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Horticultural Research in Australia

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Abstract

Market projections for Australian horticulture are strongly positive. The question is whether the horticultural sector is well positioned to take advantage. Analysis of R&D performance, based on publications, indicates that Australian researchers in horticulture perform well on the international stage in maintaining contributions and particularly in peer acceptance of their research. Its position though is threatened by the rapid increase in performance by other countries such as China and India as well as South Korea. Opportunity does exist to increase the funds available for Australian horticultural research by maximising the co-investment by government. The education and training aspects however remain a particular challenge with low and declining numbers at postgraduate, undergraduate and vocational levels. This education dearth needs to be addressed given the established link between education levels in the workforce, innovation and productivity growth. The establishment of a capacity building strategic fund by Horticulture Innovation Australia is significant as it signals recognition that action needs to be taken and provides a funding source to redress the issue.

Key words: Horticultural research and development, production horticulture, horticultural education.

Introduction

This paper provides an analysis of horticultural research in Australia. It gives an insight into the capacity in Australia to address the opportunities that potentially are opening up for Australian producers. The National Food Plan Green Paper (DAFF, 2012) showed that Australian horticulture contributed 18% by value of the national food production while fruit and vegetables made up 7% of the food and beverage processing in Australia. The sector also delivered more than 90% of the consumption of fruit and vegetables domestically. Horticulture products however were 17% of food and beverage imports. Clearly the horticulture sector is a significant contributor to rural productivity, to national quality of life and to export earnings.

Projections for the horticulture sector at the 2016 Outlook Conference show that such opportunities are substantial. World consumption of fruit and vegetables is likely to grow by more than 50% by 2050 (Figure 1) with consumption more than doubling in Asian countries (Figure 2). The challenge for Australian horticulturists is whether the capacity exists in the 30,000 businesses in the sector to take advantage of these opportunities.

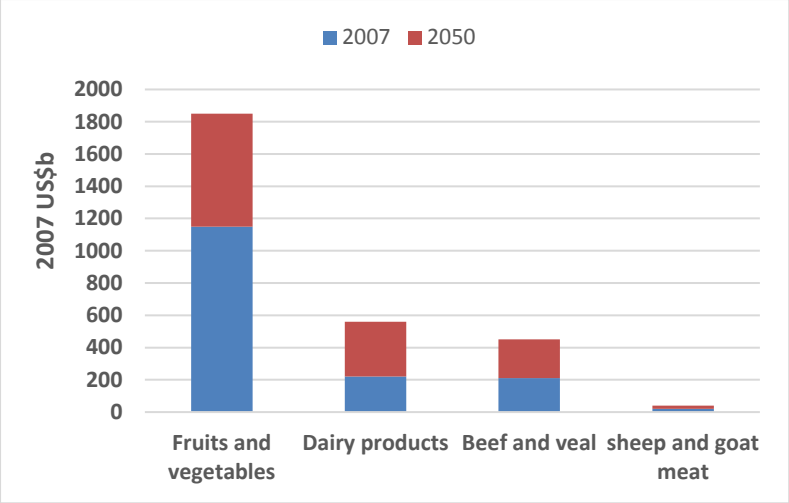


Figure 1. World consumption projections of fruit and vegetables relative to other food sources (ABARES Outlook Conference 2016)

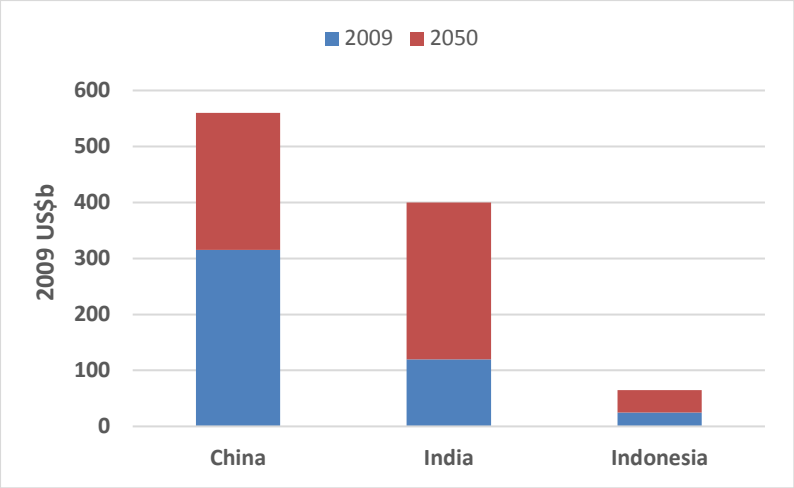


Figure 2. Projected consumption of fruit and vegetables in Asia by 2050 relative to 2009 (ABARES Outlook Conference, 2016)

Daly *et al*. (2015) indicated that this will require *inter alia* efficient management of resources, attraction of capital and skilled labour and accelerated uptake of advanced technologies. In the context of this paper they indicated that it is vital that there is ongoing investment in research and development (R&D), both public and private, to meet the challenges of climate change and deliver the transformational changes required to underpin the technological advances.

For horticulture then, it is useful to consider what is being done in R&D, who is involved and what provisions are being made for the future in research expertise and an educated workforce for implementation. This would allow some evaluation as to whether R&D is providing sufficient support to take advantage of the opportunities that are being promoted.

Method

The following is a synopsis of several research performance investigations, particularly a bibliometric analysis of Australian researchers compared globally, commissioned by the Australian Council of Deans of Agriculture. An analysis of the Excellence of Research in Australia (ERA) conducted by the

Australian Research Council is also included. Higher degree student numbers in horticulture come from the official database of University Statistics.

Published papers – A bibliometric study of agricultural research, undertaken by Science-Metrix, Canada, was commissioned by the Australian Council of Deans of Agriculture to explore the level of research and its global rating. This paper extracts the outcomes for horticulture. The process is described in Pratley (2015) as follows: *number of papers* was obtained using full-counting, i.e. each paper is counted once for each entity (e.g., country, organisations) listed. For example, a paper authored by two researchers from the University of Melbourne, one from the University of Sydney and one from the University of Toronto, is counted once only for the University of Melbourne, once for the University of Sydney, once for the University of Toronto, once for Australia and once for Canada. The period of study was 1996 – 2013 inclusive. *Number of citations* was obtained using full-counting. Citations were counted for two subsequent years following the year of publication, i.e. citations were counted for 2005–2007 for a 2005 publication, as this results in the same citation window for all years and allows comparison of yearly citation trends. Citations were undertaken for the years 1996-2011 inclusive to allow for the two year accumulation of citations.

The global data were described as 'Horticulture' through Scopus and approximated to the Fields of Research (FoR) code 0706 (Horticultural Production), the components of which are shown in Table 1. It does not include food science, genetic engineering of horticultural crops or the biological control of pests, diseases and exotic species.

Table 1. Australian and New Zealand Standard Research Classification (ANZSRC), 2008 (Australian Bureau of Statistics, 2008)

Code	Description
070601	Horticultural crop growth and development
070602	Horticultural crop improvement (selection and breeding)
070603	Horticultural crop protection (pests, diseases and weeds)
070604	Oenology and viticulture
070605	Post-harvest horticultural technologies (incl. transportation and storage)
070606	Horticultural production not elsewhere classified

ERA analysis – The Australian Research Council (ARC) has been conducting a research quality evaluation of universities in Australia on a three year basis in relation to the ANZSRC codes (see Table 1). The outcomes for horticultural production in this paper are for the 2011-2013 evaluation. Relevant data were collected from eligible institutions and then evaluated by eight Research Evaluation Committees (RECs), established at a discipline cluster level, and comprised of distinguished and internationally–recognised researchers with expertise in research evaluation (ARC 2015). For the purposes of the ERA, ARC defines research as the "creation of new knowledge and/or the use of existing knowledge in a new and creative way so as to generate new concepts, methodologies, inventions and understandings. This could include synthesis and analysis of previous research to the extent that it is new and creative" (ARC 2015).

The process is described by ARC thus: An institution was only evaluated in ERA in a two– or four–digit discipline where the number of research outputs submitted reaches the 'low volume threshold'. For horticulture where citation analysis was used, the low volume threshold was 50 apportioned indexed journal articles. No evaluation was conducted for horticultural production at a given institution if the submitted number of apportioned indexed journal articles over the reference period was fewer than 50 in any two– or four–digit FoR.

Results

Published papers Data in Figure 1 show the number of publications by Australian authors in horticulture relative to other aspects of agriculture. Horticulture represents about 10% of the agricultural publications involving Australian authors and the number has remained relatively constant over the period of study. It makes a modest contribution to the 800 papers produced more broadly in production agriculture.

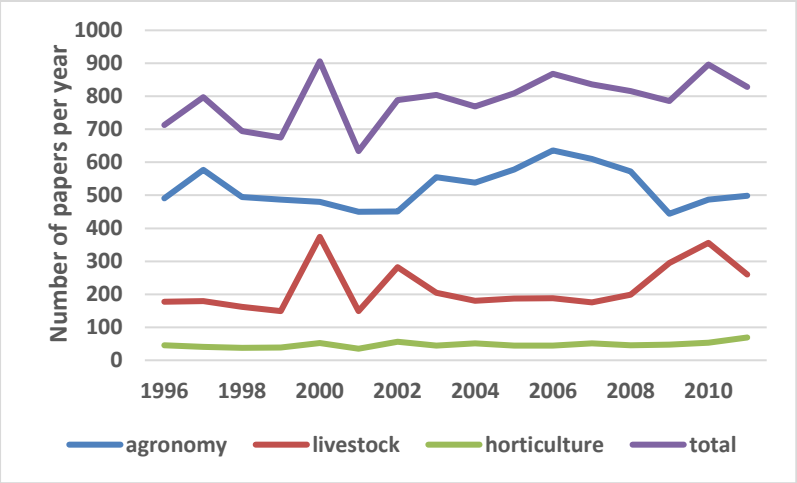


Figure 3. The number of papers produced in agronomy, animal production and horticulture for the period 1996-2013

The proportion of Australia's contribution in number of papers in horticulture globally ranges from a high of 5% in 2002 to a low of 2.5% in 2012 (Figure 4). There appears to be a decline in proportion since the 2002 high with the levels oscillating around 3.5% until 2004 and under 3% since that time.

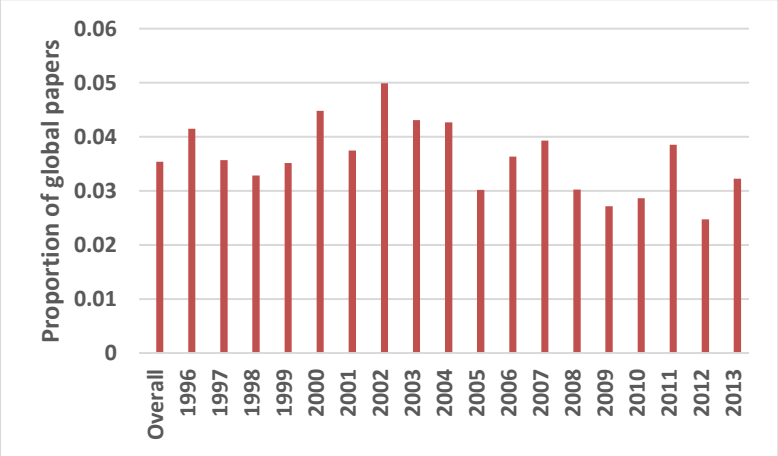


Figure 4. Proportion of global papers published annually by Australian authors in horticultural production for the period 1996-2013

The impact of the publications is another measure of performance. Citation rates are a measure of the acceptance of the work by peers and provide a relative measure of quality. Figure 5 shows the annual relative citations for Australian horticulture papers. In all years except 2001 in the period of study relative citations have been in excess of the global average, in most cases 50% higher. This is a sustained performance suggesting that world horticulture scientists trust and respect the science undertaken by Australians. Since 2002 the citation rates have approached, or bettered, double the global average suggesting a high degree of acceptance. It may also reflect to some extent the increased digital access to the world's literature. A further measure is the percentage of papers in the top cited papers globally as shown in Figure 6. It is clear that the publications from all research providers are accepted at the highest level. Overall Australia has 3.4% in the top 1% of cited papers, 12% in the top 5%, 21% in the top 10%. CSIRO is the standout performer with 7.8% of its papers in the top 1% of cited papers and 20.3% in the top 5%.

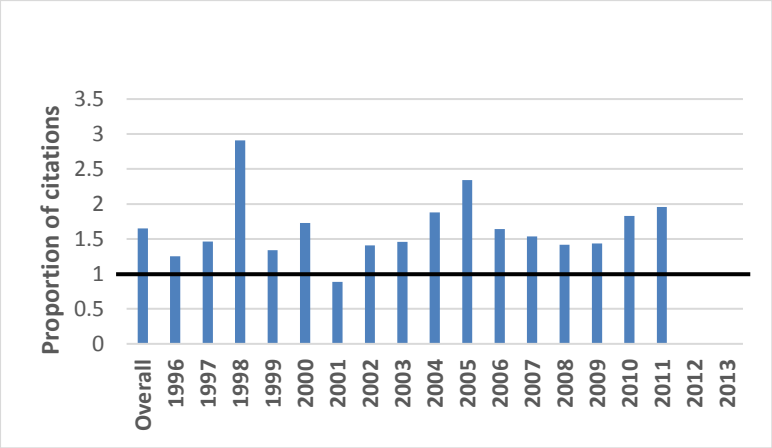


Figure 5. Relative global citations of Australian agronomy publications for the period 1996-2011. The line represents, by definition, the global average of 1.0

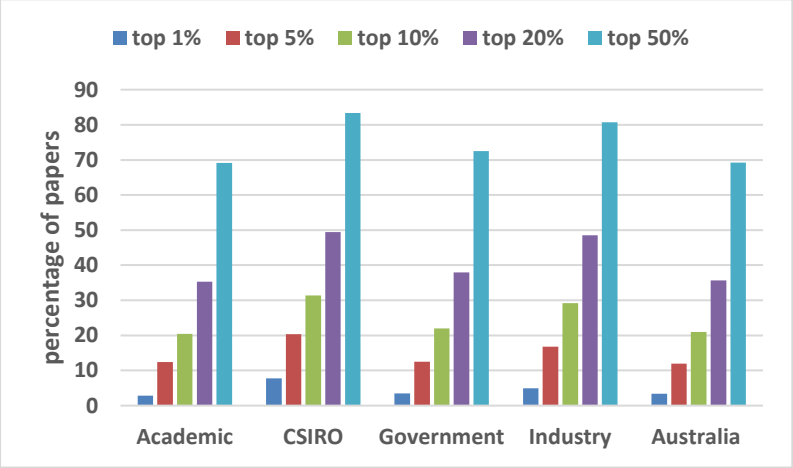


Figure 6. Percentage of Australian horticulture papers in the top 1%, 5%, 10%, 20% and 50% of papers by citation and by research provider, 1996-2011

Relative to that of many other countries, Australia ranks 7th in output of publications (Figure 7) over the 16 years of evaluation. The United States is 5 to 10 times as productive as the other top nations with second placed Japan 70% higher than 3rd placed China. Spain, India and Canada have greater output than Australia as well. Perhaps more useful is the change in output over the period. Figure 8

presents the growth ratio of output for the period 2008-2012 relative to that of 2002-2008 to show which countries appear to be investing more heavily in horticultural research. When compared with the world level defined as 1.0, a growth index (GI) is obtained, indicating if growth at the entity level is relatively stronger (GI above 1.00) or weaker (GI below 1.00). Australia is a marginal improver (1.07). Of the big players, China and India are significant improvers with South Korea, Poland and Iran substantial improvers, albeit from a smaller base. A comparison of relative citation rates between countries (Figure 9) shows that Australia is rated in the top 4 with Spain, Italy and Israel.

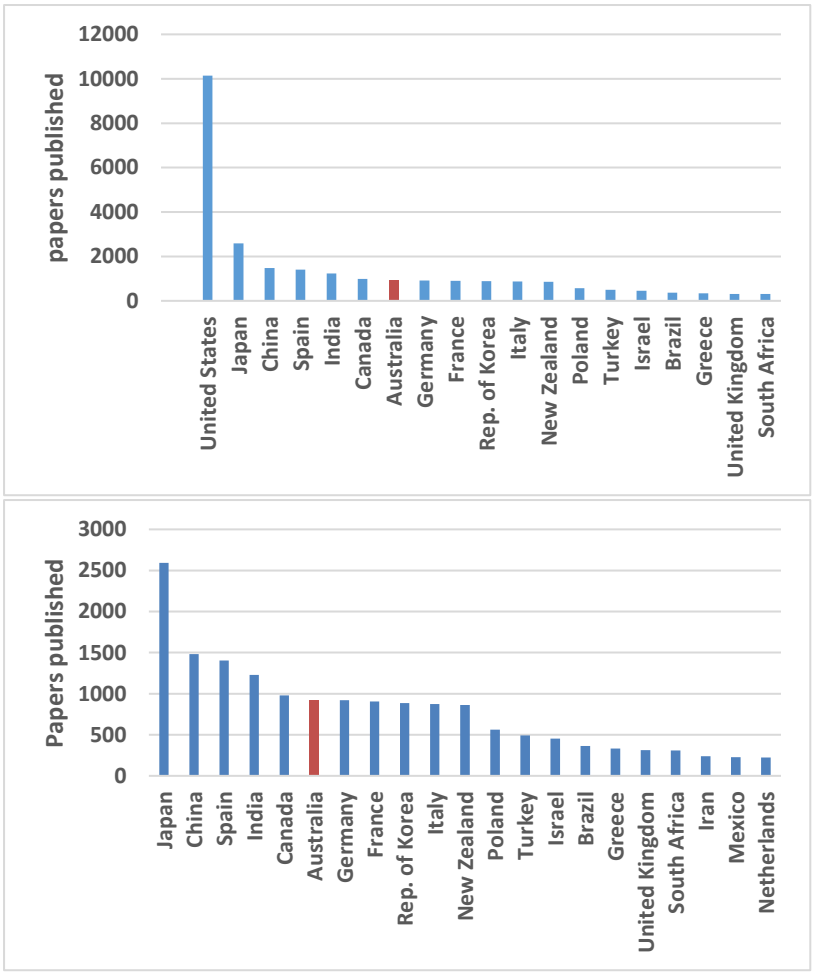


Figure 7. Total number of papers for the period 2002-2013 for horticultural production by country. Top includes the United States; Bottom excludes United States to enable relativities amongst the other main publication nations

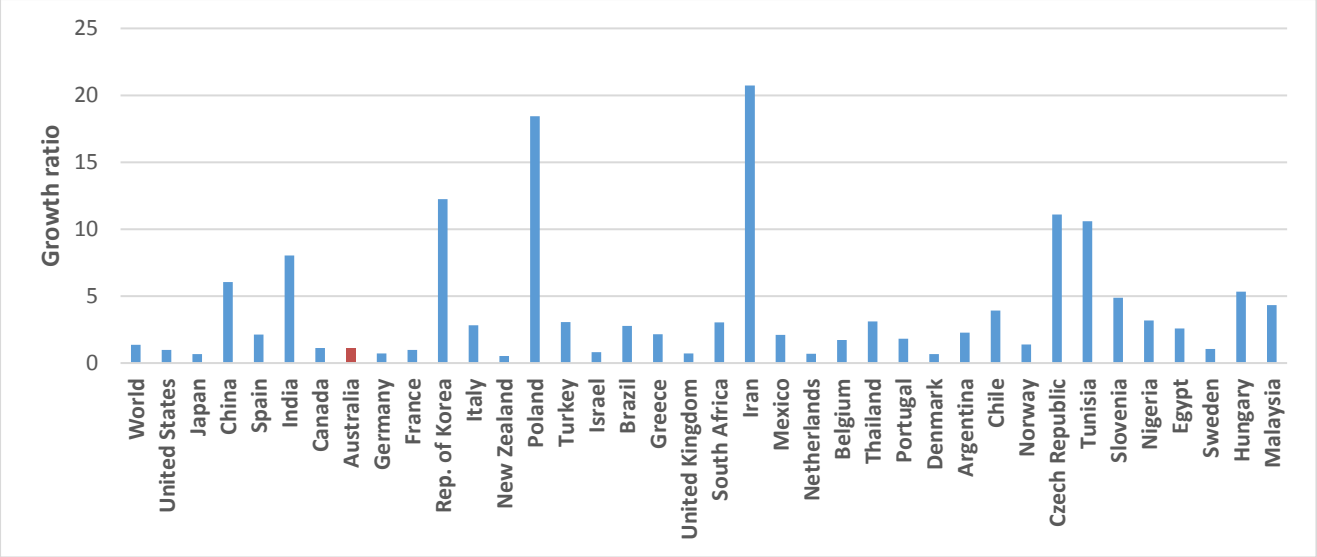


Figure 8. Growth ratio (GR) of horticultural paper publications by country. GR indicates the increase or otherwise of number of publications between the two periods 2002-2006 and 2008-2012 relative to the world output

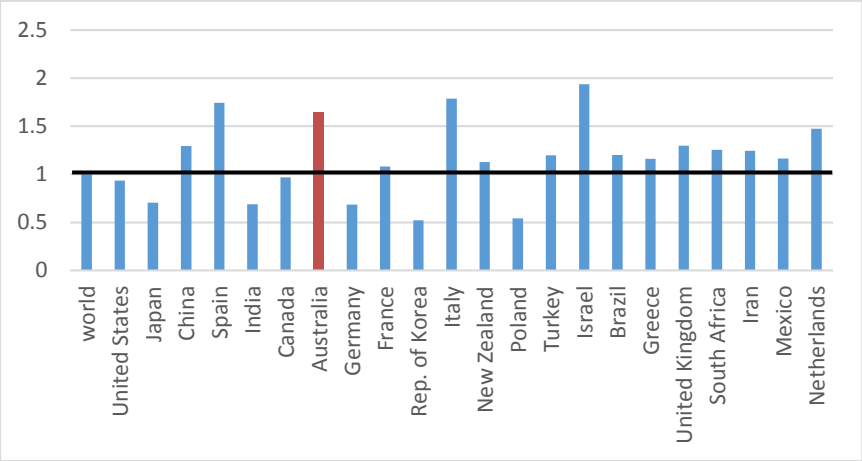


Figure 9. Relative citation rates for horticultural production papers by country for the period 2002-2013. World relative citation rate by definition is 1.0

Within Australia, the source of the papers in horticulture show that around half are produced in the universities, perhaps a quarter in government departments and the rest shared between CSIRO and Industry (Figure 10). The numbers continue to increase from the universities, which now account for up to 60% of papers. Other sectors have not changed output to any extent in that time except for the year to year variations.

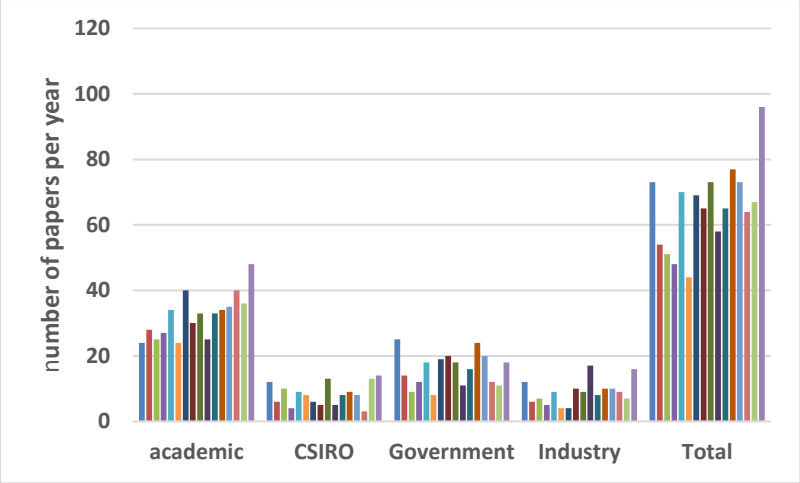


Figure 10. The number of papers published annually in horticulture by universities, CSIRO, governments and industry for the period 1996-2013. Columns represent years in chronological order.

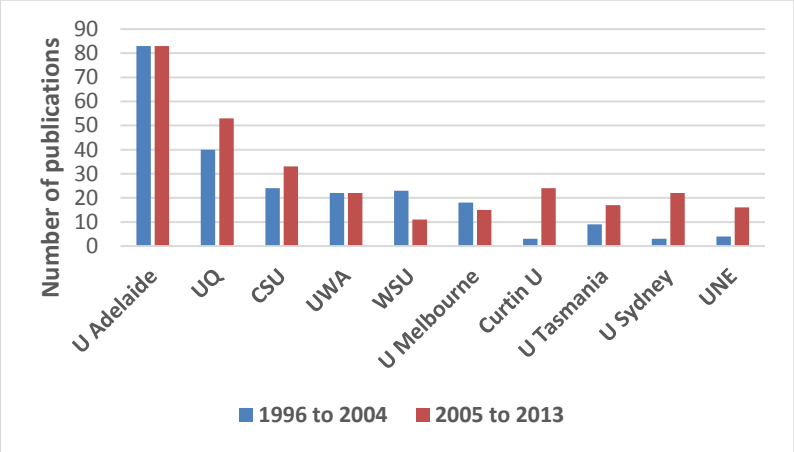
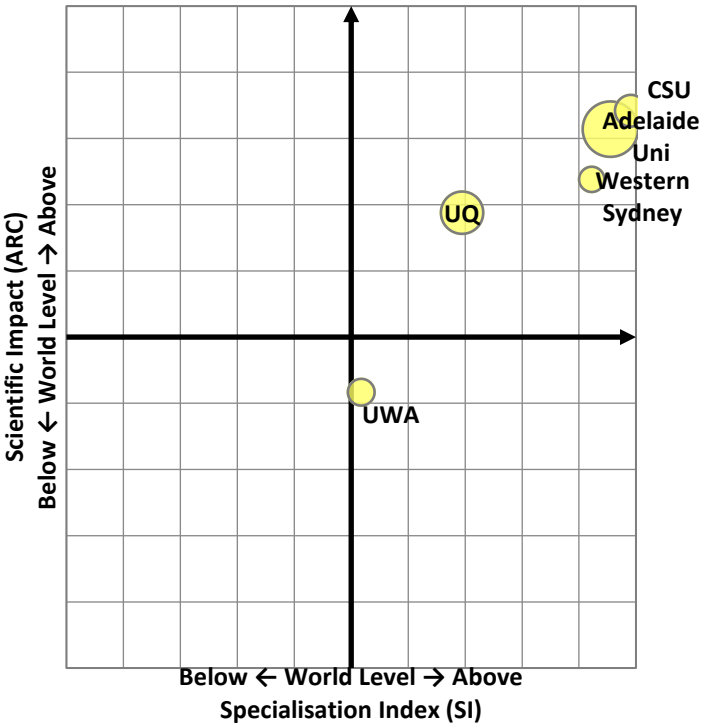


Figure 11. Total publications for the periods 1996-2004 and 2005-2013 for the universities with an average of at least one publication per year for the full period of study.



University	Specialisation index (SI)	Scientific impact (ARC)	Paper number
Adelaide	4.61	2.09	160
Queensland	1.51	1.48	96
Charles Sturt	10.48	2.31	56
Western Australia	1.04	0.85	41
Western Sydney	3.44	1.68	37

Figure 12. Global position analysis for Australian universities in horticultural production based on specialisation index (concentration of the research focus) and scientific impact (Based on relative citations).

University level analysis showed several Australian universities publishing in horticultural production (Figure 11). Of interest has been the increase in publications from most of the universities in the more recent period. Global positional analysis (Figure 12), based on the degree of specialisation and on the scientific impact using relative citations, only identifies five Australian universities in that analysis as those with fewer than 30 citation scores are not computed. Generally the universities were focused and highly cited. Charles Sturt and Adelaide Universities in particular have high SI values and most likely reflect their involvement with viticulture and oenology research.

ERA analysis **–** the process used by the Australian Research Council to evaluate research performance in each university includes a bibliometric analysis but also includes other measures such as research income, esteem, patents, plant breeding rights and similar metrics. Details are provided in ARC (2015). Universities are rated on a scale of 5 to 1 being from well above world standard to well below world standard respectively with 3 being at world standard. Table 2 shows the ratings for those universities ranked in Horticultural Production for the three ERA exercises. Only

four universities rate with Charles Sturt University being represented only in the 2015 ratings. In this process the University of Tasmania is listed in all three evaluations even though it was not in the Global Position Analysis represented in Figure 12. Western Sydney University and the University of Western Australia made the GPA but were not part of the ERA ratings.

Table 2. ERA Ratings by institution for Field of Research 0706 Horticultural Production in 2010, 2012 and 2015 (ARC 2015)

University	Rating 2010	Rating 2012	Rating 2015
Charles Sturt University	-	-	5
University of Adelaide	5	5	5
University of Queensland	4	5	5
University of Tasmania	5	4	5

5 - well above world standard, 4 - above world standard, 3 - world standard, 2 - below world standard, 1 - well below world standard

The ratings in Table 2 were based on the performance indicators as detailed in Table 3. Research income was around $11m per year and research commercialisation income of about $70,000 per year was generated, although there were no patents in the period. The full-time equivalent of around 103 staff contributed to this exercise. Research outputs are considered in more detail in Figure 13 indicating that the vast majority were in journal articles (83%) and conference papers (12%).

Table 3. University research performance in FoR 0706 in the ERA period 2011 to 2013

Indicator	Number
Research outputs	995
Research income	$32,820,142
FTEs	103
Esteem count*	1
Patents	0
Research commercialisation income	$223,110

*Esteem measures include a person who is an editor of a prestigious work, a member of a learned academy, recipient of a nationally competitive research fellowship, member of a statutory committee or recipient of an Australia Council grant or Fellowship

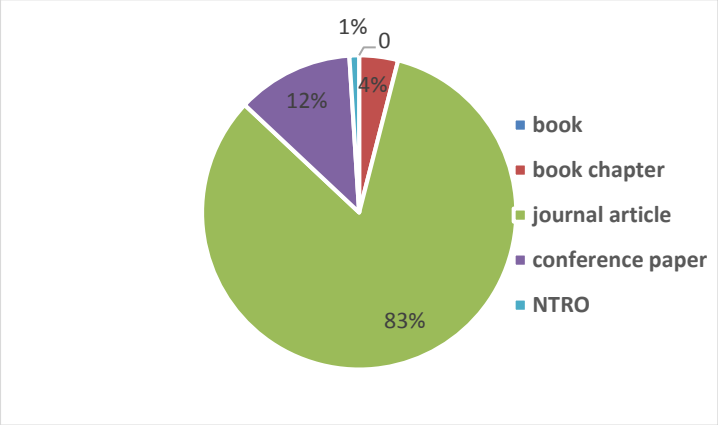


Figure 13. Research outputs from university research in horticultural production as described by the ERA process (ARC 2015). NTRO refers to non-traditional research outputs.

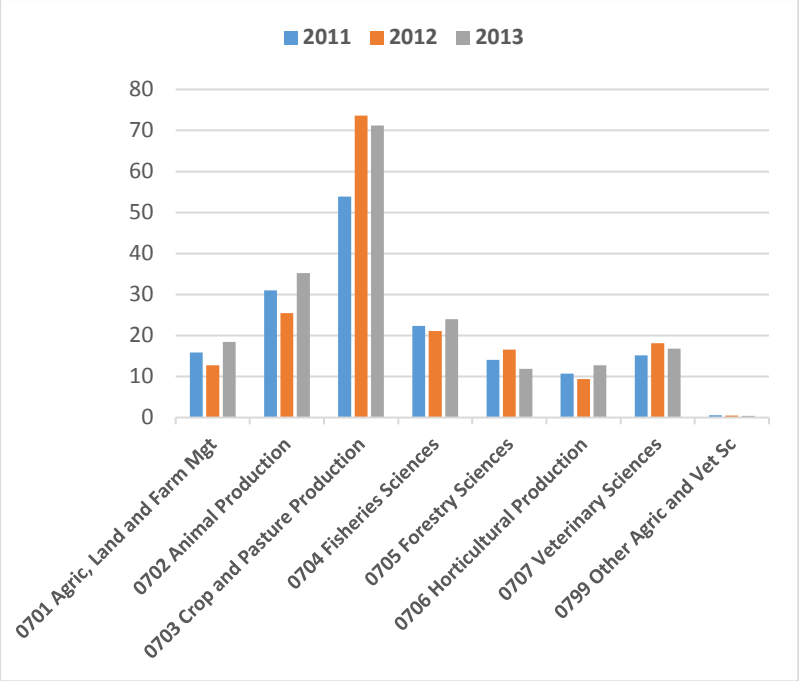


Figure 14. Research income (in AUD $) to Australian universities for horticultural research as described by the ERA process for 2011-2013 (ARC 2015)

It is useful to put the research income in context with other components of the FoR 07 category. Horticulture delivers the lowest income of the major sub-categories, the highest being Crop and Pasture Production at $199m relative to Horticultural Production at $33m. To what extent the Horticulture investment is distorted cannot be estimated but clearly there are components that are included elsewhere in plant sciences, plant biotechnology, chemistry and biology. Much depends on where the university determines to categorise its research activity.

Preparing for the future: PhD training The future research workforce depends largely on a continuous pipeline of qualified researchers from the universities. Analysis of the intakes and completions of PhD scholars provides some indication of the state of play. Intakes and graduate completions are provided over the period 2001-2014 in Figure 15. The data however are imperfect as the accuracy or otherwise is a function of the categorisation by individual universities. Initial instinct suggests that most of the PhD scholars represented in Figure 15 are viticulture students. However analysis on a per university basis (Figure 16) does not have the University of Adelaide and Charles Sturt University identified even though both universities were represented in the global Position Analysis and in the ERA. It is clear that those universities have categorised their postgraduate scholars in a non-horticulture/viticulture group. This then infers that the data represent mainstream horticulture rather than viticulture. Graduate numbers were around 10 per year until 2007 after which output has been negligible. Future prospects are also grim as intakes have been very small to non-existent for the past decade. Even international students have been absent from the data.

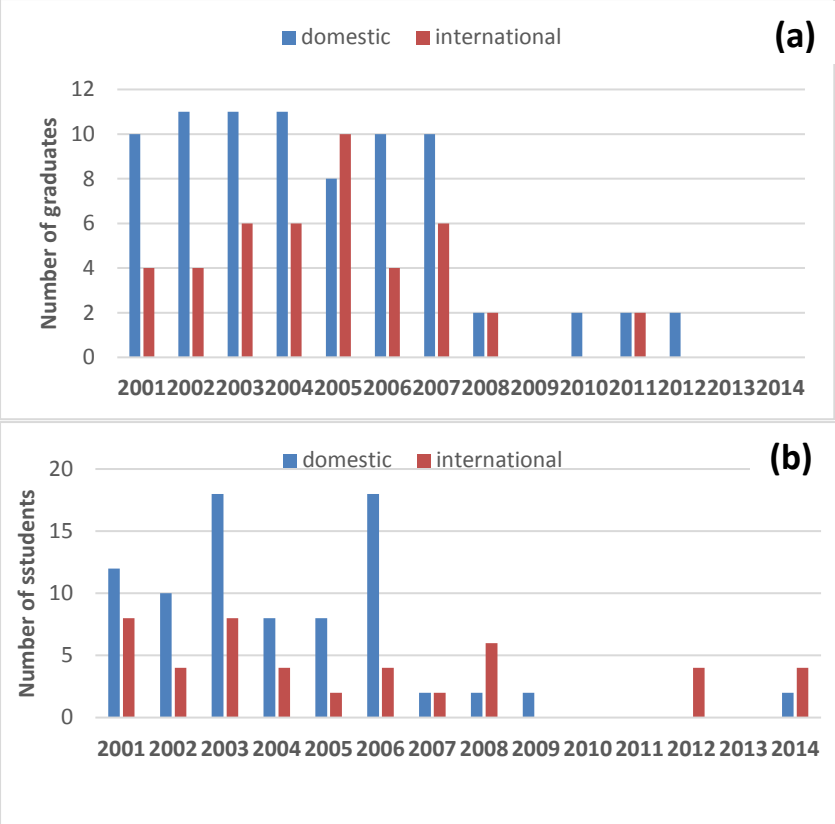


Figure 15. (a) The number of doctoral graduates in horticulture from Australian universities for the period 2001-2012 and (b) annual intake of students into doctoral studies in horticulture for the period 2001-2014 for both domestic and international categories (source: University Statistics)

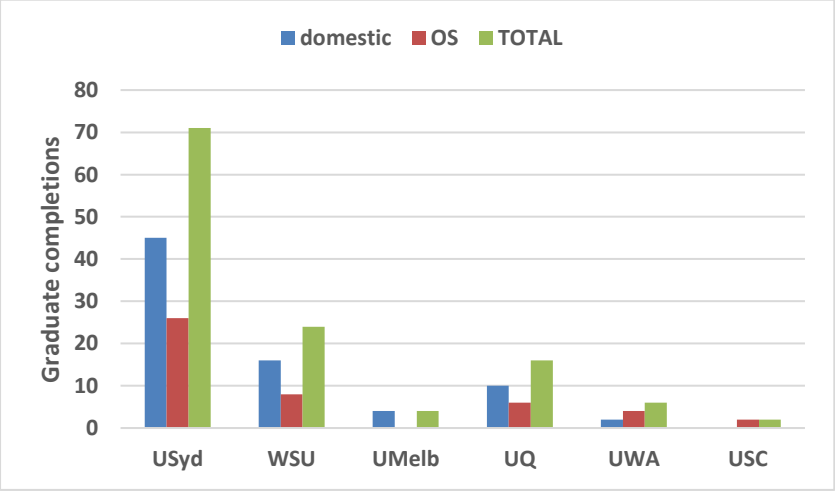


Figure 16. Doctoral completions in horticulture from individual Australian universities (source: University Statistics)

Analysis of individual universities involved in respect of the number of PhD graduates over the period of 2001-2014 shows the University of Sydney has the most although they relate to the first half of the study period when it offered a horticulture degree.

Preparing for the future: an educated workforce The outcomes of research require a receptive industry sector and workforce. Thus implementation of research and application of modern technologies are more likely with a younger, trained workforce. This emphasises the desirability for

owners and managers to be university trained and for the rest of the workforce to have at least vocational qualifications. The question then is what progress is being made in the education of the workforce in horticulture. Figure 17 shows the number of graduates in horticulture in the period 2001-2014 in horticulture/viticulture in comparison with other components of the production agriculture sub-categories. In that time horticultural graduate numbers have halved. These numbers include viticulture with the remainder most likely being in amenity horticulture. Only one non-viticulture horticulture degree remains in the university system at Charles Sturt University although there is increasing interest elsewhere and horticulture studies exist in other degrees now in several universities. The horticulture industries then compete for agricultural graduates which have also declined substantially in annual output. Future prospects are not encouraging as intakes are showing the trend worsening. In Figure 18 the horticulture and viticulture components are separated to reveal that most students are entering viticulture rather than horticulture *per se* although the declining trend is also evident for viticulture. A critical point seems to have been reached in 2009 and numbers since that time have not been sustainable for universities economically.

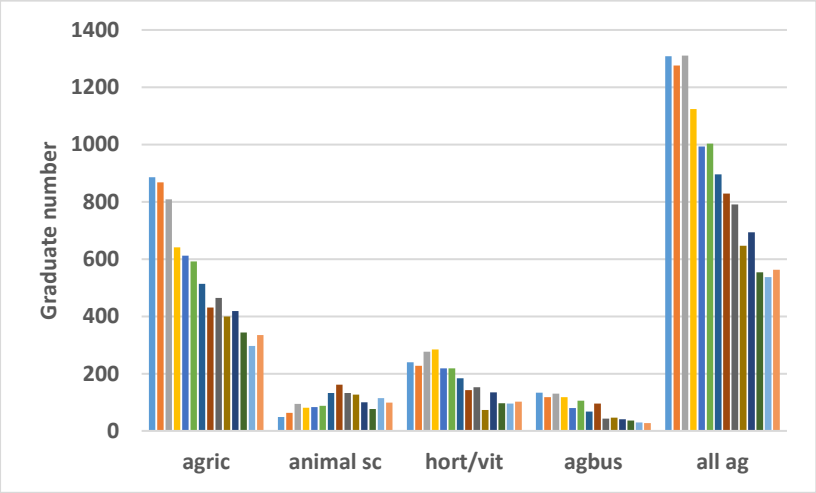


Figure 17. Annual graduate completions in agriculture, horticulture/viticulture and agribusiness from Australian universities for the period 2001-2014. Columns represent years in chronological order

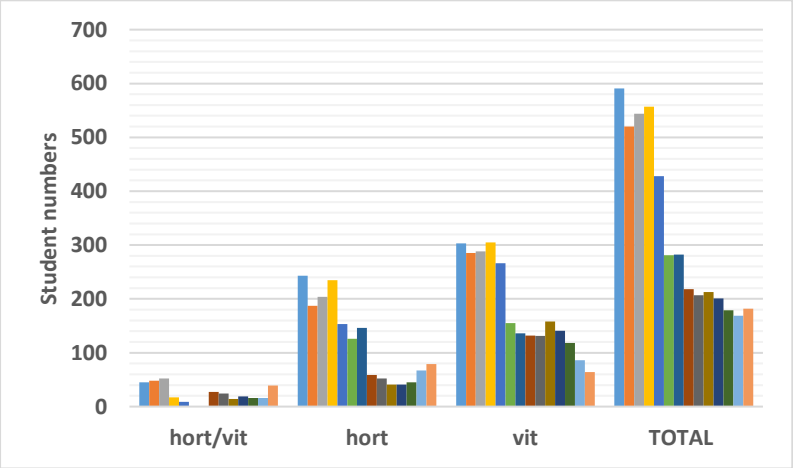


Figure 18. Annual intake numbers for horticulture and viticulture degrees in Australian universities for the period 2001-2014. Columns are years in chronological order

For the broader workforce in horticulture, an evaluation was undertaken by Aldous and Pratley (2014) as shown in Figure 19. For the amenity horticulture category there is a clear uptake of vocational programs, particularly at certificate II and Certificate III levels. This contrasts with the widespread lack of uptake by the production horticulture industries although there was a response evident for Certificate III and Certificate IV in 2012.

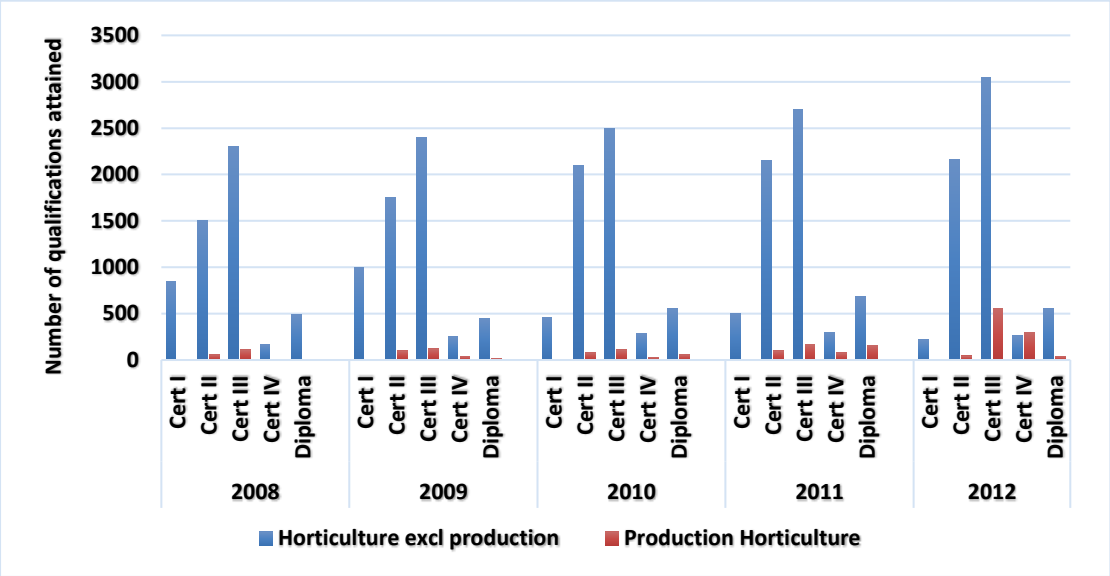


Figure 19. Comparison of qualification attainment between amenity and production horticulture industries, 2008-2012 (NCVER 2014)

Discussion

There can be no doubt that opportunities exist in increasing international markets for horticultural produce. While it is unrealistic to think that Australia could satisfy these demands it nevertheless signifies that Australia could be involved significantly while at the same time contribute markedly to export income for Australia and to sustainability and prosperity of the industries involved. However that outcome will require the sector to be supported by research and development to deliver the efficiencies, technologies and systems to enable increased productivity, as shown for agriculture more generally by Mullen and Keogh (2013).

In respect of both R&D performance and education, it is important to note that using data sources, official or otherwise, is an incomplete science. Much depends on the categorisation individual universities use for their official submissions. Clearly there would be students and research projects that are, for example, in horticultural chemistry and categorised as chemistry, or in plant science or engineering (e.g. robotics). The Australian Council of Deans of Agriculture is aware of these issues and has endeavoured to address where it can, and otherwise understand, so that the right information is delivered as far as possible. In general however the data do tell a story which needs to be considered.

The analysis described here-in indicates that Australia's record in R&D, based on bibliometrics, has been relatively impressive. Publication rates have been consistent over a long period although there is the suggestion that Australia is declining in its share of publications. Whether this is a concerning trend given the globalisation of research is perhaps debatable and is dependent on whether Australia wishes to become a bigger player. What is clear is that the quality of publications is of

world standard based on two independent analyses, the GPA and the ERA. That quality is spread across the range of research providers. Universities are producing an increasing share of the publications and this is likely to continue as state agencies, for example, constrain their involvement in agricultural R&D. The contradiction to be addressed is that universities have been constrained by the dearth of students at undergraduate and postgraduate levels and horticulture degrees consequently have been abandoned while concurrently assuming a greater share of the R&D output. It raises the question however about the sustainability of the university system to provide horticultural education without a student base. There seems to be a positive move in universities to create the availability of horticultural education within science and agriculture degrees and so there is a base on which to build should the industries want to invest.

The analyses seem to suggest that some countries are increasing their activity in horticulture substantially relative to the rest of the world. Australian horticulture thus far seems to be retaining its activity around the global average. The major funding source for R&D rests with the Research and Development Corporation Horticultural Innovation Australia (HIA, previously Horticulture Australia Limited, HAL). Those funds are generated from levies collected from producers which are then matched by the Commonwealth Government up to 0.5% of the gross value of production (GVP). Thus as GVP increases so do the possible matching funds from government. Figure 20 shows the budget provisions for horticulture from the inception of this arrangement under the Primary Industries Research and Development (PIRD) Act. The co-investment only occurs up to quantity of levies collected in any year although there are levelling provisions over time. Figure 20 provides data derived from the Australian Government Budget Papers showing the budget allocation based on GVP and the levies collected per annum which also represents the actual co-investment. The gap between the graphs represents the opportunity foregone to receive more research funds. In effect the amount is about twice that gap since the extra levy funds also go to R&D. For horticulture that represents a sizeable opportunity cost of more than $15 million per year ($30 million counting the levy as well). Over the course of the PIRD Act (i.e. since 1990/91), a total of $260 million (or $520 million with levies) has been foregone based on this simple analysis. That represents the equivalent of around five years of funding for HIA. Addressing that issue would seem to make sense and deliver the funds to underpin the growth and profitability of the sector. It is noted that some levies are directed to marketing activities and therefore do not qualify for the government co-investment.

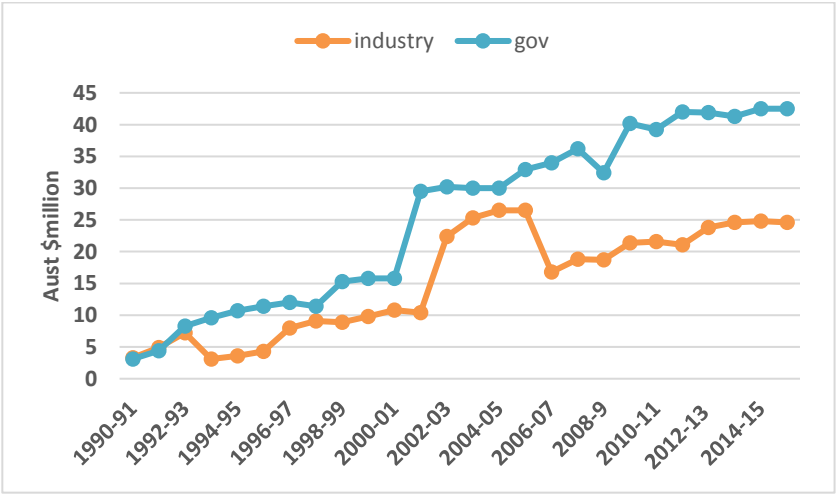


Figure 20. The quantum of levies collected from horticulture producers and the co-investment budgeted by government for the period 1990/91 to 2015/16 (Australian Government, 2016)

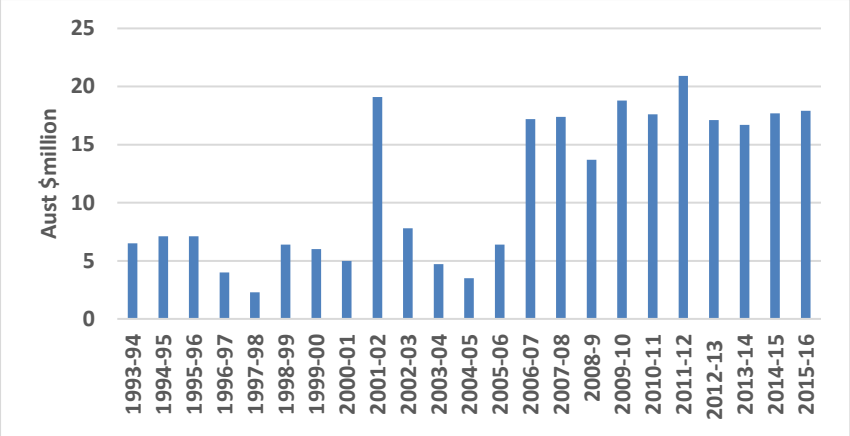


Figure 21. The estimated R&D income foregone due to the levy shortfall for the period 1993/4 to 2015/16 based on Figure 20

Perhaps the greatest cause for concern is that of education and training at all levels. There are numerous reports (e.g. Kokic *et al*, 2006; Nossal and Lim, 2011; Zhao *et al*, 2009) relating farmer educational attainment positively and significantly to productivity growth. Education also broadly influences farmers' innovation capacity, that is, their preparedness to adapt and implement new practices or technologies (Abadi Ghadim *et al*, 2005; Prokopy *et al*, 2008).

It is pleasing to report that change is in the wind. The horticultural industries through HIA have been active in the education and training space in recent years. The evolution of HAL to HIA has enabled the establishment of several strategic co-investment funds (HIA, 2016) one of which is the Leadership Fund (Building capacity) which currently has three themes: retain existing employees (by creating career pathways); promote careers in horticulture (aimed at attracting new entrants with leadership capability); and drive research innovation (through development of the research force including postgraduate research support). This strategic intent is the horticulture's most significant development towards a more professional and productive sector. This lays the foundations for the industries to take advantage of the opportunities opening up internationally.

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