15 546
2006/2007	16 224
<b>Total DAFWA investment</b>	<b>\$58 163</b>

The cost of this work to DAFWA through the FSP is estimated as being about \$58 000 over the 5 years of 2003 to 2007. That averages about \$11 600 pa. A more current cost in the order of \$16 200 pa. is based on the latest budget of 2006/07. So this current cost will be used to calculate the value as at 2007, the end of the 5 year cycle in the project.

The benefits to Western Australia’s grains industry of some of the documented research activities undertaken by the KDFG that were given the greatest promotion and extension are shown in Table 4. The results summarise the nature of the findings, the avenues of extension of the results and estimated value to the industry based on the area of impact. Not all activities are assessed, as research was still continuing into 2007 and 2008.

The Net Present Value (NPV) of the benefits to the grains industry was estimated as ranging from \$30 million pa. at the lower end to \$140 million pa. at the upper end based on assumptions made as to the area of allocation of these benefits (Table 4). This is a very simple form of attribution and economists would probably like to do a more comprehensive analysis such as those found in Nazrul (2005, 2006) or Coyle (2007). However, an average current annual value of benefit could be in the order of \$80 million pa, based on immediate adoption of those practices listed in Table 4 for which monetary values have been documented.

## **Discussion**

It is clear from the ‘first users’ survey that the support given to the KDFG is both valued by the growers and seen to be considered important to the wider grains industry of Western Australia. As a result of having increased confidence in the outcomes of the research activities by having well designed and analysed activities, growers are seen to be adopting the findings and making changes to their cropping programs accordingly.

The comments provided by the members whether being able to give qualitative examples or not of monetary values, show a clear degree of use of the findings made by the OFR activities of the group. This indicates that the changes in cropping practices that have been adopted as a result of the research have a direct impact on their cropping enterprise.

The wider impact of this work on the state’s grains industry is seen by the fact that other organisations have also recognised the quality of the research. The Western Australian No-Till Farmers Association (WANTFA) was first to highlight the KDFG’s lupin row spacing research (WANTFA, 2003). This was the catalyst for a number of GRDC supported projects into lupin row spacings. Since 2005, CSIRO has become a research partner with the KDFG. The Agribusiness Crop Update program also increasingly featured the group’s research in 2006 and 2007. Likewise, DAFWA’s pathology group was able to corroborate the group’s outcomes in tactical crop disease management (Jayasena et al, 2007).

**Table 4. Benefits of the high profile and documented OFR activities conducted by the KFDG to 2006 and estimated annual value to the Western Australian grains industry based on assumptions.**

OFR activity.	Years run.	Resultant findings.	Extension Outputs.	Values calculated (\$/ha).	Industry value. (Estimated pa).
Lupin: Seeding rates	2001	Lower seeding rates improves yields in combination with wider spacings. Wide row spacing of lupins is a risk management technique for dry seasons. Now wide industry adoption. Orientation gave no advantage.	Crop Update papers, WANTFA, International symposium, Agronomy conference poster.	Average of \$14/ha	<b>\$4.9M</b> <b>\$7.7M - \$17.5M</b> (350 000ha)
Row spacing	2002			\$22/ha -	
Orientation	2003			\$50/ha	
Canola seeding rate	2002	Low seeding rates help manage crop risk in dry years.	Crop Update paper. Media release through GRDC.	Average \$55/ha benefit.	<b>\$8.25M.</b> (150 000ha)
Cover crop research	2002 2003	Spraying out volunteer pastures and brown manure crops late has yield and weed benefits.	Crop Update paper.	Average \$50/ha benefit.	Difficult to assess extent of the application.
Potassium research	2003 2004 2005 2006	Growers can improve efficiencies and save on costs by knowing K levels in the soil.	Crop Updates paper, national agronomy conference, media release and Agmemo.	Savings of \$10 - \$40 /ha.	If adopted over 15% of the area of cereal crops, could range from <b>\$10M</b> to <b>\$40M</b>
Wheat fungicide applications.	2003 2004 2005 2006	In a wheat on wheat scenario, Flutriafol fungicide applied at seeding is the most likely to insure against disease risk with 3 – 5% yield increases. Foliar applications can be tactical according to the season.	Crop Update papers, Agmemo and media release.	Ranges from \$3/ha to \$42/ha.	Application to about 2 million ha or more a year. <b>\$6M</b> to <b>80M</b> pa. potential value
Fungicide management in barley	2004 2005 2006	Foliar applications of barley need to be tactical based on risk associated with crop sequence, crop disease risk and seasonal outlook.	Crop Update paper. Barley Symposium paper	Savings of about \$15/ha for 2006.	Continuing research as at 2006.

### Summary statement of the benefit : cost ratio.

Based on the average estimate of value of \$80 million pa that was determined earlier, it can be seen that for every \$1.00 invested by DAFWA through the FSP about \$5 000 on average has been returned to the industry. This ranges on the lower end of \$1 875 through to \$8 642 at the upper end.

These ratios are superior to any other DAFWA projects reported in recent years (Nazrul, 2005, 2006; Coyle 2007) where the best benefit to cost ratio reported in the grains industry was 23.9 for lupin product development with DAFWA funding project costs of \$2.33M (Nazrul, 2005). Within those 3 years the very best that DAFWA has done in any of its programs was a BCA of 38.5 for bulk bin exports of apples (Nazrul, 2006). Yet in this analysis of the KFDG's OFR, a conservative area of influence within the state has only been factored in.

If the above is considered as being too wide an area of impact, then looking at a more localised area of impact such as those shires immediately surrounding the focus of this work where the environment is considered similar to that of Kellerberrin should not be unreasonable. Table 5 provides an estimate of the areas of the main grain commodities that were the focus of the OFR listed in table 4. If the benefits shown as \$/ha are applied to this area of impact and the BCA is calculated similarly then a return of \$1 100 pa is made for every \$1.00 invested by DAFWA in this activity. This is still a very good return on investment providing an average annual benefit of \$17.8M to the grains industry of these central wheatbelt shires.

**Table 5. Estimated area (ha) of the main grain commodities sown in 2006 for the shires around Kellerberrin\*.**

Shire	Wheat	Barley	Canola	Lupins
Kellerberrin	49 004	10 734	2 294	5 714
Wyalkatchem	37 975	7 972	600	3 177
Trayning	54 711	7 321	574	5 617
Nungarin	62 162	5 377	746	1 566
Merredin	109 557	15 772	2 611	4 470
Bruce Rock	102 659	32 281	6 541	6 299
Quairading	42 278	9 762	954	4 921
Tammin	35 930	9 011	1 543	4 466
Cunderdin	60 354	12 964	1 613	16 074
Total area	554 630	111 194	17 476	52 304

\* industry sourced data for the 2006/07 season.

Even if calculated in a more thorough way, taking into account adoption rates, depreciation and risk analyses, it would still seem that the NAD, FSP investment return in OFR with the KFDG is likely to exceed anything that any other DAFWA project may be capable of providing for the grains / agricultural industry of Western Australia. This work is simply put as being in orders of magnitude superior to any other DAFWA project in existence.

Not shown in this analysis is the level of in-kind support given to this work. It could be estimated that agribusiness contributed to about \$20 000 pa. It is documented that the GRDC contributed \$50 000 in support through 2 years funding from the Western Agribusiness Trial Network. The growers in conducting the research have also contributed greatly through the giving of time and the on the ground application of the research. This has been estimated at about \$20 000 pa.

If DAFWA was removed from this work, it would limit the scope of the exposure of the findings to the wider state's grains industry and hence overall industry benefits would be slower in their adoption relying on the 'diffusion process' rather than on active promotion within the grain's industry network. DAFWA aided the facilitation of the extension of the information to the wider state agribusiness network. Crop Update papers and presentations, papers to International and National conferences, media reports and AgMemo distribution statewide are driven by DAFWA. In addition to this the delivery to research staff within DAFWA and the Agricultural Research Western Australia (ARWA) networks would be limited along with the analysis service that is foundational to providing confidence in the findings delivered to growers. DAFWA is also seen by growers as being unbiased in the assessment of any commercial products and this carries high value in the broad-acre grains industry.

Agribusiness may not necessarily contribute as greatly to this work if DAFWA was removed from the process due to constraints to their time and the need to run a fee/service industry to growers to maintain their basic existence. It is also unreasonable to expect agribusiness to give valuable time and wear the burden of costs over and above their already generous in-kind contribution to this task. This has been recognised in recent years through the GRDC allocating funds to the Agribusiness research network in the 3 regions nationally.

### Conclusions

It can be seen from the success of this activity that the promotion and support of OFR by DAFWA has clear benefits that meet Key Strategy (DAWA, 2003) areas of 1) Production efficiency and growth, 2) Environmental stewardship and 3) Capacity in addition to Service Delivery strategies of 1) Community and Client perspective and 2) People, Learning and Innovation.

Arguably the FSP has had significant impact within the current Grains Industry Plans (2007, internal publication), in the areas of maintaining enterprise profitability within each of the grains commodity portfolios ie wheat, barley etc. This activity has demonstrated conclusively that it has been able to do this with wide industry impact. Wide row spacing of lupins and the application of fungicides at seeding (Jayasena et al, 2007) have been adopted by the wider grains industry.

From this example it could be considered that within the wider FSP across the broad-acre regions of the state, similar activities could be undertaken using staff best suited to advisory and with the necessary technical abilities to support the innovative key grower groups and agribusiness' where their time and resources are limited. That is to supply rigorous design and analysis services and to facilitate the extension of the information generated to the wider industry.

### Acknowledgements

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### References

- AgMemo 2006, '*Seeding with fungicides to increase wheat yields*', Department of Agriculture, Western Australia, Autumn article.
- AgMemo 2007, '*You need to delve deeper for potassium answers for your crop*', Department of Agriculture and Food, Western Australia, Autumn article.
- Blanchard, R 2007. '*Barley Breeding Project*' In Coyle P (ed) 2007, *Returns on R&D investment of DAFWA: Benefit cost analysis 2006 – 2007*, Department of Agriculture and Food, Western Australia, Bulletin 4736.
- Countryman, 2004. '*Crop booster*', May 30, 2004, p1.
- Countryman, 2005. '*Potassium answers sought*', April 28, 2005, p14.
- Countryman, 2006. '*Test yield results*', March 23, 2006, p21.
- Countryman, 2007. '*Potash mystery unearthed*', April 19, 2007, p12.
- Coyle P (ed) 2007, *Returns on R&D investment of DAFWA: Benefit cost analysis 2006 – 2007*, Department of Agriculture and Food, Western Australia, Bulletin 4736.
- DAWA 2003, Agriculture, food and fibre industries contributing to the sustainable benefit of all Western Australians. Department of Agriculture Western Australian Strategic Plan 2003 – 2013. <http://www.agric.wa.gov.au/pls/portal30/docs/FOLDER/IKMP/ABT/CORP/STRATPLAN%20BROCHURE.PDF>
- Evans L, 2006, '*Durum Industry Development*', In Nazrul I (ed) 2006, *Returns on R&D investment of DAFWA: Benefit cost analysis 2005 – 2006*, Department of Agriculture and Food, Western Australia, Bulletin 4709.
- Jayasena K, Thomas G and Beard C 2007, '*Cereal seed dressing and in-furrow fungicides 2006 – 2007*', Farmnote 205, Department of Agriculture and Food, Western Australia.
- GRDC 2004, '*Less seed more grain*', Crop Doctor segment and media release for the GRDC Western Region, April 2004.
- Kolb D 1984, *Experiential Learning: Experience as the Source of Learning and Development*, Prentice-Hall, Inc., New Jersey, USA. As quoted in Weinstein (1999).
- Nazrul I (ed) 2005, *Gains from DAWA's R&D investment: Benefit cost analysis, 2004-05*, Department of Agriculture, Western Australia, Miscellaneous Publication 28/2005.
- Nazrul I (ed) 2006, *Returns on R&D investment of DAFWA: Benefit cost analysis 2005 – 2006*, Department of Agriculture and Food, Western Australia, Bulletin 4709.
- Russell J 2002, '*Test As You Grow manual*' In the Test As You Grow Kit, Department of Agriculture, Western Australia, Miscellaneous Publication 2/2002.
- Russell J and Roe A, 2004a '*Lupin row orientation in low rainfall areas*', in N Morgan (ed) , *Proceedings of the 2004 Agribusiness Crop Updates, Farming Systems Update, Feb. 18-19 2004*, Department of Agriculture, Western Australia, pp 21- 22.

- Russell J and Roe A, 2004b, 'Canola seeding rates in low rainfall areas', in N Morgan (ed.) , *Proceedings of the 2004 Agribusiness Crop Updates, Farming Systems Update, Feb. 18-19 2004*, Department of Agriculture, Western Australia, p 23-24.
- Russell J and Roe A, 2004c, 'Grower investigations to improve the viability of risk prone crops in low rainfall environments of the central wheatbelt of Western Australia', in H Palta (ed.) *Adaption of plants to water limited Mediterranean- type environments, An international symposium*, CSIRO Centre for Environment And Life Sciences, Sept 14, 2004.
- Russell J, 2005, 'In a world of Precision Agriculture, weigh trailers are not passé', in N Eva (ed.) , *Proceedings of the 2005 Agribusiness Crop Updates, Farming Systems Update, Feb. 16-17 2005*, Department of Agriculture, Western Australia, pp 33-34.
- Russell J and Roe A, 2005a, 'On farm research to investigate fungicide applications to minimize leaf disease impacts in wheat', in R Horne (ed.) , *Proceedings of the 2005 Agribusiness Crop Updates, Cereals Update, Feb. 16-17 2005*, Department of Agriculture, Western Australia, pp 70-71.
- Russell J and Roe A, 2005b, 'Investigations into the influence of row orientation in lupin crops', in P White (ed.) , *Proceedings of the 2005 Agribusiness Crop Updates, Lupins and Pulses Update, Feb. 16-17 2005*, Department of Agriculture, Western Australia, pp 37-38.
- Russell J and Roe A, 2005c, 'Cover crop management to combat annual ryegrass resistance and improve wheat yields', in N Eva (ed.) , *Proceedings of the 2005 Agribusiness Crop Updates, Farming Systems Update, Feb. 16-17 2005*, Department of Agriculture, Western Australia, pp 35-36.
- Russell J, Roe A and Eyres J 2006a, 'On farm research to investigate fungicide applications to minimise leaf disease impacts in wheat – part II', in S Penny (ed.) , *Proceedings of the 2006 Agribusiness Crop Updates, Cereals Update, Feb. 15-16 2006*, Department of Agriculture, Western Australia, pp 79-82.
- Russell J, Roe A and Eyres J 2006b, 'Potassium response in cereal cropping within the medium rainfall central wheatbelt', in S Penny (ed.) , *Proceedings of the 2006 Agribusiness Crop Updates, Cereals Update, Feb. 15-16 2006*, Department of Agriculture, Western Australia, pp 68-71.
- Russell J, Eyres J, Roe A, Fosbery G and Oliver Y 2006c, 'Developing a better understanding of determining potassium requirements in cereal cropping in the central wheatbelt of Western Australia', in Turner NC, Acuna T and Johnson RC (eds.). "Ground-breaking stuff". *Proceedings of the 13th Australian Agronomy Conference, 10-14 September 2006*, Australian Society of Agronomy, Perth, Western Australia. [http://www.regional.org.au/au/asa/2006/concurrent/adoption/4541\\_russellj.htm#TopOfPage](http://www.regional.org.au/au/asa/2006/concurrent/adoption/4541_russellj.htm#TopOfPage)
- Russell J, Roe A and Fosbery G 2006d, 'How a participatory research approach has improved the viability of lupin crops in Western Australia', in Turner NC, Acuna T and Johnson RC (eds.). "Ground-breaking stuff". *Proceedings of the 13th Australian Agronomy Conference, 10-14 September 2006*, Australian Society of Agronomy, Perth, Western Australia. [http://www.regional.org.au/au/asa/2006/poster/adoption/4542\\_russellj.htm#TopOfPage](http://www.regional.org.au/au/asa/2006/poster/adoption/4542_russellj.htm#TopOfPage)
- Russell J, Eyres J, Fosbery G and Roe A 2007a, 'Brown manuring effects on a following wheat crop in the central wheatbelt', in D Arbrecht (ed.) , *Proceedings of the 2007 Agribusiness Crop Updates, Farming Systems Update, Feb. 14-15 2007*, Department of Agriculture and Food, Western Australia, pp 149-153.
- Russell J, Eyres J, Fosbery G and Roe A 2007b, 'Seeding rate and nitrogen application and timing effects in wheat', in D Arbrecht (ed.) , *Proceedings of the 2007 Agribusiness Crop Updates, Farming Systems Update, Feb. 14-15 2007*, Department of Agriculture and Food, Western Australia, pp 142-145.
- Russell J, Eyres J, Fosbery G and Roe A 2007c, 'Foliar fungicide application and disease control in barley', in D Arbrecht (ed.) , *Proceedings of the 2007 Agribusiness Crop Updates, Farming Systems Update, Feb. 14-15 2007*, Department of Agriculture and Food, Western Australia, pp 146-148.
- Russell J, Eyres J, Fosbery G and Roe A 2007d, 'Using on-farm research to refine management guidelines', in "What's happening down south" *Barley in the southern hemisphere, Proceedings of the 13<sup>th</sup> Australian Barley Technical Symposium, Aug 26–30 2007*, Fremantle, Western Australia, pp 185-193.
- Tozer P, 2006, 'Rapid adoption of a systems approach to weed management in the NAR region of Western Australia', In Nazrul I (ed) 2006, *Returns on R&D investment of DAFWA: Benefit cost analysis 2005 – 2006*, Department of Agriculture and Food, Western Australia, Bulletin 4709.
- WANTFA 2003, 'Effects of time of sowing, plant density and row orientation on lupins at various row spacings', in T Gillam (ed.) *Farming Systems: sustainable and high production agriculture – now*, April 2003, Vol 11, No 2, pp 608-609.
- Weinstein K 1999, *Action Learning. A practical guide*, 2<sup>nd</sup> edition, Gower, England.

