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Global review and gap analysis of nursery industry research and development initiatives

Final Report

Hort Innovation

This report has been prepared by:

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Table of Contents

Executive Summary **1**

1 Introduction **6**

2 Approach **7**

2.1 FRAMEWORK 7

2.2 DOCUMENT REVIEW 8

2.3 INDUSTRY CONSULTATION 9

2.4 ANALYSIS 10

3 Now - Current Situation **11**

3.1 INDUSTRY PROFILE 12

3.2 WHY IS INDUSTRY STRATIFICATION IMPORTANT? 15

3.3 CHALLENGES AND OPPORTUNITIES 18

3.4 KEY NATIONAL OBSERVATIONS AND TRENDS 20

3.5 KEY ISSUES FACING THE NURSERY INDUSTRY AND DRIVERS OF FUTURE RD&E 22

3.6 RECENT AUSTRALIAN NURSERY RELATED RD&E PROGRAMS 25

3.7 CAPACITY AND CAPABILITY OF KEY AUSTRALIAN RD&E PROVIDERS 28

3.8 UNDERSTANDING THE INTERNATIONAL R&D LANDSCAPE FOR THE NURSERY INDUSTRY 30

3.9 RECENT INTERNATIONAL RD&E PROGRAMS OF RELEVANCE TO THE AUSTRALIAN NURSERY INDUSTRY 31

3.10 CAPACITY AND CAPABILITY OF KEY INTERNATIONAL RD&E PROVIDERS 33

4 Where - The Future **35**

4.1 VISION 35

4.2 WHAT 35

4.3 WHO 37

5 How - The RoadMap **40**

Appendix 1: Consultation List **47**

Appendix 2: Recent (< 5years) Australian nursery related RD&E projects **49**

Appendix 3: Capacity and capability of Australian RD&E providers **56**

Appendix 4: Recent projects (< 5 years) relevant to the Australian nursery industry delivered by international R&D providers. 66

Appendix 5: Capacity and capability of international RD&E providers 74

Executive Summary

Like a number of horticultural industries in Australia, the nursery and garden industry faces numerous challenges such as labour attraction and retention, increasing production costs and a need to be 'clean and green'. There are opportunities to address these, and other challenges, through targeted research, development and extension (RD&E) which focuses on improving production efficiencies, reducing the environmental footprint of nursery businesses and better understanding nursery and garden customers.

Developing an effective RD&E program that meets the needs of industry requires an understanding of the current operating environment of the nursery industry and that of RD&E providers in Australia. Review of the nursery industry profile, current challenges and opportunities, and national trends show that while considerable research has occurred in the past, new technology and practices are slow to be adopted by nursery businesses. Reasons for this are varied with lack of an effective extension program a likely contributor. The diversity of business size, capacity and capability and range of products developed within the nursery industry influences the RD&E needs of individual businesses and these differences need to be considered when extending research outcomes. The stratification of industry into steady, advancing and progressive producers, and using extension approaches based on the capacity and attitudes of these producers is recommended as an effective way to increase the adoption of research outcomes.

The nursery industry is currently investing in a range of research and development (R&D) to meet the needs of industry, as guided by the industry's Strategic Investment Plan (SIP). However, there are a number of issues where limited R&D is currently occurring and that represent significant risk to industry if not addressed. These are focused predominately on the needs of the production sector and include:

- Reducing the environmental footprint through improved resource use efficiency
- Improving production and process efficiencies (both in the field and within protected cropping systems)
- Reducing production costs through automation and uptake of new technology
- Improving supply chain efficiencies and logistics
- Improved understanding by industry of end user needs/desires.

We recommend that these five issues become the future focus areas of the Australian Nursery RD&E Roadmap that will assist industry to achieve Outcome 4 of the SIP (that is, improved productivity and professionalism through the creation and adoption of innovation and industry best management plans). Also of concern was the apparent disconnect between industry and researchers, and a lack of coordination and understanding between the production sector, retailers and consumers. An increased focus on development and extension in the RD&E focus areas listed above will facilitate greater outcomes for industry, with the last two focus areas in particular requiring greater coordination and collaboration between industry sectors.

To assess the ability of the nursery industry to address these issues we examined the current capacity and capability of RD&E providers in Australia. The review identified that given direction and investment from industry there is extensive capacity and capability within Australia to conduct RD&E that will address these issues. In fact, Australia is leading the way globally in a number of research fields of relevance to the nursery industry including the use of Next Generation Sequencing technology to speed up biosecurity processes, finding sustainable ways to increase the level of green infrastructure in urban space and advancing the production of plants within protected systems. This research, and the organisations delivering it, show that it is not necessary to always look outside of Australia for innovative new technology. For further detail on recent Australian RD&E of relevance the nursery industry, and the capacity and capability of Australian RD&E organisations, see Sections 3.6 and 3.7.

Internationally, R&D for the nursery industry is driven by stringent regulations around resource management and finding ways to offset reducing labour availability. This is particularly evident in Europe (Germany and the Netherlands), the United Kingdom (UK) and in particular regions of the United States. There are opportunities for the Australian industry to learn from the R&D that is currently occurring in these countries and adopt practices and technology to our conditions and systems. Research areas of interest, and programs, that will assist the Australian nursery industry to meet its R&D priorities include:

RESEARCH FOCUS	ORGANISATION
Reducing the environmental footprint through better resource use efficiency	Institutions in Germany, the Netherlands and the US are currently conducting research programs to address this issue due to increasing regulatory pressure.
Improving systems and practices through: ▪ Better greenhouse/protected cropping design ▪ Managing labour shortages and costs ▪ Agri-technology and automation.	▪ The University of Wageningen in The Netherlands has research teams and facilities focussed on improved production within a protected cropping system. ▪ The Agriculture Horticulture and Development Board (AHDB) in the UK is currently funding research into innovative ways to manage labour shortages and costs. ▪ The AHDB in the UK, the University of Wageningen and various private providers in Europe are researching or have developed new technology to automate production systems.
Understanding consumer behaviour and purchasing patterns	Researchers at the Michigan University and Texas A&M University in the USA are currently researching and analysing consumer behaviour and purchasing patterns.
Urban greening and ‘Green Care’	Urban greening and ‘Green Care’ are a focus of research programs conducted at Vineland Institute in Canada, University of California and Germany.

For further detail on current international RD&E of relevance the nursery industry, and the capacity and capability of international RD&E organisations, see Sections 3.8 and 3.9.

Collaboration between RD&E providers in Australia and those internationally already occurs, and the majority of international providers interviewed expressed a desire to collaborate further with Australia. Collaboration is a great way to leverage investment, share resources, counter production seasons and identify new opportunities. Building collaboration between Australia and international providers should be a two-pronged approach that grows the reputation of nursery RD&E conducted within Australia and fosters international relationships/linkages. Both of these objectives could be achieved by developing a program approach to RD&E invested in by the nursery industry.

Adopting a program approach to RD&E for the nursery industry will assist industry to meet key challenges through delivery of holistic work packages focused on providing real outcomes for businesses that focus on the five key goals identified in the RD&E Roadmap. Engagement of a program coordinator to facilitate the strategic commissioning of research where required, promote linkages between sectors of the industry and RD&E community and ensure that the research program, communications and extension are coordinated is vital. The coordinator has to ensure that industry gets what they have asked for and that success/adoption is monitored.

To facilitate the delivery of an integrated program approach to RD&E for the Australian nursery industry we recommend a model as shown below in Figure 1 with specific recommendations provided in Table 1.

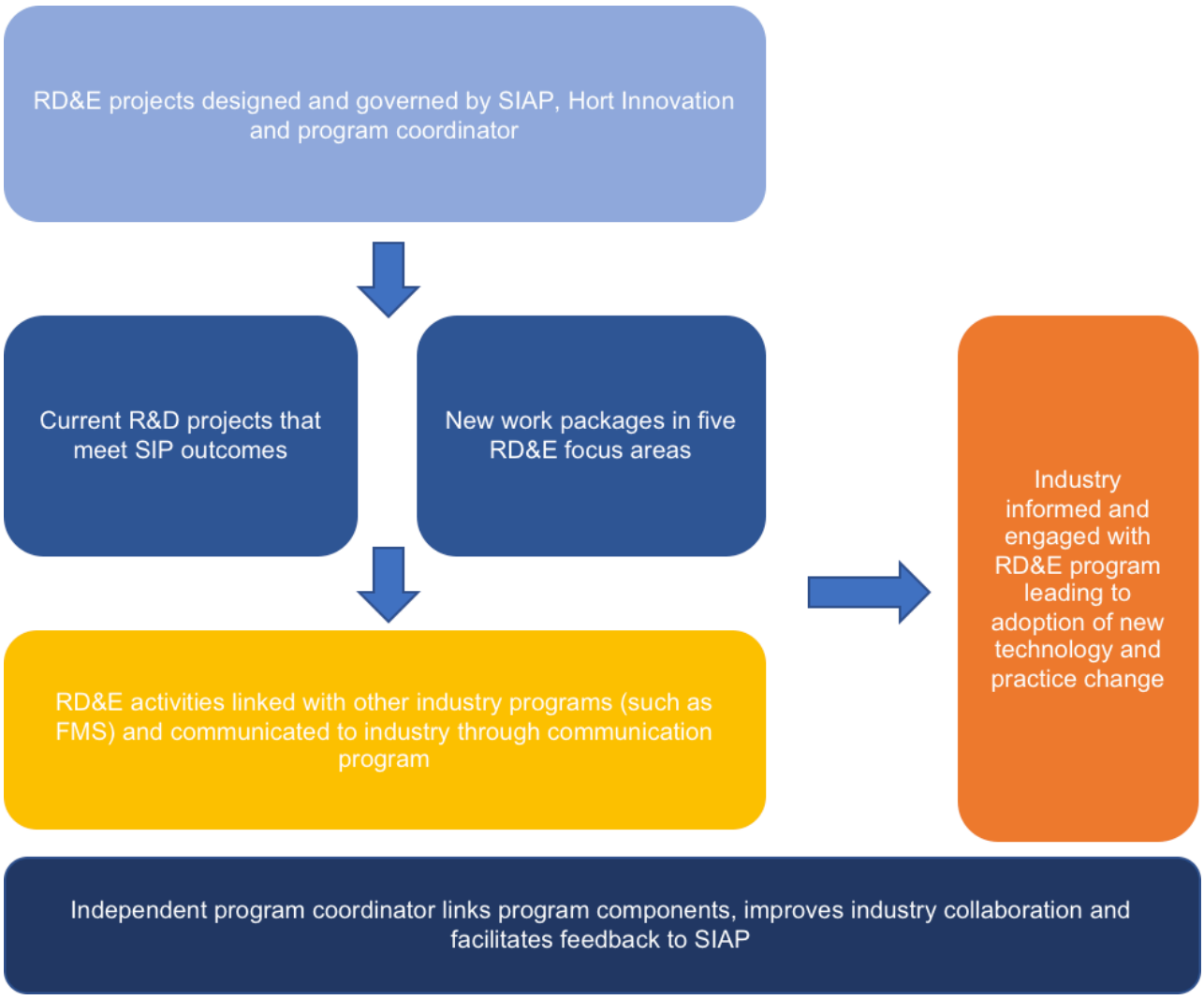

Figure 1: Model of program approach to delivery of RD&E for the Australian nursery industry

Table 1: Approach and recommendations for an integrated RD&E program

APPROACH	RECOMMENDATIONS
Adopt a program approach	Adopt a program approach to nursery industry RD&E to ensure research is meeting industry needs, that R&D outcomes are being adopted by industry and that industry sees a return on investment. This will be achieved by: ▪ Continuing to support current and ongoing R&D that addresses the key industry issues identified in Table 3-7 (Section 3.5) and achieves the outcomes of the SIP. ▪ Commissioning work packages that fill the identified RD&E gaps of: ▪ Reducing the environmental footprint through improved resource use efficiency (*extension focussed package*) ▪ Improving production and process efficiencies (both in the field and within protected cropping systems) (*extension focussed package*) ▪ Reducing production costs through automation and uptake of new technology (*development and extension focussed package)* ▪ Improving supply chain efficiencies and logistics (*integrated research and extension focused package*)

APPROACH	RECOMMENDATIONS
	▪ Improved understanding by industry of end user needs/desires (*integrated research and extension focused package*). ▪ Engaging a program coordinator who is independent to the other components of the program (such as the services provided by the work package deliverers, the communication program and industry).
Develop work packages that truly integrate RD&E	Design efficient, effective work packages that deliver industry relevant RD&E by: ▪ Clearly defining the purpose and business relevant outcomes of the R&D ▪ Using teams of RD&E providers that can bring all the skills and expertise required to ensure that project outcomes are taken up by industry (not just research). ▪ Ensuring that research conducted previously over the last ten years both in Australia and internationally is not repeated and outcomes are delivered to industry via extension rather than conducting further research. ▪ Extracting readily useable information (from previous research projects) and developing into resources for communication and extension. ▪ Ensuring levy funded research outcomes are captured in a way that is useful for industry. A suggestion is that outputs from research should be in the form of a research paper and engaging extension/communication resources rather than a standard report. ▪ Linking in with existing programs such as the Nursery Production Farm Management System to deliver some of the work packages (where appropriate). ▪ Tailoring extension delivery according to type of producer targeted (refer to Section 3.2 which discusses industry stratification). ▪ Ensuring that extension involves active participation from industry members rather than communications to a passive audience. ▪ Including economic analysis in R&D projects where feasible. ▪ Including a program logic, KPI's and monitoring and evaluation plan to ensure the impact of projects is identified and monitored.
Engage an independent program coordinator	Engage an independent coordinator to integrate the program components, build the reputation of the program and ensure that future investment is leveraged by: ▪ Ensuring that the Strategic Investment Advisory Panel (SIAP) is provided with sufficient information and process to make critical decisions regarding future RD&E investment. ▪ Developing ongoing relationships/linkages with key R&D providers nationally and internationally identified during this review to enable collaboration on future R&D projects. ▪ Continuing to identify gaps and commission (in conjunction with the SIAP and Hort Innovation) targeted research projects to address these gaps. Where possible including international collaborators (such as University of Wageningen) to leverage off activity occurring elsewhere. ▪ Developing ongoing relationships/linkages with other relevant industry sector organisations such as Protected Cropping Australia and PMA – ANZ to: o Enable collaboration on future R&D that is of relevance to the nursery industry o Build industry capacity and skills associated with protected nursery production systems. ▪ Building connections between R&D providers, technology developers and industry (in collaboration with an industry extension program). Activities could include regular R&D forums open to all industry members where researchers provide updates on recent projects and new technologies including those developed by commercial companies are featured. Interactive workshops and or field visits would be an important part of forums.

APPROACH	RECOMMENDATIONS
	▪ Build connections between producers and the market (retailers, wholesalers, consumers).

For further information on the RD&E Roadmap including specific goals, timelines, approach, target audience and recommended actions refer to Section 5 (The Roadmap).

1 Introduction

WHY IS RD&E IMPORTANT?

- An effective research, development and extension (RD&E) program provides the basis for a sustainable and profitable industry.
- Collaboration between Australia and international teams provide the opportunity to leverage investment, utilise skills and capacity effectively, and identify opportunities.

An effective research, development and extension (RD&E) program provides the basis for a sustainable and profitable industry. It creates opportunities for improvement in management practices, fosters innovation and ultimately improves business profitability. It is therefore vital that investment in RD&E addresses the key issues facing the industry. An RD&E program must be based on a sound strategic plan drawing on the existing knowledge pool, with an understanding of the industry, RD&E skills and experience.

Collaboration amongst relevant multi-skilled RD&E teams nationally and internationally are vital so that resources are used wisely, complex issues can be dealt with and return on investment is maximised.

This project builds the base for an innovative RD&E program for the Australian nursery industry. The outputs of this review will enable industry to develop a targeted program that delivers desired outcomes for nursery businesses and builds industry capacity. To achieve this we have provided industry with:

- A greater understanding of relevant RD&E activities conducted nationally and internationally
- Information on how Australia can leverage research results and collaborate with international R&D programs
- Information on the current capacity and capability for conducting nursery relevant RD&E within Australia
- A road map that provides clear and concise actions on how to address the key issues facing the production sector of the Australian nursery industry and how to monitor success.

2 Approach

HOW DID WE DO IT?

- Desktop and literature review
- Industry and RD&E provider consultation
- Analysis.

Our approach to this project has been to use a straightforward framework of 'Now-Where-How' and SWOT (Strength, Weaknesses, Opportunities and Threats) analysis to guide our review and develop a RD&E road map. This has involved:

- Identifying the key issues and RD&E drivers for the Australian nursery industry within its current operating environment ('Now'),
- Determining opportunities and future goals for the program ('Where'), and
- Detailing the actions and capacity required to reach those goals ('How').

Our review of national and international RD&E and understanding of RD&E program development and coordination, have guided these processes throughout the duration of the project. The review was largely focused on addressing the needs of the production sector but did capture elements across the value chain.

The key outcomes industry is seeking to address through investment of the R&D levy are outlined in the Nursery Strategic Investment Plan (SIP) 2017 – 2021. The SIP has been an important reference document during the 'now' and 'where' phase of the review and has provided valuable information on the strengths and weaknesses of the industry as well as key threats and opportunities. The road map we have developed will contribute to the achievement of Outcome 4 of the SIP, which is "*improved productivity, profitability and professionalism through the creation of opportunities through innovation and adoption of industry best management practices*".

2.1 FRAMEWORK

We have used a simple framework for the collation and analysis of data, involving assessment of:

1. **Now** – we developed a strong understanding of the key challenges and opportunities, and hence RD&E drivers for the nursery industry (both internationally and nationally), current nursery related RD&E, as well as the capacity of RD&E providers to meet and align with needs. This included analysis of inherent strengths and weaknesses (SW) of the nursery industry, including technology access and use, skills, knowledge, attitudes and aspirations.
2. **Where** – this phase shifted the focus to understanding where the nursery RD&E program needs to be in the near future. We examined both internal and external drivers (such as policy directions, RD&E gaps/needs and potential partnerships) that the program must respond to, opportunities and threats (OT) and articulated a long-term goal.
3. **How** – this stage brought together the understanding of the current environment with the future goal position of an RD&E program and lessons learnt from the international RD&E scan. Information gathered during the 'now' and 'where' phases was analysed to develop an action plan (road map) that concisely steps through the actions needed to progress towards the new long-term goal. The ultimate goal of the RD&E plan, when implemented, relates to the profitability and sustainability of the nursery industry as stated in the SIP.

This framework is illustrated in Figure 2-1 with more details of each of these stages provided below.

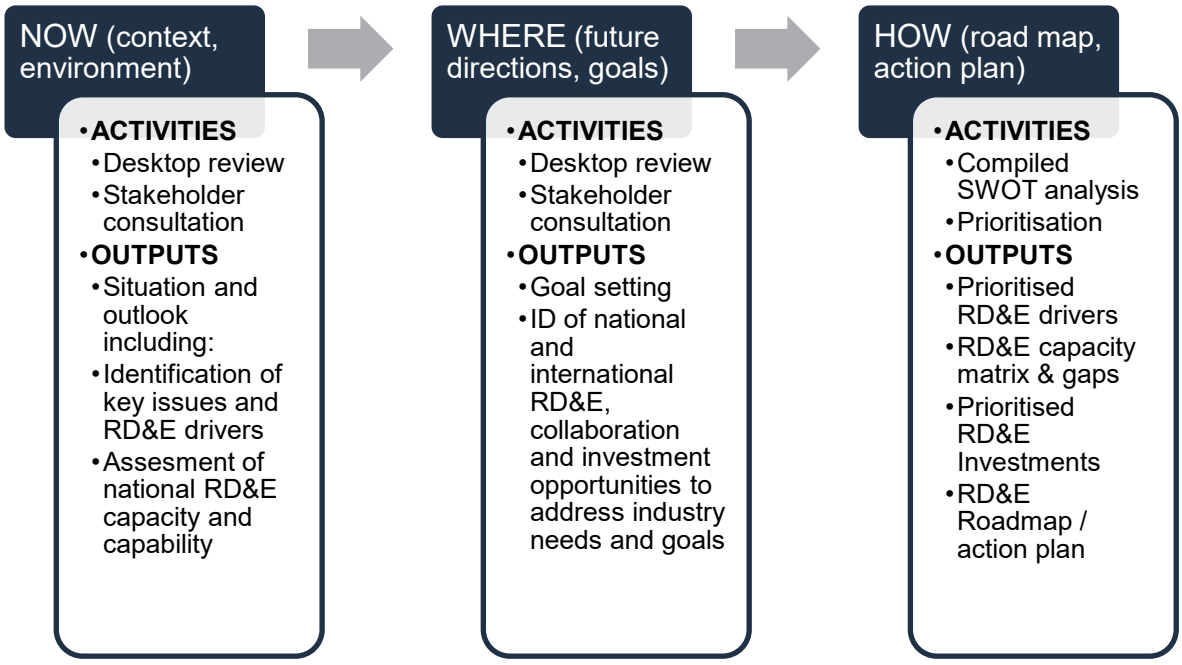

Figure 2-1: Framework stages

2.2 DOCUMENT REVIEW

The review included a global desktop/literature review and consultation with key research agencies nationally and internationally to:

- Identify the main issues the nursery industry is facing nationally and internationally and, from an RD&E viewpoint, the major drivers for industry
- Assess these international issues against relevancy for the Australian industry and prioritise accordingly
- Identify RD&E capability (people) and capacity (facilities) internationally and domestically
- Detail current international and domestic RD&E investments and programs in public and where appropriate, private sector entities
- Provide critique and commentary of global trends and relevancy to Australia
- Provide alignment against the Nursery Industry Strategic Investment Plan 2017-2022.

We established a framework at the start of the desktop review to ensure that the right data was collated and allowed for easy identification of information gaps, which were then addressed during industry consultation. The framework provided information according to the following key questions:

What are the key issues facing the nursery industry and how might these act as drivers for future RD&E?

These included issues/drivers such as:

- Increasing environmental/sustainability concerns
- Increasing regulatory concerns
- Ability of industry to harness new communication and precision technology
- Ability of industry to harness new technologies to save labour and other costs

- Meeting the increasing sophistication of customer's demands and QA needs
- Biosecurity management
- Supply chain management and markets.

The current industry SIP has been a key reference document for answering this question.

What is the capacity and capability of the RD&E community to address these issues both nationally and internationally?

Based on the issues/drivers identified for the Australian nursery industry, what is the:

- Current expertise in terms of knowledge and skills of researchers, industry development officers and other service providers and the future outlook i.e. demographics and potential for new skilled recruits
- Current facilities available to deliver R&D such as field sites/glasshouse facilities that could be used to conduct research and analysis
- Supply chain and market research expertise
- Extension and capacity building ability.

Which recent and current RD&E programs are addressing key issues both nationally and internationally?

Assessment of recent and current projects have included consideration of:

- Relevance of activities, current and future skills to the key issues identified for the Australian nursery industry
- Extension activities and resources of relevant R&D and effectiveness/adoption
- Opportunities to collaborate and leverage off project activities
- Models that have worked well in other countries and for other horticulture industries that could apply to the nursery industry
- Gaps, opportunities and resource needs.

2.3 INDUSTRY CONSULTATION

RMCG consulted with key industry stakeholders and research agencies both nationally and internationally to determine/confirm:

- What are the key issues facing the Australian nursery industry and what should be the drivers of future RD&E (these were identified in the current SIP and confirmed during interviews)?
- What RD&E delivery of relevance to the nursery industry is currently taking place in Australia and abroad, and by whom?
- What are the opportunities to coordinate and collaborate RD&E activities with other service providers to achieve mutually beneficial outcomes?
- What may be some of the barriers to success and how could they be overcome?

Consultation occurred via targeted interviews. This provided us with a deeper understanding of motivations and perspectives, the 'why' behind certain views and suggested approaches (qualitative data). The interview questions were tailored towards the various industry sectors and RD&E providers and guided by the framework.

An interview guide for stakeholder consultation was developed, which ensured that there was consistency in the information collected throughout the entire consultation stage to allow for the analysis of responses. One-to-one interviews followed the interview guide and included a flexible, conversational and semi-structured part around key themes so that interviewees could discuss concepts they felt important. This gave us qualitative data to understand motivations and context, important for the synthesis of findings.

Interviews were undertaken with key industry members and those currently involved in RD&E relevant to the nursery industry. Interviews were conducted face-to-face or by telephone, depending on the location of the individuals. Details of those consulted are provided in Appendix 1.

Each stakeholder was sent a letter including information of the project prior to being contacted verbally. The letter outlined the role of RMCG, the purpose of the project and stakeholder involvement. This was followed by a phone call to establish their willingness to participate and organise a time and date for an interview.

2.4 ANALYSIS

The information collated during the desktop/literature review and industry/RD&E provider consultation was analysed in conjunction with an assessment of the current industry operating environment to develop four key outputs which guided the development of the RD&E road map for the Australian nursery industry.

This stage provided the 'how' of the project, outlining to industry the steps required to deliver prioritised RD&E investments. The three key outputs are outlined below:

OUTPUTS	DESCRIPTION
Description and ranking of RD&E drivers and focus areas	During the desktop review and industry consultation we assessed the profile of the nursery industry, the challenges and opportunities and identified the RD&E drivers which are likely to impact on the future sustainability and profitability of the nursery industry. The drivers were then prioritised according to those that will have the main impact so that investment (in terms of time and money) is used most effectively. Drivers were prioritised according to a range of aspects such as: ▪ Likelihood of success of R&D and adoption via extension ▪ Risk to industry if issue is not addressed ▪ Relevance to the Australian nursery industry and potential benefit to industry stakeholders ▪ Time required to address an issue. Economic analysis of the potential cost to industry of issues not being addressed was not conducted during the review.
RD&E capability/ resources matrix	The desktop review and industry consultation identified the current capacity and capability of nursery relevant RD&E providers within Australia and internationally. The expertise, facilities, experience and reputation of various service providers was documented and their ability to address each of the five key industry issues assessed against the relevant topic/focus areas of the future RD&E program.
Road map (action plan)	The road map provides a set of clear and concise recommendations/calls for action to assist industry in rolling out a coordinated, collaborative RD&E program for the Australian nursery industry.

3 Now - Current Situation

WHY DO WE NEED TO KNOW WHAT'S CURRENTLY HAPPENING?

The current operating environment, industry profile and national trends will have a direct impact on RD&E needs and how RD&E should be delivered to industry. These have been considered in the development of the RD&E roadmap.

The current operating environment for the Australian nursery industry (greenlife industry) has a direct impact on future RD&E needs and how that RD&E should be delivered to achieve the greatest impact for industry. The current situation analysis included:

- Review of the industry profile and how the diversity of businesses within industry impacts on RD&E needs and delivery
- Analysis of industry strengths, weaknesses, opportunities and threats (SWOT)
- Observations of trends relating to RD&E and the nursery industry nationally.

The current situation and key issues/drivers provided us with a framework to assess:

- The current scope and level of RD&E activity addressing key issues both in Australia and internationally
- The capacity and capability of RD&E providers within Australia and internationally to address these issues.

The outcomes of the current operating environment and issues analysis are discussed in Sections 3.1 – 3.5.

3.1 INDUSTRY PROFILE

The Australian nursery and garden industry is highly diverse, with a range of business sizes and values, production systems and markets. This will impact on how research outcomes should be communicated and extended to industry.

An analysis of industry statistics was recently undertaken to create a more accurate profile of the Australian nursery industry. During the analysis, 221 nursery businesses were surveyed with the results summarised in Table 3-1.

Table 3-1: Characteristics of the Australian nursery industry based on survey responses collated during the Nursery & Garden Industry Statistics 2017 Data Collection Project

CHARACTERISTIC	IMPACT
Industry profile	More than half of all greenlife production businesses are small businesses (56%), turning over $500,000 or less in a year. A further 27% report sales of between $500,001 and $2 million while the remaining 17% sell more than $2 million worth of plants. This latter group (17%) accounts for 74% of total national turnover in the nursery industry.
Skills	In a recent survey investigating skills shortages in the nursery industry, 37.5% of the survey respondents believed that they did not have the skills in their business to run it as expected, 12.5% were unsure[1]. They key areas of skills needed for the future included: robotics and automation, environmental management and sustainability, agronomy, logistics (transport/shipping and distribution), QA systems, product development and staff development.
Number and value of plants sold	An estimated 1.6 billion plants are sold by greenlife production businesses at a total value of $2.3 billion. Some of these plants are sold to other production business either for immediate re-sale at a marked-up price or for growing on and selling later.
Employment	Greenlife production businesses employ approximately 27,000 people, mostly directly relating to growing and caring for plants, but also in administration and other roles in the business. Approximately half these people work full time while others are part time or casual employees, equating to 19,000 Full Time Equivalent (FTE). The 'average' business estimates that 32% of the income derived from sales is spent on wages. It should be noted however, that not all the 221 businesses that participated in the survey keep accurate records and the proportion may be slightly different in actuality.
Confidence	Confidence in the future is widespread due to a belief that demand for greenlife product will continue. As a result, future intentions are typically to grow the business or at least remain steady, with only 6% intending to exit without selling to another greenlife entity. Business investment in infrastructure and to a lesser degree, technology is widespread. Those expecting to exit are more likely to be small businesses rather than larger operations.

The survey results provided in Table 3-1 present a snapshot of a diverse industry that ranges from some large 'blue chip' enterprises that generate the vast majority of sales, to small family run or hobby type businesses.

[1] Survey results from the Nursery Career Pathway project

This diversity presents some challenges for the industry overall and future support and services should include components that cater for the different needs covering the entire scale[2].

This diversity will also have an impact on:

- The RD&E needs of individual businesses
- How relevant RD&E outcomes will be to individual businesses
- How research should be communicated and extended to facilitate adoption.

The nursery industry profile, and differing RD&E requirements need to be considered in the development of an effective RD&E plan. Aspects of the nursery industry that will impact on the development and delivery of RD&E are discussed in Table 3-2 below.

[2] *This information has been taken from the Nursery & Garden Industry Statistics 2017 Data Collection Report (DTER, NGIA, AAL).*

Table 3-2: Key considerations for the development and delivery of RD&E for the Australian nursery industry

ASPECTS THAT INFLUENCE RD&E NEEDS	DISCUSSION
The Australian nursery industry contains a range of business sizes and value	56% small businesses (less than $500,000 turnover) 27% medium businesses ($500,001 - $2 million turnover) 17% large businesses (more than $2 million turnover) Business size will impact on the need and relevance of RD&E and the ability of individual businesses to adopt new technology and/or practices. Some high-tech solutions may not be relevant or affordable for small businesses.
Knowledge, skills, attitudes and aspirations vary	Knowledge, skills, attitudes and aspirations will impact on the need and relevance of RD&E and the ability of individual businesses to adopt new technology and/or practices. Different R&D focus areas and extension approaches may be required to match the needs of different groupings or sectors. R&D outputs in areas where a business has a low or no skills can most likely not be adopted. Capacity building is a prerequisite for the adoption of R&D.
The Australian nursery industry contains a range of sectors servicing a wide range of markets using various supply chains	Different R&D focus areas and extension approaches may be required to match the needs of different sectors.
Biophysical production conditions and regulatory context vary widey	Climatic zones have a major influence on plant species, production conditions and markets. The business location impacts on access to infrastructure, labour, production inputs/resources (fertilisers, pesticides, water) and communication services (internet, telecommunication). It also affects regulations on environmental management and biosecurity needs.
Disconnect between the consumer and industry	Producers often grow what they love to grow or what grows well in their environment; with changes in markets due to consumer attitudes and needs or fashion potentially being overlooked. Opportunities originating from changes due to climate or how people live in cities (i.e. apartments versus ½ acre blocks, time constraints) may not be exploited. Discussion with major retailers indicated that many growers were unaware of where their markets were heading and what consumers wanted.
A lack of an extension program for the industry will hamper uptake of R&D and innovation	There is a difference between communication of R&D outputs and adoption by producers. Adoption refers to end users applying the knowledge or a recommended practice to their advantage. Active, targeted and genuine end-user engagement is required to foster adoption. R&D communication is mostly in the form of research papers or one-way information (in magazines or newsletters) to passive end-users. Researchers do produce knowledge that can influence practices and improve profitability. However, researchers are not usually active change agents, generally being rewarded for conducting and publicising 'good research' rather than achieving change or economic outcomes for producers. While researchers can provide information in innovative and accessible ways; peers, respected advisers, local knowledge, customs and family members have more influence on producers' decisions than researchers.

The diversity of business sizes, level of professionalism and production sectors within the nursery industry and the impact this will have on the development and delivery of RD&E are discussed further in Section 3.2.

3.2 WHY IS INDUSTRY STRATIFICATION IMPORTANT?

HOW DOES THIS IMPACT ON THE DELIVERY OF RD&E?

- The needs of individual businesses will differ according to their size, attitude and capacity to change.
- Producers within the nursery industry can be loosely grouped into three categories (steady, advancing and progressive).
- Extension of research outcomes should be tailored to these three categories and use approaches that meet their needs and considers their capacity.

In order to develop an RD&E plan with an effective approach to extension which meets the needs of all of the nursery industry, there needs to be recognition that there is no 'average' nursery producer with significant variation in age, cultural background, aspirations, education and training level, as well as operation size, production system, business structure and business priorities. Location, product types, markets and supply chain arrangements contribute to the diversity. All of these factors impact on how nursery producers seek, understand and utilise information that relates to their business.

It should also be recognised that communication and extension are vital for the adoption of R&D and need to be part of the plan. While communication is important, it does not necessarily lead to adoption. Communication entails providing information to an audience, which can remain passive. Some communication may not reach the entire target audience. Extension involves active involvement of producers in trialling, discussing and adapting new concepts and technologies to their business, taking the different needs of producers into account.

In order to tailor the content and delivery of nursery RD&E, it is suggested that producers within the nursery industry could be grouped loosely into three categories based on the size of operation, attitude towards innovation and change (progressiveness) and capacity to adopt new technologies. These are discussed in Table 3-3 and Table 3-4 below. Obviously there are certain producers who will not fit within these groupings or may display some characteristics but not others.

Table 3-3: Attributes of three categories of producers/businesses within the Australian nursery industry

PRODUCER/ BUSINESS ATTRIBUTES	STEADY PRODUCERS (ABOUT 56%)	ADVANCING PRODUCERS (ABOUT 27%)	PROGRESSIVE PRODUCERS (ABOUT 17%)
Producer characteristic	▪ Adverse to risk ▪ Short-term thinking ▪ Slow to adopt new technology	▪ Cautious with risk ▪ Considers strategic advantages ▪ Adopts technology with majority of others	▪ Comfortable with risk ▪ Long-term, strategic thinkers ▪ Early adopters of new technology
Business characteristic	▪ Small size, low complexity, low employee numbers. ▪ Limited need for specialists skills within the business, simple structural organisation. ▪ Minimum process control.	▪ Medium size, complexity, structural organisation, employee numbers. ▪ Some need for specialists skills within the business. ▪ Adequate process control.	▪ Large size, high complexity, structural organisation and planning, high employee numbers. ▪ Need for specialists skills within the business. ▪ Good process control and efficiency.
Financial management characteristics of business owners	▪ Low average cash income, basic preparation of detailed budgets. ▪ Mostly operational planning conducted, no business plans.	▪ Moderate average cash income, preparation of straightforward budgets (e.g. gross/net margins). ▪ Risk and financial consequences considered when planning and making decisions.	▪ Highest average cash income, preparation and close monitoring of budgets. ▪ Main decision drivers are risk and economic/financial considerations when preparing business/ strategic plans.
Cost of production	▪ Limited control over/understanding of cost of production.	▪ Reasonable control over and understanding of cost of production.	▪ Good control over and understanding of cost of production.
Use of technology	▪ Low use and capacity to introduce.	▪ Use of technology to improve efficiencies and manage data.	▪ Use of technology and desire to increase its use (e.g. automation, communication, data management, supply chain management).
Supply chain	▪ Limited supply chain management.	▪ Commencing or interested in proactive supply chain management and logistics.	▪ Good, proactive supply chain integration and logistics management.
Environmental management	▪ No or low interest in participation in environmental programs.	▪ Interest in participation in environmental programs.	▪ Active environmental management is part of production approach.
Main markets supplied	▪ Local markets.	▪ Local and interstate markets.	▪ Major retailers and wholesale markets nationally.
Quality assurance	▪ No system or structured record keeping.	▪ Increasing use of QA programs and or record keeping.	▪ Use of QA programs.

Table 3-4: Delivery of extension to meet three categories of producers/businesses within the Australian nursery industry

EXTENSION PRINCIPLES	STEADY PRODUCERS (ABOUT 56%)	ADVANCING PRODUCERS (ABOUT 27%)	PROGRESSIVE PRODUCERS (ABOUT 17%)
Main information sources used to learn and/or progress the business	▪ Trusted people in the industry, neighbours, workshops, informal training, practical, ready to use content. ▪ Little time for reading.	▪ Increased attendance at field days, workshops, study tours and other specific events, some have formal training. ▪ Prepared to spend some time reading.	▪ Increased attendance at conferences, travel, advice from outside the business, some formal. ▪ Want to know and read about R&D, new technologies, future opportunities.
Preferred main extension service providers	▪ Extension officers, agronomists (no charge), informal, free extension providers, IDOs.	▪ As for 'steady producers' plus; grower associations, trainers coming on farm, informal extension providers. ▪ Limited willingness to pay.	▪ As 'steady producers' plus; paid advisers and trainers, Universities, State DPI staff, other researchers. ▪ Will pay for good services.
Expectation of extension programs	▪ Relevance of 'ready to use' information. ▪ Locally or regionally oriented. ▪ Build on existing knowledge and experience, flexible, brief, hands on, known outcomes.	▪ Relevance of information, happy to adapt learnings. Mainly regionally oriented. ▪ Use digital technologies. ▪ Build on existing knowledge and experience, flexible, not longer than one day, known outcomes.	▪ Relevance of information, innovative, cutting edge. ▪ Happy to leave region. ▪ Use digital technologies. ▪ Want to be challenged, but build on existing knowledge and experience, flexible, high quality, known outcomes.
Learning pattern, networking[3]	▪ Local focus of learning and networks, sometimes people focussed.	▪ Local and people focussed tending towards outward looking/ networking.	▪ Outward looking (nationally, internationally) and extensive networks.
Staff – highest attainment levels used	▪ Employ staff that 'can do the job' and have training needed for compliance.	▪ Employ multi-skilled staff with mainly low and medium attainment levels.	▪ Employ some staff with high attainment levels for specialised jobs.
Generalised expectation of staff training	▪ Do not require formal training, support learning on the job, not overly keen on having staff going away for training.	▪ Do not require formal training for most staff, support learning on the job and may get a trainer in or send staff to workshops or field days.	▪ Value proof of formal training and higher attainment levels and also learning on the job, may get a trainer in or send staff to workshops, field days or short courses.

The delivery of research outcomes to the three categories of producers using targeted extension approaches is discussed further in the RD&E roadmap provided in Section 4 (The Future).

[3] Kilpatrick S. 2003. How farmers learn: Different approaches to change. The Journal of Agricultural Education and Extension. Volume 9, Issue 4.

3.3 CHALLENGES AND OPPORTUNITIES

Like many other horticultural industries, the nursery sector is facing challenges such as labour attraction and retention, increasing production costs and a need to be 'clean and green'. There are opportunities to address these, and other challenges, through targeted research and development which focuses on improving production efficiencies, reducing the environmental footprint of nursery businesses and a better understanding of nursery and garden customers.

This section provides an overview of the challenges and opportunities facing the nursery industry based on information gathered from the desktop review, SIP and consultation with industry stakeholders.

The strengths, weaknesses, opportunities and threats for the Australian nursery industry are provided in Table 3-5. These outcomes of the analysis were considered in the development of the RD&E road map.

Table 3-5: SWOT analysis of the Australian nursery industry

STRENTHS	WEAKNESSES
▪ As a 'green' industry, the nursery industry has a positive image for government, the media and the community. Nursery products are an important part of the Australian lifestyle ▪ The industry provides major environmental, economic, health and wellbeing benefits to the Australian community; its products make a difference ▪ The industry contributes significantly to the Australian economy. Demand for nursery products is increasing ▪ A passionate industry community: diverse, innovative and knowledgeable ▪ An excellent national biosecurity system protects the Australian industry from major pests and diseases ▪ Excellent diversity of plants, including Australian natives, ensures that there is a plant for all seasons and regions ▪ Levy funded R&D has already addressed a wide range of industry issues ▪ The industry offers a solution to global problems through supplying new varieties to combat a range of environmental problems.	▪ Limited data on the industry and its contribution to the Australian economy ▪ Very easy to enter the industry, resulting in many smaller operators selling at low prices, sometimes with low quality and reducing overall industry profitability ▪ Chain store/large retailers are dominant within the retail sector ▪ Red tape for market access – no harmonised approach between the states. Lack of system for nursery registration poses a biosecurity risk ▪ Lack of industry training and development recognition. Not enough suitably qualified people or young people entering the industry and building a career ▪ The level of business and technical sophistication throughout the industry is generally low ▪ Industry does not sell itself well enough; needs greater effort in shaping end-user perceptions about the industry and plants ▪ Not addressing the barriers for the poor uptake of technology and innovation within the industry ▪ 'Backyard operators' and those who do not know their cost of production or the value of their product ▪ High staff turnover, and the inability to attract and retain suitably qualified people into the industry.
OPPORTUNITIES	**THREATS**
▪ Make cities more liveable as per the 202020 Vision program, and run suitable programs that promote the benefits of greenlife and nursery products ▪ Capitalise on the impact of greenlife mitigating climate change	▪ Increase in biosecurity risks (national and international) ▪ Biosecurity risks associated with a relaxation of quarantine vigilance, and hence potential for pest and disease incursions from overseas, including Asian imports

STRENTHS	WEAKNESSES
▪ Capitalise on the push for introducing more biodiversity, shelterbelt and riparian vegetation in the landscape ▪ Continue and maintain the strong focus on biosecurity to protect Australia from overseas pest and disease incursion ▪ Harmonise interstate biosecurity protocols and have nursery registration ▪ Develop better industry data showing value of industry, number of people employed and benefit to economy ▪ Expand reach to capture opportunities within production horticulture ▪ Improve use of technology: ▪ Monitoring ▪ Disease detection ▪ Remote systems ▪ Automation ▪ Waste heat and electricity obtained from bio-energy ▪ Stronger focus on BMPs within the industry to improve professionalism, quality of plants and production efficiencies, including reducing use of chemicals ▪ Support industry training and development as a way to attract younger people into the industry. Create better career paths to attract forward-thinking people into the industry ▪ Establish a sustainable production program to demonstrate that the industry looks after plant, people and profits ▪ Increase the economic size of the industry by strongly positioning the financial, health and wellbeing benefits of plants with target audiences ▪ Demonstrate benefits of greenlife on reducing temperature in a changing climate.	▪ Local planning not permitting enough green space in developments. Australian community lacks perceived value of greenlife products ▪ Drought, national water reform and government policies that restrict access to water for nursery production and green space ▪ Rising cost of production, including for unskilled labour, energy ▪ Urbanisation creating greater pressure on peri-urban nursery businesses ▪ Inadequate knowledge of the consumer; the industry does not take into account the future needs of the consumer ▪ Greater competition for discretionary income, for example, spending on leisure versus spending on nursery products ▪ Reduced access to input, such as existing and new chemicals.

3.4 KEY NATIONAL OBSERVATIONS AND TRENDS

- The capacity and capability to deliver RD&E by traditional providers has reduced in response to decreased public funding. This has been offset by an increase in private providers and increasing levels of collaboration and leveraging between organisations.
- Issues and trends faced by the nursery and garden industry are being addressed by research projects however the lack of extension activity will hamper the ability of industry to respond to trends such as increasing environmental regulation, consumer demands and new technology.
- Communication and understanding between the research community and industry is poor.
- Coordination and communication between the production sector, retailers and the consumers could be improved.

RESEARCH, DEVELOPMENT AND EXTENSION (RD&E)

Investment in, and delivery of, RD&E for Australian horticulture has seen substantial change over the past decade. There is:

- ↑ Pressure on public funding
- ↑ Capability constraints (infrastructure and people)
- ↑ Privatisation and globalisation of RD&E (such as biotechnology, extension)
- ↓ Investment from traditional public sector partners
- ↓ Ability to maintain required R&D capacity in regional Australia.

An increasing need to collaborate and leverage has evolved to ensure investment is utilised effectively. The majority of RD&E occurring for the Australian nursery industry is funded via Horticulture Innovation Australia (Hort Innovation) using industry levies and matched government funds. The nursery and garden associations (NGIs) communicate research outcomes and other relevant information (i.e. on new technologies) to their members. However, targeted extension of research findings to nursery producers to enable adoption of new technologies and methods is currently not occurring.

Funding for basic research for the nursery sector is limited. Communication between the nursery industry and the research sector (universities, government departments) could be improved. Australian research providers are keen to work more collaboratively with the nursery industry and improve communication to see greater adoption of outcomes. Researchers within the Green Infrastructure Research Group at the University of Melbourne indicated disappointment that products such as the Growing Green Guide hadn't been supported and used more by industry to increase demand and drive plant sales. Similarly, industry members can feel that research outcomes are not business focused or have practical application to addressing their needs.

INDUSTRY

The main trends observed for the nursery industry and hence drivers of change are provided in Table 3-6.

Table 3-6: National trends and their impact on the Australian nursery industry

TREND	IMPACT
Urbanisation and desire for 'green cities' to improve amenity, liveability, biodiversity (bird and bee habitats) and microclimate	This will require the nursery industry to focus on/produce: ▪ Resilient plants (climate, water) ▪ Native plants ▪ Plants for small spaces, rooftops and potted colour.
Increasing environmental sustainability focus	This will lead to the: ▪ Use of trees to mitigate climate change ▪ Need for efficient use of water and nutrients ▪ An expectation by consumers that growers reduce the use of chemicals ▪ Environmental plantings (offsets, shelter, biodiversity corridors) ▪ A need to recycle and re-use water, plastics and waste substrates.
Increased biosecurity vigilance	Biosecurity impacts on the nursery industry via: ▪ Incursions and state biosecurity responses affecting trade ▪ Quarantine costs and time frames for plant imports.
A need for targeted and efficient education, training and labour	▪ Delivery of nursery specify courses are scarce even though a nursery specific TAFE training package exists (may need to be updated to incorporate new technologies) ▪ Finding and retaining labour is challenging.
Distance to market is increasing	Nursery production has to move out of ever-expanding cities, increasing transport costs for nurseries supplying urban areas
Chain stores like Bunnings have a major impact on sales	These retailers are looking to the nursery industry to: ▪ Improve product consistency and uniformity ▪ Manage risks such as adverse weather conditions causing breaks in production ▪ Plan for succession ▪ Understand market trends and what consumers are looking for ▪ Improve information available to consumers on green plants.
New technologies like robotics, automation or internet/satellite-based applications are not used to a great degree	Uptake of new technology is hampered by: ▪ Cost of new technology ▪ Business size ▪ Skills ▪ Capacity to deal with IT issues ▪ Uncertainty around the selection of the right technology for the business and how long it may be current ▪ Support from overseas technology suppliers may be patchy and 'spare parts' difficult or slow to get ▪ Issue around different technology platforms communicating with each other.

3.5 KEY ISSUES FACING THE NURSERY INDUSTRY AND DRIVERS OF FUTURE RD&E

The current operating environment for the nursery industry (discussed in Sections 3.1 – 3.4) was assessed in conjunction with the Nursery Industry SIP and the National Horticulture RD&E Framework to understand the key issues facing the nursery industry and how these issues might drive future RD&E to ensure the sustainability and profitability of the industry. The issues identified were validated and added to during consultation with industry members. The issues and their implications for the nursery industry are discussed in Table 3-7 below. These RD&E drivers provided the framework for assessment of current RD&E activity and capacity in Australia.

Table 3-7: Key issues and RD&E drivers facing the Australian nursery industry

ISSUES	RD&E DRIVERS	DISCUSSION
I. Environmental stewardship and sustainability	Assist the nursery industry to mitigate and adapt to climate related changes in production conditions and markets	Climate change and variability (e.g. reduced rainfall and higher temperatures in southern Australia, more extreme weather events in northern Australia), are major R&D drivers for the greenlife industries. The main implications are rising input costs (energy, fertiliser, fuel, water) placing increased pressure on production costs for the sector and government policy changes affecting both production of lifestyle horticulture products and consumer demand for them. Examples of the latter are reduced access to urban water for irrigation of outdoor gardens and reduced plantings of garden plants and turf in southern Australia.
	Reduce the environmental footprint of green infrastructure and plant production through better managed input/output usage (resource use efficiency)	Increasing regulation and consumer expectations will place greater pressure on the nursery industry to become more efficient and sustainable with the management of production inputs such as water, fertilisers and chemicals. There will also be a need for industry to demonstrate greater stewardship of the recycling and re-use of outputs such as plastic pots/bags, substrates, greenhouse covers, irrigation lines and other materials.
II. Improving systems and practices	Improve production/process efficiencies (both in the field and within protected cropping systems)	Improvement of production management and resource use efficiencies through the adoption of good management practices and process control will assist the industry as a whole to become more professional and profitable. In particular the production of plants within protected cropping systems will become increasingly more technical and businesses will require support to build capability in this area.
	Improve supply chain efficiencies and logistics	On-going adaptation in the way plants are managed, transported and sold will require nursery businesses to be innovative and respond to changing markets and opportunities. Looking for opportunities to streamline and reduce double-handling will assist business to be more efficient and profitable.
	Improve pest, disease and weed management	The management of pests, weeds and diseases remains a key issue for the nursery industry. Innovation into better diagnostics tools, better monitoring, faster response times, and use of electronic documentation and data management are some examples that will provide benefits to the industry.

ISSUES	RD&E DRIVERS	DISCUSSION
	Reduce production costs through automation and uptake of new technology	Labour is a significant component of the cost of production. A number of industries have used automation to streamline their labour inputs and processes. Modification of these may offer the nursery industry more efficient options.
	Better industry data (good decisions are based on good data)	There is limited information currently available on the size, structure and value and other aspects of the nursery industry that affect RD&E needs. The industry must obtain accurate data in order to monitor its contribution to the Australian community and economy, and to have a stronger understanding of consumers, their needs, wants, and reasons for purchasing. It must monitor trends to enable better decisions to be made about marketing and promoting greenlife products and services. This information will also help to position the industry to ensure it captures long-term demand and sales opportunities. Most importantly, the data that is generated on consumers and their requirements must be well researched and communicated to industry. Improved data and knowledge is also needed about growers. This will be used to target communication and extension activities and to highlight potential RD&E areas.
III. Biosecurity	Prevent and manage the introduction of new pests, diseases and weeds	The prevention and management of new exotic pests, diseases and weeds entering the country, and interstate and international market entry issues are key areas affecting growth and profitability within the sector. There is a need to continue awareness raising, knowledge about threats and prevention as well as practices.
	Improve quarantine/biosecurity efficiencies	There is a need to decrease the time taken for new genetic material to be processed through quarantine, without jeopardising Australia's biosecurity status, as the process currently presents significant risk to innovation for nursery businesses.
IV. Increasing the demand for nursery products	Create better plants	Sourcing, selection and evaluation of new genetic material will facilitate the development of new plant products that meet the needs of consumers/industry and are 'fit for purpose'. Given the size and diversity of the industry, and the cost of breeding, an investment in sourcing and evaluation would be most appropriate.
	Improve understanding by industry of end user needs/desires	There is a disconnect between changing end user needs/desires and an awareness of industry and producers of what these are. End users range from home gardeners through to the green infrastructure and urban landscape sector. Industry needs to be on the front foot of driving new products and trends that meet market needs and grow the market.
	Improve horticultural literacy (understanding of plants)	The need for end users to have a better understanding of basic plant management (home gardeners) through to a better technical knowledge by landscape architects of plant suitability and required management was discussed as a key challenge for the nursery industry. The industry has to understand knowledge gaps and engage with media that reach target audiences to 'educate' markets.
	Influence policy makers and the public on the value of greenlife and nursery products	Greenlife and nursery products provide a multitude of environmental, social and economic benefits that greatly enhance the liveability and biodiversity of Australian urban and rural environments. Economic modelling to quantify and effectively communicate these benefits in urban, peri-urban and rural environments is required. This data will ensure that green infrastructure and associated biodiversity are valued as a community asset for

ISSUES	RD&E DRIVERS	DISCUSSION
		the health and well-being of the Australian urban and rural populations, environment, climate change mitigation and prosperity of the Australian economy.
	Increase the level of green infrastructure	Cutting edge research into aspects of greening cities and communities helps to ensure Australia's nursery and turf industries are ready for the future and contributes to the 202020 Vision of an increase of 20 per cent in urban green space in the next two years. Research into the development of green infrastructure will promote greater sustainability of green space across urban areas, and at the same time boost the value of green life industries, and deliver return on investment for levy payers.
V. Skills and workforce management	Attract and retain skilled staff within the nursery industry to build capacity and capability	The availability, delivery and uptake of training for new and existing industry members at all levels including improved management practices, technology adoption and the development of career pathways to ensure a source of workers and managers/leaders for the future is a key to the ongoing success of the industry.

3.6 RECENT AUSTRALIAN NURSERY RELATED RD&E PROGRAMS

WHILE A NUMBER OF THE ISSUES FACING THE NURSERY INDUSTRY ARE BEING ADDRESSED THROUGH CURRENT (OR RECENT) PROJECTS, KEY GAPS IDENTIFIED INCLUDE:

- Reducing the environmental footprint of green infrastructure and plant production through better managed input/output usage (resource use efficiency)
- Improving production/process efficiencies (both in the field and within protected cropping systems)
- Improving supply chain efficiencies and logistics
- Reducing production costs through automation and uptake of new technology
- Improved understanding by industry of end-user needs/desires

During the desktop review and industry consultation the scope and level of RD&E activity conducted within the last five years addressing the key industry issues was identified. RD&E activity is funded by the Nursery Industry R&D levy in conjunction with federal government funds or by other R&D providers such as state governments. RD&E activity within each of the key issue areas is discussed below with the details of individual projects provided in table form (in Appendix 2)

I. Environmental stewardship and sustainability

There a number of projects such as the 'Which Plant Where' database and the 'evaluation of nursery tree stock balance parameters' which are helping the nursery industry to mitigate and adapt to climate change. However there currently aren't many projects addressing resource use efficiency within the nursery industry.

II. Improving the adoption of new systems and practices

A key gap in terms of current RD&E is in the area of **improving the adoption of new systems and practices** both in the field and within protected cropping systems. In particular:

- Reducing the environmental footprint through improved resource use efficiency (better input/output use management)
- Improving production and process efficiencies (both in the field and within protected cropping systems)
- Improving supply chain efficiencies and logistics
- Reducing production costs through automation and uptake of new technology (although there are a number of projects assessing new technology in other industries, there are none specifically addressing nursery needs).

A number of these topics have been investigated previously through R&D projects however due to low adoption the need is still present. Future activity in this area needs to focus on engaging industry and supporting them in adopting new systems and practices.

III. Increasing the demand for nursery products

There is a significant amount of current activity addressing the need to develop more green space and educate the public and policy-makers on the benefits of green space. This has been directed by the 202020 Vision which is a collaboration between industry, business, NGOs, government, academia and individuals to create 20% more green space by 2020. The nursery R&D levy funds a number of projects which fit within this Vision. By creating more green space these projects will have a flow on effect to the nursery industry of **increasing demand for plant nursery products** however three of the other RD&E drivers within this overall issue of 'increasing demand' are currently not addressed well. These include:

- **Create better plants** – the nursery industry made a strategic decision not to invest in a plant breeding program for a number of reasons including that breeding programs are expensive and require long time-frames. The diversity of product lines within the nursery industry also makes it difficult to deliver outcomes for the benefit for all sectors of the industry. Review of current RD&E shows however that there are a number of sourcing and evaluation programs managed by R&D providers within Australia that could provide benefit to the nursery industry if they wanted to prioritise the development of new plant products. NSW DPI, although currently focused on citrus, has strong capacity, capability and networks to run this type of program.
- **Improve understanding by industry of end-use needs/desires** – discussion with major retailers identified a disconnect between production and market needs, in particular for products sold to the public. The view was that there was a poor understanding of what consumers want, the demographics (younger market) and new trends. There is currently no RD&E conducted in Australia addressing this knowledge gap and it is therefore viewed as a priority for future RD&E.
- **Improve 'horticultural literacy' (understanding of plants and how they grow)** – consultation with the Green Infrastructure Research Group at Melbourne University highlighted the need for improved 'horticultural literacy' for both the general public and those that work with plants (such as landscape architects). There are currently no projects addressing this need. It would create an increased demand for nursery plant products if people had a greater understanding, and hopefully desire to work with, plants. However, this issue is broader than the nursery industry and similar to the 2020202 Vision activity would require a collaborative effort between numerous stakeholders.

IV. Biosecurity

The prevention and management of new pests is currently being addressed through a number of **biosecurity** programs. However, the length of time taken for new plant products to pass through quarantine was nominated as a key risk for nursery businesses. Identification of new technology which may speed up the screening processes within quarantine was recently conducted by Agriculture Victoria and the outcomes of this review should be assessed in terms of what future RD&E is required to see it applied and to reduce the risk to nursery businesses. The use of Next Generation Sequencing (NGS) has been a key research focus for Murdoch University and it has the potential to dramatically speed up screening processes within quarantine. Collaboration and funding by the nursery industry with this R&D provider would facilitate the wider use of this technology.

V. Skills and workforce management

The nursery industry has identified and responded to the challenges of **climate change** and **workforce attraction and retention**. Skills and workforce management are also being addressed by a number of across industry funded projects and the nursery industry.

In conclusion

Analysis of the current level of RD&E demonstrates that while some issues are being addressed a number of key RD&E gaps are evident. These gaps are primarily within 'Issue II - Improving systems and practices' and 'Issue III - the need to improve industry understanding of end user needs/desires'. Based on this analysis the five future priority focus areas for nursery RD&E are:

- Reducing the environmental footprint through improved resource use efficiency
- Improving production and process efficiencies (both in the field and within protected cropping systems)
- Improving supply chain efficiencies and logistics
- Reducing production costs through automation and uptake of new technology

- Improved understanding of end user want/needs.

The types of activities required within these focus areas to address industry needs are discussed further in Section 4 (Where - The Future) and Section 5 (How – The RoadMap). While research is a key component of addressing industry needs moving forward, an increased focus on industry engagement, communication and collaboration across all sectors of the value chain and those servicing it is required.

3.7 CAPACITY AND CAPABILITY OF KEY AUSTRALIAN RD&E PROVIDERS

WITH DIRECTION AND FUNDING FROM INDUSTRY, THERE IS THE POTENTIAL TO ADDRESS A NUMBER OF KEY ISSUES THROUGH TARGETED RD&E:

Australian R&D providers have a wide-range of capabilities and capacity to deliver R&D outputs for the nursery industry. Australia is leading the way globally in a number of research fields of relevance to the nursery industry including:

- The use of Next Generation Sequencing technology to improve the efficiency of screening process for biosecurity at Murdoch University
- Urban greening – Green Infrastructure Research Group at Melbourne University
- The development of new tissue culture systems to improve the time taken to generate new seedlings at QAAFI/University of Tasmania
- The development of new technology for monitoring of plants and the automation of production tasks at University of Sydney and UNE
- Production of plants within a protected system (glasshouses/greenhouses) at the University of Western Sydney.

These programs highlight the level of expertise and capacity within Australia to address industry priorities and that it isn't always necessary to look internationally for innovative technology or practices.

The capacity and capability of Australian RD&E providers conducting research of relevance to the nursery and garden industry was assessed. Table 8 provides an overview of the facilities and expertise of reviewed R&D providers including an indication of their particular expertise of relevance to the nursery industry.

The R&D providers reviewed are those that are currently contributing to the nursery industry both directly and indirectly in Australia. They comprise universities, government research institutions, peak industry bodies and private providers that are located throughout Australia. Many of these institutions are currently cooperating with each other and/or collaborating with international organisations.

Although this does not represent a comprehensive review of all R&D providers, we attempted to cover all those with the greatest potential to contribute to the nursery industry in the future. A number of the providers reviewed are currently not delivering RD&E for the nursery industry but have the capacity and capability to do so should direction and investment be provided. The review highlighted the exceptional level of capacity and capability of R&D providers in Australia. Although reduction in government funding has resulted in reduced expertise and facilities in a number of the state providers, this has been offset to a degree by the increased involvement of private providers and, for horticulture, the retention of an R&D levy program. Only NSW DPI has a dedicated extension service, however researchers are usually prepared to communicate research findings to growers and get involved in extension activities delivered by extension specialists.

Further detail on the capacity and capability of individual organisations is provided in Appendix 4.

Table 3-8: Summary of capacity and capability of Australian RD&E providers of relevance to the Australian nursery industry

		Melbourne University	SARDI	QAAFI	QUT	USQ	UNE	WA	NSW DPI	Agriculture Victoria	University of Western Sydney	TIA	University of Sydney	NGIs	Private Providers
Research Facilities	Protected cropping		✓						✓	✓	✓	✓			
	Laboratories	✓	✓	✓				✓		✓	✓	✓	✓		
	In-field			✓		✓	✓	✓	✓	✓		✓			
Research Expertise	Plant protection	✓	✓	✓				✓	✓	✓			✓		✓
	Plant physiology	✓	✓					✓	✓	✓	✓	✓	✓		✓
	Genetics / Breeding		✓	✓				✓	✓	✓					✓
	Agri-tech / Precision Ag			✓	✓	✓	✓			✓			✓		✓
Extension Expertise / Industry Development									✓					✓	✓
Collaboration Experience and International Linkages		✓		✓				✓	✓	✓	✓	✓	✓	✓	✓
Speciality (of relevance to the nursery industry)		Green Infrastructure Tissue culture Plant health	Soil biology and diagnostics	Tissue culture	Agri-tech	Agri-tech	Precision Agriculture	Genomics (Next Gen Sequencing)	Sourcing and evaluation of new genetic material	Agri-tech	Protected cropping systems and urban greening	Tissue culture and seed quality	Soil and precision agriculture	Comms and industry linkages	Consumer and market analysis

3.8 UNDERSTANDING THE INTERNATIONAL R&D LANDSCAPE FOR THE NURSERY INDUSTRY

Much of the research work in Europe and the United States (US) (especially in California) is policy driven. Climate change and environmental stewardship are major drivers relevant to the nursery industry. This results in research focussing on the following areas:

- Climate change mitigation and adaptation
  - Reducing emissions, energy efficiency
  - Carbon foot-printing
  - Lifecycle analyses (carbon, water)
  - Affecting the urban microclimate, reducing the heat island effect of cities.
- Environmental stewardship
  - Reducing the use of agricultural chemicals via new genetics for disease resistance and tolerance and alternative approaches such as ‘natural pesticides’ and cultural methods (such as cover crop use in tree nurseries)
  - Reducing water use by producers, households and in public green spaces
  - Recycling of water, nutrients and waste materials (especially plastics)
  - ‘Sustainable supply chains’.

Additional drivers are:

- Deriving social benefits from using plants in landscapes, parks, gardens, public buildings, institutions and homes, especially for health and wellbeing
- Increasing productivity through resource use efficiency (land, water, inputs) and automation (less labour).

3.9 RECENT INTERNATIONAL RD&E PROGRAMS OF RELEVANCE TO THE AUSTRALIAN NURSERY INDUSTRY

International RD&E of relevance to the Australian nursery industry is focussed on:

- Reducing the environmental footprint through better resource use efficiency (Germany, the Netherlands and the US) due to increasing regulation
  - Improving systems and practices through:
  - Better greenhouse/protected cropping design (University of Wageningen - the Netherlands)
  - Managing labour shortages and costs (SmarHort program – AHDB)
  - Automation (AHDB, University of Wageningen and private providers)
- Understanding consumer behaviour and purchasing patterns (Michigan University and Texas A&M University)
- Urban greening and 'Green Care' (Canada, University of California and Germany).

The international RD&E activity of relevance to the Australian nursery industry (conducted within the last 5 years) is discussed by issue below:

I. Environmental stewardship and sustainability

As discussed in Section 3.8 increasing regulation in **resource use efficiency** has resulted in RD&E providers focussing on ways to reduce the environmental footprint of plant production. This is particularly evident in Europe (Germany and the Netherlands) and in some states in the US. California in particular, through the California Centre for Urban Horticulture, have developed a water use efficiency rating system which is used for all new landscaping. The Wageningen University and Research (WUR), a number of German Universities and the University of California all have on-going research programs investigating better ways to manage inputs and the re-use and recycling of outputs, with Wageningen focussing on innovative ways to manage plastic.

II. Improving systems and practices

Improving systems and practices is also a key focus of research in the Netherlands, Canada and the UK. The Greenhouse Horticulture Unit at WUR is developing new complete concepts and integrated designs of production systems with mobile cultivation systems, revolutionary greenhouse designs or systems for the early detection of plant diseases. In the UK, the Agriculture and Horticulture Development Board (AHDB) has funded a number of research projects investigating innovative ways to manage pest and disease and reduce labour costs through automation. In particular, their GROWBOT project is exploring the use of new, human-robot interactive, soft robotic systems and their application for semi-automated propagation of multiple varieties of ornamental plants. There are also a number of private providers based in Europe who are currently developing and selling various types of automation suitable for use in nursery production systems.

III. Biosecurity

Biosecurity was not a focus of this review as it is likely to be country specific and dependent on existing regulations/quarantine specifications. Of potential to increase the efficiency of quarantine processes is the use of next gen sequencing (NGS) currently part of a research project by WUR. There are potential collaboration opportunities with Murdoch University in Western Australia, who is also investigating the potential of this technology.

IV. Increasing the demand for nursery products

There are a number of projects internationally which are looking at innovative ways to **increase demand for plant products.** There are a number of on-going breeding programs in Europe (Euro-Trials) and in America (University of Kansas) that are assessing new ornamental and woody plant varieties. To speed up the breeding process, which has traditionally been difficult for ornamentals, a number of projects are investigating the use of molecular and genetic tools to improve the efficiency of plant selections (Wageningen University).

Researchers based at Michigan University and Texas A&M University in the US have conducted a number of projects on **consumer purchasing behaviour and preferences.** These researchers (predominately Bridget Behe and Charlie Hall) have significant expertise and experience in marketing, financial analysis and benchmarking, and the situation/outlook for nursery and greenhouse crops in the US.

Urban greening and associated research on key factors that influence tree survival (soil quality and health, tree species selection and water use efficiency) is part of programs managed by University of California and Vineland Institute in Canada. The social and health benefits of plants is also being investigated by the Faculty of Agricultural Sciences and Landscape Architecture in Germany as part of their 'Green Care' program.

V. Skills and workforce management

Skills and workforce management has been a significant focus for the AHDB and is likely to be an on-going concern given the imminent departure from the European Union and a subsequent decrease in availability of labour. SmartHort aims to help the UK horticultural industry increase productivity and address the challenge of access to affordable labour through; improving management practices; supporting skills development; and identifying new technologies. As part of this program they are investigating how automation and robotics may help to offset labour pressures in the long-term. Short-term solutions may be found through changes to management practices, such as the introduction of Lean, Champion and Continuous Improvement. Investing in the skill-set of the workforce through training and apprenticeship schemes could also help to increase productivity and improve staff retention and recruitment.

Areas where we were unable to find significant levels of RD&E activity internationally included:

- Improving supply chain efficiencies and logistics
- Better industry data (there are some older analyses conducted in the US but nothing recent)
- Influencing policy makers and the public on the value of green-life and nursery products.

Further details on RD&E conducted internationally of relevance to the Australian nursery industry is provided in detailed table form in Appendix 5.

3.10 CAPACITY AND CAPABILITY OF KEY INTERNATIONAL RD&E PROVIDERS

International RD&E providers, predominantly throughout Europe and North America, have a wide-range of capabilities and capacity to deliver research and development relevant to the Australian nursery industry. These include:

- Germany has a range of basic through to applied R&D facilities conducting research into nursery related issues.
- There are a number of universities within the US collaborating on nursery RD&E (including Michigan University, Kansas University, Purdue University, Texas A&M University and University of California). Within these organisations there is a strong focus on extension of research outcomes to industry.
- The Agriculture and Horticulture Development Board (AHDB) in the UK invest in a range of nursery related RD&E on behalf of the nursery industry.
- Vineland Institute in Canada.

The majority of these organisations, particularly in the UK and Europe collaborate extensively and expressed a desire to collaborate with Australia in the future.

The capacity and capability of international RD&E providers conducting research of relevance to the Australian nursery and garden industry was assessed. Table 9 provides an overview of the facilities and expertise of reviewed R&D providers including an indication of their particular expertise of relevance to the Australian nursery industry.

International providers, predominantly throughout Europe and North America, have a wide-range of capabilities and capacity to deliver research and development relevant to the nursery industry. The institutions reviewed are those that are currently contributing to the nursery industry both directly and indirectly throughout the world. They consist of an assortment of research universities, government research institutions, peak industry bodies and private extension providers that are located in nursery production areas in relevant countries. Some of these institutions are currently collaborating with organisations within Australia and of those contacted, all of them expressed a willingness to collaborate in the future.

Further detail on the capacity and capability of individual international organisations is provided in Appendix 6.

Table 3-9: Summary of capacity and capability of international RD&E providers of relevance to the Australian nursery industry

		WUR The Netherlands	JKI Germany	Leibniz Institute Germany	The Hort Institute Germany	DCPS Germany	Fac of Ag Sci and Land Arch Germany	Competence Center for Nursery Germany	Michigan University USA	Texas A&M Uni USA	Purdue Uni USA	Kansas Uni	Uni of California	Uni of Georgia	Vineland Canada	NZPPI NZ	Scion Research NZ
Research Facilities	Protected cropping	▯	▯	▯	▯	▯		▯				▯	▯	▯	▯		
	Laboratories	▯	▯	▯		▯								▯	▯		
	In-field	▯	▯		▯			▯				▯	▯		▯		
Research Expertise	Plant protection	▯	▯	▯				▯	▯		▯	▯	▯		▯		
	Plant physiology	▯	▯	▯				▯	▯		▯	▯	▯	▯	▯		
	Genetics / Breeding	▯	▯			▯						▯			▯		
	Agri-tech / Precision Ag	▯						▯					▯		▯		
	Resource use efficiency	▯	▯	▯	▯				▯		▯		▯		▯		▯
	Urban greening				▯	▯	▯						▯				
	Consumer research								▯								
	Industry analysis									▯							
Extension Expertise / Industry Development									▯	▯	▯	▯	▯		▯	▯	
Speciality (of relevance to the nursery industry)		Protected cropping Environmental stewardship Quarantine screening using NGS	Plant protection	Plant health and propagation	Substrates and urban greening	Plant propagation and urban greening	Green Care	Plant protection Substrates	Consumer research and extension	Industry analysis	Extension	Plant breeding	Water use efficiency	Plant responses to light	Agri-tech	Biosecurity	Re-usable pots

4 Where - The Future

To enable industry to address the key issues identified in Section 3.5 we have developed an RD&E roadmap. This roadmap has been developed based on our understanding of the current operating environment for the nursery and garden industry, and the capacity and capability of Australian RD&E providers. A number of opportunities to collaborate and leverage international activity were identified during the review however the nursery and garden industry require direction, support and a framework which enable them to take advantage of these opportunities. This roadmap will guide industry on the journey towards an innovative and profitable future. The roadmap will provide the base for:

- An RD&E program responsive to industry and market needs
- High adoption of innovative technologies and improved communication and collaboration by industry members
- Stronger partnerships between researchers and extension specialists within Australia and internationally
- Improved relevance and usefulness of RD&E outputs for the Australian nursery industry
- Improved networks and communication within industry, RD&E providers and between these groups.

4.1 VISION

An RD&E program that builds the capacity and capability of nursery and garden industry members resulting in a more sustainable, innovative and profitable industry.

4.2 WHAT

The program should deliver specific work packages addressing the five key focus areas outlined in Table 10 (below). The issues and RD&E drivers originally identified in Table 3-7 (Section 3.5) were assessed and prioritised according to:

- Their relevance to the current, and potential future, operating environment of the Australian nursery industry
- The risk to industry if the issue is not addressed
- The likelihood of resolving the issue with RD&E
- The current operating environment of the nursery industry (industry profile, SWOT and future trends).
- Of the 15 original RD&E drivers, these five focus areas were chosen and are discussed further in Table 4-1 below.

Table 4-1: Top five RD&E focus areas for the Australian nursery industry

RD&E FOCUS AREA	RELEVANCE TO AUSTRALIAN INDUSTRY	RISK TO INDUSTRY IF NOT ADDRESSED	LIKELIHOOD OF SUCCESS
Improve understanding by industry of end user needs/desires and use this to drive demand	**High** (consultation with retailers, R&D providers and industry members identified a disconnect between producers and other supply chain members and consumers).	**High** (failing to understand consumer needs and desires will result in poor product demand or inability to grow the market and ultimately result in a less profitable industry).	Although a substantial amount of work is occurring to meet the 202020 Vision there appears to be a distinct disconnect between understanding market needs and trends, and producers. There has not been a lot of research conducted on consumer needs and/or the communication of this back to producers. To meet this objective a holistic RD&E approach is required.
Improve production efficiencies (both in the field and within protected cropping systems)	**High** (as input costs are likely to rise, producers will need to become ever more efficient to remain profitable).	**Medium to high** (if producers are unable to improve production efficiencies this will reduce the viability of businesses).	A large amount of research has occurred both within Australia and overseas on ways to improve production efficiencies. With an effective communication and extension program it is likely that substantial efficiency gains could be made by 'steady' and 'progressive' producers*.
Reduce the environmental footprint of green infrastructure and plant production through better managed input/output usage (resource use efficiency, waste minimisation)	**Medium to high** (although there currently aren't strong regulatory requirements to efficiently manage resources, given global trends, this is likely to become a much stronger driver in the future).	**High** (Consumers and the public will expect production industries to manage resources efficiently in order to have a 'social license' to produce. Unsustainable practices have the potential to tarnish the whole of industry).	European producers are currently subject to much stronger regulation in terms of resource use and recycling. Australia could adapt and build on the wealth of research already conducted in these countries to develop better resource efficiency. With an effective communication and extension program it is likely that the ability of industry to sustainably manage resources could be improved. High environmental management practices could be used a tool to market greenlife products (EnviroVeg is one example how an industry led and owned program could be developed).
Reduce production costs through automation and uptake of new technologies in all areas of production, starting with those providing	**High** (particularly as costs associated with labour are likely to increase in the future and the ability to attract and retain labour will become more difficult).	**Medium to high** (failure to automate and use new technologies that fit the business is likely to lower the viability of individual businesses within the Australian nursery industry as	The development and application of technology within agriculture is a key area of R&D at the moment. The nursery industry has an opportunity to learn, build and adapt what is happening in other horticultural industries as well as working with commercially orientated R&D providers to automate specific nursery industry production practices from manual tasks to monitoring and data analysis. Development and extension approaches should target

RD&E FOCUS AREA	RELEVANCE TO AUSTRALIAN INDUSTRY	RISK TO INDUSTRY IF NOT ADDRESSED	LIKELIHOOD OF SUCCESS
the greatest return on investment		labour resourcing becomes more difficult).	'progressive' and 'advancing' producers as these are most likely to be able to incorporate this type of technology into their businesses.
Improve supply chain efficiencies and logistics*	**Medium to high** (improving the supply chains by individual businesses and ways to manage processes and relationships effectively will provide producers with greater control and profitability).	**Medium (**poorly organised supply chains and logistics, within a business and between a business, suppliers and customers can reduce the profitability of all involved).	The nursery industry has funded several projects dealing with this topic, but general uptake appears to be low. Success will depend on active engagement with nursery producers to ensure recommendations from previous projects are implemented at an industry and business level. 'Steady' and 'progressive' producers are the likely target audience.

*Definitions:

Grouping of producers according to their capacity and capability is discussed in Section 3.2. For extension purposes, producers within the nursery industry can be loosely categorised as 'steady', advancing and 'progressive'. The needs of these groups will differ and extension approaches should be modified accordingly.

Supply chain efficiency is related to whether all businesses involved in producing a product and bringing it to the consumer have processes that use resources in the best way possible (financial, human, technological or physical resources). For a nursery that means all goods coming into the business and products leaving the business do this with minimum losses (in time, funds or resources). This requires process mapping as a first step and communication and ideally cooperation with all involved in the supply chain. The idea is to create a profitable outcome for all involved.

Well organised **logistics** are essential to efficient supply chains, this applies to logistics with the business e.g. dealing with incoming goods or getting plants/products ready for dispatch as well as transport logistics from business to business. Again, process mapping is used to analyse the logistics aspect of supply chains.

4.3 WHO

As discussed in Section 3 there is extensive capability and capacity to deliver RD&E of relevance to the Australian nursery industry. Expertise and research focus does vary between organisations and this should be considered when assessing which providers are most suited to answering specific R&D questions.

RD&E providers in general should have an understanding of the nursery industry, production systems and experience in delivering extension programs. For addressing some issues, multi-disciplinary teams with a range of expertise may be best and this could require collaboration between different providers. Based on the five key RD&E focus areas identified, potential providers able to deliver projects in these areas are outlined in Table 4-2.

Table 4-2: RD&E providers with the capacity and capability to deliver projects within the key RD&E focus areas

RD&E FOCUS AREA	AUSTRALIAN PROVIDERS	INTERNATIONAL PROVIDERS
Improve understanding by industry of end user needs/desires	Consumer and market analysis providers such as Nielsen, Euromonitor International and Freshlogic.	Bridget Behe at Michigan University and Charlie Hall at Texas A&M University have conducted extensive research into consumer purchasing behaviour and preferences. The lessons learnt from their work in the USA could provide valuable insight into end user needs and future trends in Australia.
Improve production efficiencies (both in the field and within protected cropping systems)	Given the extensive amount of previous research, a focus on development and extension is a more valuable approach to practice change within industry. Providers with extension capabilities such as NSW DPI and private providers are recommended.	Collaboration with RD&E providers such as WUR, organisations in Germany and the AHDB in the UK is recommended based on their current research focus and capabilities.
Reduce the environmental footprint of green infrastructure and plant production through better managed input/output usage (resource use efficiency)	Given the high level of R&D currently conducted internationally, programs that focuses on development and extension rather than research are recommended. Providers with the ability to learn, adapt and extend research occurring internationally are recommended.	Collaboration with RD&E providers such as WUR, organisations in Germany, the Vineland Institute in Canada and the University of California (US) is recommended based on their current research focus and capabilities.
Reduce production costs through automation and uptake of new technology	Research providers such as University of Western Sydney, USQ's National Centre for Engineering in Agriculture and the University of New England in collaboration with a commercial developer are recommended.	Collaboration with RD&E providers such as WUR, the Vineland Institute in Canada and the AHDB is recommended based on their current research focus and capabilities.
Improve supply chain efficiencies and logistics	Supply chains and logistics analysis/training/extension providers.	We were unable to find international R&D providers working in this focus area. However researchers based at American Universities such as Charlie Hall have conducted numerous industry analysis projects and are likely to be useful collaborators.

DEVELOPING GLOBAL PROJECTS

Collaboration between RD&E providers in Australia and those internationally already occurs, and the majority of providers we interviewed expressed a desire to collaborate further with Australia. Collaboration is a great way to leverage investment, share resources, counter production seasons and identify new opportunities. Building collaboration between Australia and international providers should be a two-pronged approach as discussed below:

Build the reputation of nursery RD&E in Australia

Develop a program approach to nursery RD&E conducted in Australia which focuses on the five key RD&E focus areas nominated in Table 12. The Australian apple and pear industry and the potato industry have developed a program approach for RD&E which utilises the services of an independent program coordinator to ensure that research outcomes are effectively communicated to industry, research projects are coordinated (preventing silos and duplication) and that research, communication and extension efforts are coordinated. The research program is branded and this helps create recognition and reputation for the activity within this program both nationally and internationally. The presence of a coordinator also provides a single contact point for those working in this field wishing to collaborate with the program and provides an easy point of contact for international researchers.

Build international relationships

This project has helped to identify the key RD&E organisations of relevance to the Australian nursery industry. While initial contact was made with a number of these institutions during the industry review, building collaboration requires the development of on-going relationships to identify new opportunities and to build trust and cooperation. The role of an independent program coordinator could be extended to include this role. New advancements in technology and practices internationally will be on-going requiring someone to maintain a ‘watching brief’ on activity that could be of relevance to the nursery industry.

As discussed in Section 3.9, the AHDB are currently managing a program called SmartHort which aims to help the horticulture industry increase productivity and address the challenge of access to affordable labour through; improving management practices; supporting skills development; identifying new technologies. As part of this program a conference will be held in the UK during March 2019 where guest speakers from around the world will be sharing technological developments and examining the potential of such technologies in light of current labour shortages. It is an opportunity to discover the latest high-tech advancements, meet the people behind the innovation and find out how to invest in the technology that could make a positive impact in the nursery industry. It is recommended that attendance at the conference is included as part of this review to identify any additional technology of relevance and to build on the contacts made during consultation. Following the conference, a report back to industry (via the SIAP and other industry events) on the key outcomes of the conference and visits to RD&E providers could be made.

5 How - The RoadMap

It is recommended that the nursery industry adopt a program approach to RD&E where the program focuses on addressing key priorities (delivery of work packages identified in Table 5-2). Engagement of a program coordinator to facilitate the strategic commissioning of research where required, promote linkages between sectors of the industry and RD&E community and ensure that the research program, communications and extension are coordinated is vital. The coordinator has to ensure that industry gets what they have asked for and that success/adoption is monitored. Promoting a program approach will also facilitate international linkages by building a reputation and presence.

To facilitate the delivery of an integrated program approach to RD&E for the Australian nursery industry we recommend a model as shown below in Figure 5-1 with specific recommendations provided in Table 5-1.

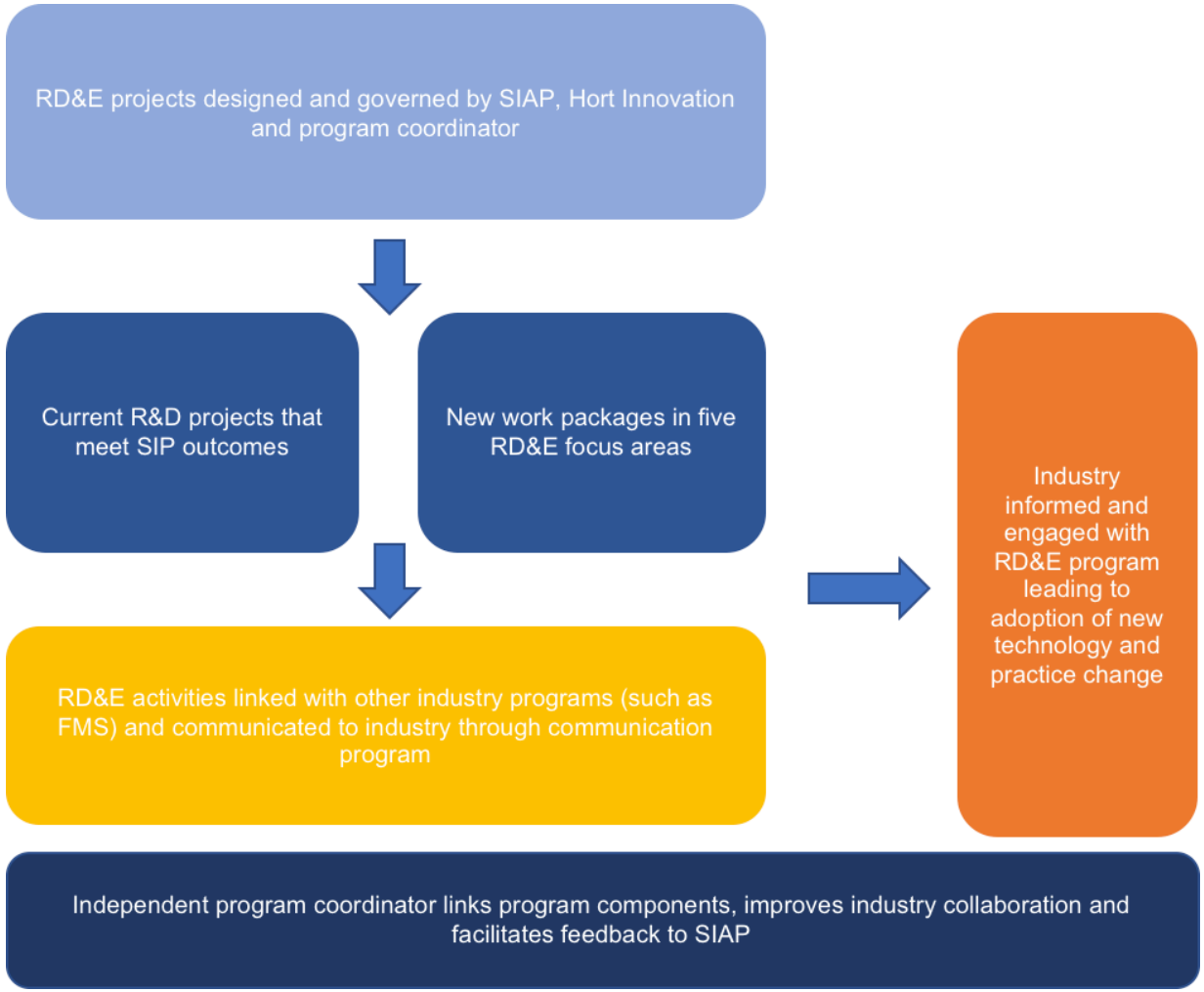

Figure 5-1: Model of program approach to delivery of RD&E for the Australian nursery industry

Table 5-1: Key recommendations for integrating RD&E activities and facilitating the delivery of useful and relevant outcomes

APPROACH	RECOMMENDATIONS
Adopt a program approach	Adopt a program approach to nursery industry RD&E to ensure research is meeting industry needs, that R&D outcomes are being adopted by industry and that industry sees a return on investment. This will be achieved by: ▪ Continuing to support current and ongoing R&D that addresses the key industry issues identified in Table 3-7 (Section 3.5) and achieves the outcomes of the SIP. ▪ Commissioning work packages that fill the identified RD&E gaps of: ▪ Reducing the environmental footprint through improved resource use efficiency (*extension focussed package*) ▪ Improving production and process efficiencies (both in the field and within protected cropping systems) (*extension focussed package*) ▪ Reducing production costs through automation and uptake of new technology (*development and extension focussed package)* ▪ Improving supply chain efficiencies and logistics (*research focused package*) ▪ Improved understanding by industry of end user needs/desires (*research focused package*). ▪ Engaging a program coordinator who is independent to the services provided by the other sectors of the program (such as the work package providers, communications program and Hort Innovation).
Develop work packages that truly integrate RD&E	Design efficient, effective work packages that deliver industry relevant RD&E by: ▪ Using teams of RD&E providers that can bring all the skills and expertise required to ensure that project outcomes are taken up by industry. ▪ Ensuring that research conducted previously over the last ten years both in Australia and internationally is not repeated and outcomes are delivered to industry via extension rather than conducting further research. ▪ Extracting readily useable information (from previous research projects) and developing into resources for communication and extension. ▪ Ensuring levy funded research outcomes are captured in a way that is useful for industry. A suggestion is that outputs from research should be in the form of a research paper and engaging extension/communication resources rather than a standard report. ▪ Linking in with existing programs such as the Nursery Production Farm Management System to deliver some of the work packages (where appropriate). ▪ Tailoring extension delivery according to type of producer targeted (refer to Section 3.2 which discusses industry stratification). ▪ Ensuring that extension involves active participation from industry members rather than communications to a passive audience. ▪ Including economic analysis in R&D projects where feasible. ▪ Including a program logic and monitoring and evaluation plan to ensure the impact of projects is identified and monitored.

APPROACH	RECOMMENDATIONS
Engage an independent program coordinator	Engage an independent coordinator to integrate the program components, build the reputation of the program and ensure that future investment is leveraged by: ▪ Ensuring that the Strategic Investment Advisory Panel (SIAP) is provided with sufficient information and process to make critical decisions regarding future RD&E investment. ▪ Developing ongoing relationships/linkages with key R&D providers nationally and internationally identified during this review to enable collaboration on future R&D projects. ▪ Continuing to identify gaps and commission (in conjunction with the SIAP and Hort Innovation) targeted research projects to address these gaps. Where possible including international collaborators (such as University of Wageningen) to leverage off activity occurring elsewhere. ▪ Developing ongoing relationships/linkages with other relevant industry sector organisations such as Protected Cropping Australia and PMA – ANZ to: o Enable collaboration on future R&D that is of relevance to the nursery industry o Build industry capacity and skills associated with protected nursery production systems. ▪ Building connections between R&D providers, technology developers and industry (in collaboration with an industry extension program). Activities could include regular R&D forums open to all industry members where researchers provide updates on recent projects and new technologies including those developed by commercial companies are featured. Interactive workshops and or field visits would be an important part of forums. ▪ Build connections between producers and the market (retailers, wholesalers, consumers).

For each specific issue RD&E focus area (Goal), an expected timeline (short, medium, long), suggested approach (research, development or extension) and producer group (steady, progressive or advancing) has been provided. Specific actions to realise each goal has also been provided.

Table 5-2: Expected timeline, recommended approach and industry sector and actions for five focus areas (work packages) of the Australian nursery RD&E roadmap

FOCUS AREA	TIMELINE	APPROACH	PRODUCER GROUP	ACTIONS
Improve production efficiencies (both in the field and within protected cropping systems)	Outcomes achieved in the short to medium term	Development Extension	Steady and progressive producers	▪ Ensure outputs and outcomes of previous R&D (conducted over last 10 years) on best management practices for field and protected cropping nursery systems are made available to industry members in an effective extension program to foster adoption. ▪ The extension program should link with, and leverage, the NIASA program within the Nursery Production FMS and also work with those outside this program. ▪ Extract readily useable information from previous research and develop into material to be used within the existing communications program (Cox Inall and NGIA). ▪ Identify knowledge gaps and commission new RD&E projects to address these. Where possible build on and collaborate with research currently conducted by organisations such Wageningen in the Netherlands, German and Californian providers. Projects must have a smart extension component. ▪ Develop ongoing relationship/linkage with the protected cropping sector through organisations such as PCA to build industry capacity and skills associated with protected nursery production systems.
Reduce the environmental footprint of green infrastructure and plant production through better managed input/output usage (resource use efficiency)	Outcomes achieved in the short to medium term	Development Extension	Steady, progressive and advancing producers	▪ Ensure outputs and outcomes of previous R&D (conducted over last 10 years) on resource use efficiency is made available to industry members in an effective extension program to foster adoption. ▪ Build on the wealth of international R&D conducted on resource use efficiency particularly in Northern Europe (Germany and the Netherlands). ▪ Identify knowledge gaps and commission new research projects to address these. Where possible include international collaborators such as WUR in the Netherlands, universities in Germany and in the US. ▪ Extract readily useable information from previous research and develop into communication and extension resources to be used within existing communications program (Cox Inall and NGIA).

FOCUS AREA	TIMELINE	APPROACH	PRODUCER GROUP	ACTIONS
				▪ Develop extension program that improves resource use efficiencies within nursery production systems. Program to link and leverage the NIASA program within the Nursery Production FMS and also work with those outside this program.
Improve understanding by industry of end user needs/desires	Outcomes achieved in the medium term	Research (market and consumer) Development Extension	Progressive and advancing producers	▪ Conduct consumer and market based research to better understand consumer trends and future purchasing habits/trends in Australia (such as the Harvest to Home project https://www.harvesttohome.net.au/fruitmushroomnuts). ▪ Engage with researchers based in the US (Michigan State University, Purdue University and Texas A&M University) to understand and build on the research and extension conducted there on consumers and markets ▪ Build linkages between producers and their customer (retailers and consumers) so that understanding and expectations are shared. This could include activities such as industry forums where attendance by all sectors of industry are encouraged to discuss recent consumer research outcomes and build networks. Forums should also include presentations by specialists in consumer and market analysis. ▪ Extension activities should focus on progressive and advancing producers.
Improve supply chain efficiencies and logistics	Outcomes achieved in the medium to long term	Research (new supply chain dynamics) Development Extension	Progressive and advancing producers	▪ Implement previous research funded by the nursery industry e.g. via planning workshops on process flows and logistics. ▪ Identify (research) any changes in supply chains and issues around those that occurred in the past 10 years and ensure outcomes are provided to industry in a usable format – not just as a report. ▪ Connect with organisations such as the Produce Marketing Association A-NZ (PMA-ANZ) to increase capacity through attendance at supply chain management courses and awareness of new technology/practices in this area (such as LEAN).
Reduce production costs through automation and uptake of new technology	Outcomes achieved in the long term	Research (agri-tech) Development Extension	Advancing producers	▪ Review technology currently available in Australia and internationally for its suitability for adaptation to Australian conditions. The review should include technology available in other industries (not just nursery) and provide practical recommendations.

FOCUS AREA	TIMELINE	APPROACH	PRODUCER GROUP	ACTIONS
				▪ Where existing technology is not currently available, scope industry needs, and work with a commercial provider to develop technology that facilitates automation. Ensure that provider is focussed on industry ready outcomes rather than further research. ▪ Link with other industry projects that are currently investigating agri-technology and automation and seek to build on this work. Current project examples include the Developing Agri-Tech solutions for the Australian apple industry led by SwarmFarm Robotics and The National Tree project delivered by UNE and project partners. There are also relevant data capturing/monitoring and data analytics projects and opportunities to be explored. ▪ Work specifically with advancing producers to identify needs and champion new technology as it is likely that only larger and corporate types of business will be able to afford to integrate this type of technology into their businesses. ▪ Facilitate adoption by using advancing producers as examples through the development of case studies and demonstration sites.

Appendix 1: Consultation List

The following industry members and RD&E providers were consulted during this review:

ORGANISATION	SECTOR	LOCATION
Nursery and Garden Industry Association	Industry Association	Australia
Nursery and Garden Industry Victoria	Industry Association	Australia
International Plant Propagators Society - Australia	Industry Association	Australia
Protected Cropping Australia	Industry Association	Australia
Anthony Tesselaar International	Business	Australia
Proteaflora	Producer	Australia
Ball	Producer	Australia
Bunnings	Supply Chain members	Australia
Horticulture National RD&E Framework – Executive Support (Victoria Taylor)	R&D Policy	Australia
Tasmanian Institute of Agriculture	R&D Provider	Australia
National Vegetable Protected Cropping Centre (HIE)	R&D Provider	Australia
Green Infrastructure Research Group (Melbourne University)	R&D Provider	Australia
South Australian Research and Development Institute	R&D Provider	Australia
Centre for Comparative Genomics (Murdoch University)	R&D Provider	Australia
New South Wales Department of Primary Industries	R&D Provider	Australia
Agriculture Victoria	R&D Provider	Australia
University of Hohenheim	R&D Provider	Germany
Landwirtschaftskammer Schleswig-Holstein (Agricultural Council of Schleswig-Holstein)	R&D Provider	Germany
Agriculture and Horticulture Development Board	R&D Funder	United Kingdom
University of California Nursery and Floriculture Alliance	R&D Provider	United States
University of Wageningen	R&D Provider	The Netherlands

The following stakeholders were identified and approached for consultation but we were unable to secure an interview:

ORGANISATION	SECTOR	LOCATION
NGIQ	Industry Association	Australia
THG	Producer	Australia
Brocklands Nursery	Producer	Australia
QAAFI	R&D Provider	Australia
Department of Young Plants in Zentralverband Gartenbau (Horticulture Peak Industry Body)	Industry Association	Germany
Woody Plant Nursery Association	Industry Association	Germany
AmericaHort	Industry Association	United States
Nursery owner in The Netherlands	Producer	The Netherlands

Appendix 2: Recent (< 5years) Australian nursery related RD&E projects

ISSUES	RD&E DRIVERS	RECENT AND CURRENT PROJECTS	SUMMARY	FINISHES	PROVIDER
Environmental stewardship and sustainability	Assist the nursery industry to mitigate and adapt to climate change	Evaluation of nursery tree stock balance parameters (NY15001)	This project originally ran from mid-2015 to April 2017, looking at how species differences and climatic conditions in different production regions can affect the root-to-shoot balance in tree stock. It is now in an industry engagement phase, to communicate the research findings back to growers and help the adoption of the relatively new nationwide quality assessment standard for nursery-grown trees for landscape use. This will involve the development of grower-friendly guidelines around the current industry standard for tree stock for landscape use and the project's new information on tree stick balance, as well as workshops and presentations.	2018	University of Western Sydney
		Which plant where, when and why database (GC15002)	This project brings together a consortium of researchers to investigate the suitability of various plants species under current and future climate scenarios. The project is the first of its kind and will culminate in an online interactive tool that will map the distribution of suitable habitats for various plant species across Australia.	2021	Macquarie University, Western Sydney University and NSW Office of Environment and Heritage
	Reduce the environmental footprint of green infrastructure and plant production through better managed input/output usage (resource use efficiency)	None			
		Tissue culture	Tissue culture of avocado plants	Current	QAAFI

ISSUES	RD&E DRIVERS	RECENT AND CURRENT PROJECTS	SUMMARY	FINISHES	PROVIDER
Improving systems and practices	Improve production/ process efficiencies (both in the field and within protected cropping systems)		Tissue culture of Boronia clones and general optimisation of the tissue culture process	Current	Tasmanian Institute of Agriculture (TIA)
	Improve supply chain efficiencies and logistics	None			
	Improve pest and disease management	BioClay	A spray of nano-sized degradable clay used to release double-stranded RNA, that protects plants from specific disease-causing pathogens	Current	QAAFI
	Reduce production costs through automation and uptake of new technology	Robotics	The Australian Centre for Field Robotics (ACFR) conduct research in autonomous, remote sensing and developing robotics and intelligent software for the agriculture community. They are committed to developing technologies in four core areas: sensors, fusion and perception movement, control and decisions modelling, learning and adapting architectures, systems and cooperation of robotics and intelligent systems. A recent example is the RIPPA robot developed for the vegetable industry.	Current	ACFR (University of Sydney)
		Multi-scale monitoring tools	National Tree Project. Multi-scale monitoring tools for managing Australian tree crops – industry meets innovation. This project seeks to use the latest high resolution satellite imaging systems, cloud-based computing, data discovery and computationally efficient analytics, on-ground robotics and an increasingly 'connected' producer base to offer two key innovation pathways to improved production, auditing, biosecurity and disaster recovery for Australia's tree crop industries.	Current	University of New England and project partners
		Developing agri-tech solutions for the	This project will develop a new system to measure tree canopy and flower density and deliver a variable and dilution spraying solution for apple flower thinning. The University of New South Wales will develop the algorithms to count the flower density, ADAMA will supply the decision support tool to it's	Current	Led by SwarmFarm Robotics with project partners

ISSUES	RD&E DRIVERS	RECENT AND CURRENT PROJECTS	SUMMARY	FINISHES	PROVIDER
		Australian apple industry	agronomy network, and Bosch will supply the key technology necessary for the system.		
	Better industry data	Horticulture Statistics Handbook 2015-2018	Availability of valid statistical information is a key enabler across horticulture. The Australian Horticulture Statistics Handbook is presented by Hort Innovation for the purpose of consolidating horticulture statistical information for use by horticulture industry members and other stakeholders. The handbook is an analysis that combines all available data on production, international trade, processing volumes and fresh market distribution in order to produce statistics on 75 horticultural categories. It adopts a modelling approach that centres on determining the fresh market value and volume for each category, that reconciles production with local and international distribution channel throughputs.	2018	Hort Innovation
		Nursery Industry Statistics and Research (NY16004)	NY16004 Nursery Industry Statistics & Research was a strategic levy investment project designed to capture critical, timely and accurate data for the Australian nursery and garden industry.	2018	NGIA
Biosecurity	Improve quarantine/biosecurity efficiencies	Plant diagnostic toolkit	Use of Next Gen Sequencing to screen new genetic material entering the country for viruses and viroids.	Current	Roberto Barrero (Murdoch University)
		A review of diagnostic technologies to benefit the Australian nursery industry (NY16003)	This investment was contracted to identify smart surveillance tools for detecting endemic and exotic pets of relevance to the Australian nursery industry, in both lab and point-of-care settings.	2018	The Victorian Department of Economic Development Jobs, Transport & Resources (DEDJTR),
	Prevent and manage the introduction of new pests	RD&E program for control, eradication and preparedness for Vegetable	For and funded by the nursery and vegetable industries, this project is set to bolster preparedness for and protection against the potential spread of vegetable leafminer (Liriomyza sativae) through Australian growing regions. The pest is capable of infesting a broad range of crops and was first detected on the country's mainland in 2015, in a backyard garden in the Cape York Peninsula community of Seisia. Specific project activities	2020	Cesar

ISSUES	RD&E DRIVERS	RECENT AND CURRENT PROJECTS	SUMMARY	FINISHES	PROVIDER
		leafminer (MT16004)	include developing information and resources for monitoring, managing and eradicating leafminer; identifying and modelling the spread of the pest; reviewing and looking at accessibility of chemical and biological control options; and generally increasing awareness and understanding of vegetable leafminer in the relevant industries.		
		Building the resilience and on-farm biosecurity capacity of the Australian production nursery industry (NY15002)	This project aims to enhance the biosecurity preparedness of the Australian nursery industry. Key project activities continue to include: Production of content and imagery for the industry's Pest Identification Tool (www.pestid.com.au), to make diagnostic identifications more financially viable for production nurseries. Delivery of webinars as well as workshops in all states and territories, with the 2017 workshop series focusing on steps nursery managers can take to diagnose unknown plant health problems. Development and updating of grower resources including pest management plans, fact sheets and contingency plans. Diagnostics, with samples submitted for analysis by pest and disease diagnostic service Grow Help Australia.	2020	QDAF
		National nursery industry biosecurity program (NY15004)	This project aims to ensure production nurseries in Australia are aware of and prepared for incursions of exotic plant pests, and that they have effective market access mechanisms in place to maintain business functionality.	2020	Nursery & Garden Industry Australia
Increasing the demand for plant nursery products	Create better plants	Variety sourcing and evaluation	Evaluation of varieties and rootstock (in citrus).	Current	NSW DPI
	Improve understanding by industry of end-user needs/desires	None			
	Improve horticultural literacy (understanding of plants)	Certified Nursery Professional (CNP) program	This program is a professional recognition scheme for individuals within the nursery industry. CNP members are acknowledged for their skill and expertise within the nursery and garden industry.	Current	NGIA

ISSUES	RD&E DRIVERS	RECENT AND CURRENT PROJECTS	SUMMARY	FINISHES	PROVIDER
	Influence policy makers and the public on the value of green-life and nursery products	Integrating plant life into building and infrastructure rating tools (NY16007)	This project is responsible for measuring the benefits of vegetation in the built environment. The end goal is to provide scientific evidence to the Green Building Council of Australia and the Infrastructure Sustainability Council of Australia, to underpin the development of 'credits' in their rating tools relating to the integration of plants in the buildings and infrastructure.	2018	Edge Environment
		Where should all the trees go - delivering the insights to stakeholders (NY17000)	This project follows previous project Where should all the trees go? An investigation of the impact of tree canopy cover on socio-economic status and wellbeing in LGAs (NY16005). This earlier investment looked at changes to canopy cover in Australian's metropolitan local government areas (LGAs), identifying priority areas for greening across Australia and monitoring progress towards the 202020 Vision goal of making Australia's urban areas 20 per cent greener by the year 2020. The project also looked at the relationships between tree canopy cover and socio-economic, health and wellbeing factors in LGAs. The new investment is taking findings from the earlier research and delivering them at workshop-style information sessions across the country for industry leaders, landscape architects, government department staff and other relevant stakeholders.	2018	Republic of Everyone
		Greener cities, healthier lives (GC15005)	This investment is set to provide the first systemic evidence on the benefits of green space on people, from birth to older age, in Australia. It will provide industry and policy makers with evidence-based research on the minimum threshold of local green space necessary for favourable health and societal outcomes.	2021	University of Wollongong
	Develop green infrastructure	202020 Vision training/capacity building program (NY16009)	This program carries on from the industry's previous 202020 Vision training initiative (project NY16002). Like its predecessor, it is responsible for driving awareness of and engagement with 202020 Vision activities and resources through national and regional workshops and regular updates provided to growers and other industry stakeholders.	2019	Republic of Everyone
		Researching the benefits of demonstration	This project will assist in better understanding and overcoming some of the fundamental cultural, community and horticultural barriers to greater green roof construction in Australia. Specifically, the project will: Assess the	2020	Melbourne University

ISSUES	RD&E DRIVERS	RECENT AND CURRENT PROJECTS	SUMMARY	FINISHES	PROVIDER
		green roofs across Australia (GC16002)	effectiveness of a demonstration green roof in overcoming barriers to green roof uptake; Develop proven palettes for different green roof build-ups applicable to southern Australia (Sydney, Melbourne, Adelaide, Hobart and Perth); Evaluate the maintenance requirements of different green roof build-ups, including plant species, so that robust and reliable implementation guidelines can be developed; And determine the types of green roof plants that are aesthetically attractive to a wide range of people.		
		Metropolitan urban forestry (NY17005)	This investment feeds in to the industry's 202020 Vision initiative. It will develop a deeper understanding of urban greening at a metro/state level, including identifying any barriers to establishing green space. It will also provide education and a touch point for organisations including councils, government departments and others seeking information on green space in the context of planning. This will include delivery of regular e-newsletter updates through the 202020 Vision network.	2018	Republic of Everyone
		Woody meadow project'	This project aims to improve amenity space through better planting, better design, and better plant use. In particular, increasing interest in planting of low input native shrubs in urban areas.	Current	GIRG (Melbourne University)
Skills and workforce management	Attract and retain skilled staff within the nursery industry to build capacity and capability	Green Industry Growing Leaders Program (MT16002)	This project runs and supports the participation of nursery and turf workers in an industry-specific leadership education course, the Green Industry Growing Leaders Program. The Program is designed to help participants define their leadership style; manage conflict and shape team culture; communicate effectively and more.	2019	Right Mind International
		Attracting new entrants into Australian horticulture – promoting careers in horticulture (LP15006)	This Hort Frontiers Leadership Fund project includes contribution from the nursery levy. It is responsible for engaging graduate students with the horticulture industry. It has a two-phase approach designed to attract the right people, retain them and support their ongoing leadership development. The first phase involves students undertaking internships within horticulture business, for which funding support is offered for both the student and the business. The second phase involves employment of students following graduation, with Hort Innovation co-investing to support the first-year salary and participation in a five-day leadership program.	2021	Rimfire Resources

ISSUES	RD&E DRIVERS	RECENT AND CURRENT PROJECTS	SUMMARY	FINISHES	PROVIDER
		Global Masterclass in Horticultural Business (LP15001)	This project is part of the Hort Frontiers Leadership Fund, with the nursery levy supporting scholarships across all key growing regions, for industry levy-payers to take part in the Masterclass in Horticultural Business course. The Masterclass is a unique offering designed to grow participants' business and leadership skills.	2021	UTAS
		Review of nursery industry career pathways (NY17002)	This project will develop a tactical plan for successful career path development for the industry in the short to medium term and longer-term strategies to sustain an interest in working in the industry on many levels. Recommendations will address staff attraction, retention and development of the industry's workforce to underpin its economic sustainability.	2018	RMCG

Appendix 3: Capacity and capability of Australian RD&E providers

This section provides some detailed information on the expertise, facilities, key research programs and areas of speciality of R&D providers relevant to the nursery industry.

THE UNIVERSITY OF MELBOURNE

The University of Melbourne, Agriculture and Food Sciences, Faculty of Veterinary and Agricultural Sciences, has capability and capacity to deliver a range of plant science related research. The university employs a number of individuals with qualifications that have significant relevance to the nursery industry, these are a diverse-range of entomologists, plant pathologists, and plant physiologists. These researchers have contributed to many publications that have relevance to the nursery industry. Along with the research capacity, the University of Melbourne offers a range of agriculture-related undergraduate and postgraduate degrees with a focus on climate change, industry development and sustainability.

The university has a number of controlled growing environments that currently facilitate, and have the potential to facilitate further, research related to the nursery industry. These consist of greenhouses and nurseries in both Melbourne (Burnley), and greater Ballarat (Creswick). These controlled growing environments offer the following:

LOCATION	FACILITIES
Creswick	▪ Temperature, CO2 and humidity-controlled greenhouse with the ability to facilitate pathogen and transgenic research ▪ Temperature controlled single-chamber nursery glasshouse ▪ Various growth and incubator cabinets
Burnley	▪ Nursery complex with various commercial nursery equipment, including three single-chamber nursery greenhouses with limited temperature control. ▪ Open irrigated garden plots ▪ Four shadehouses

Along with the extensive facilities offered in both Creswick, Burnley and laboratories within the main city campus, the university can offer access to specific research groups relevant to the nursery industry.

Green Infrastructure Research Group

The Green Infrastructure Research Group conducts a range of RD&E throughout Australia, working primarily to integrate green spaces into a range of built environments. The Research Group consists of a number of staff who cover projects aimed to develop and sustain green infrastructure in urban and semi-urban environments. The research team involves of a diverse range of social scientists, ecologists, and horticulturalists. Research conducted by the group has a high capacity to influence the uptake of plants for green spaces throughout Australia. Research conducted focuses on the following areas:

- Varieties of growing media
- Plant evaluation and plant selection
- Plant performance and connection between soils and plants
- Social research – people's preference and behaviours around plants (particularly around green roofs and walls).

The Research Group is currently working on a number of projects that relate to the development of green walls, urban forests, and green roofs within urban environments within Australia.

Plant health and biosecurity

Consisting of a research team of five staff (three Professors and two Research Fellows) and nine research students, this faculty focuses on research related to plants' responses to biotic and abiotic stresses. This research group aims to produce crops that have greater resilience to a range of pathogens, resulting in less reliance on fungicides, and a greater resistance to a wide-range of environmental stresses. Publications that have resulted from this area of research have not focussed specifically on the nursery industry but do relate to the industry indirectly.

Plant molecular biology and biotechnology

Focussing on pasture, vegetable and other horticultural crops, the Plant Biotechnology Group researches a range of topics that focus on future agronomic and environmental stresses. This research group has had a range of achievements over the pasts years; of most relevance to the nursery industry are the development if the world's first report of successful tissue culture based micro-propagation system for macadamias. The group consists of a total of eight researchers (two Professors, three Research Fellows, one fellow, and two technical assistants). A range of research has been published from this area that relates to the nursery industry, including:

- In vitro plant regeneration from immature seed cotyledon explants of macadamia (*Macadamia tetraphylla* L.)
- *In vitro* shoot multiplication of *Macadamia tetraphylla* L. Johnson
- Male gametic cell specific gene expression in flowering plants
- Isolation and characterization of a flowering plant male gametic cell-specific promoter
- Molecular mechanisms of DNA damage and repair: Progress in plants
- *Agrobacterium* mediated transformation of Australian cultivars of cauliflowers, *Brassica oleracea var. botrytis*

SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE - SARDI

The South Australian Research and Development Institute (SARDI) is one of the largest R&D institutes in South Australia (SA) focussing on developing sustainable solutions to a wide-range of agriculture, aquaculture and horticulture-related issues. The institute is operated by the South Australian government and is the main research institute for primary industries in SA. Currently made up of 22 professionals, SARDI has staff working in the fields of biosecurity, forestry and horticulture. These fields are represented by the institute's Sustainable Systems research division, which contains a range of advanced scientific infrastructure. The main research centres that conduct horticultural research include:

- The Plant Research Centre (located at the University of Adelaide's Waite Campus)

- Molecular Diagnostic Centre
- Loxton Research Centre.

The capabilities of the institute cover a wide-range of scientific disciplines and various agriculture-related topics which include:

- Climate applications
- Water resources, viticulture and irrigated crops
- Crop Improvement
- New variety agronomy
- Entomology
- Soil biology and diagnostics
- Plant heath and biosecurity.

SARDI offers state-of-the-art research facilities that have the capacity to conduct research related to the abovementioned topics. Although not currently conducting any research relevant to the nursery industry SARDI has the capacity and capability to do so.

QUEENSLAND ALLIANCE FOR AGRICULTURE AND FOOD INNOVATION – QAAFI

The Queensland Alliance for Agriculture and Food innovation (QAAFI) is part of the University of Queensland and is partially supported by the Queensland Government. QAAFI is currently listed as Australia's number one agricultural research institute and the fifth global agriculture research institution. The institute possesses a wide-range of capabilities and significant capacity to conduct R&D relevant to the nursery industry. QAAFI has a total of four research centres all with the main aim to improve the productivity and sustainably of agricultural industries in Australia and around the world. The key fraction of QAAFI which is relevant to the nursery industry is the Centre for Horticultural Science. This research centre aims to drive innovation and industry adoption of various improvements that are being made for the horticultural industry. This research centre focuses on three main research themes:

1. Horticulture crop breeding and agronomy
2. Plant protection
3. Emerging horticultural technologies.

These three key research areas within the Centre for Horticultural Science are represented by 16 researchers from the University of Queensland. Each of the researchers possess a variety of skills relative to horticultural and plant sciences. QAAFI conducts research relevant to horticulture and the nursery industry at research facilities located in Brisbane, South-West and Darling Downs, Wide Bay Burnett, and Far-North Queensland most. These facilities contain a range of controlled growing environments and plant-focussed research laboratories all well-appointed with state-of-the-art equipment. Some of the key R&D currently being conducted by QAAFI across these facilities includes:

- Reducing pesticide application - BioClay
- Tissue culture of avocado
- Protecting Queensland's banana industry – *Fusariam* and panama disease research
- Black spot in Queensland's mandarins
- Boosting macadamia yield.

QUEENSLAND UNIVERSITY OF TECHNOLOGY

The Queensland University of Technology's (QUT) prime capability and capacity in relation to the horticulture and nursery industries is contained in their digital agriculture research. Of particular interest is their work in robotics and autonomous systems. This research area contains a broad-range of research projects that relate to the agricultural industry. Those research projects being conducted of relevance to the nursery industry include:

- Harvey – the robotic capsicum harvester
- AgBot/AgBot II.

WESTERN AUSTRALIAN STATE GOVERNMENT

Murdoch University

Murdoch University conducts the majority of its horticulture-related research and has most of its capacity and capability within its School of Veterinary and Life Sciences and its Centre for Comparative Genomics. Encompassed in the Murdoch University's School of Veterinary and Life Sciences, the general horticulture-related R&D conducted covers the following:

- Plant biotechnology and genetic manipulation
- Microbial genomics
- Biosecurity and crop diseases
- Development of new varieties.

Researchers within the university have access to farmland located over three locations throughout WA. The farmland across this area equals an accumulated total of nearly 200 hectares. Along with this, the university's researchers have access to the State Agricultural Biotechnology Centre located at the universities main campus.

Centre for Comparative Genomics

The Centre for Comparative Genomics is a Western Australian State Government Centre of Excellence. It has four main research themes consisting of personalised medicine, animal health, food security and high-performance computing. Research is conducted in the centre's specialised laboratories which includes the Bioinformatics Research Laboratory. The laboratory is offering a range of computational tools, visualisation strategies and internet-based information management systems, which may be applicable to the nursery industry.

Research groups within the university contain individuals who have qualifications relating to a diverse-range of horticulture topics including plant biotechnology, genomics and plant biosecurity. The key research most recently produced by the university relevant to the nursery industry was initially funded by the Plant Biosecurity CRC and aimed to develop a system to accelerate current quarantine times using Next Generation Sequencing (NGS).

NEW SOUTH WALES DEPARTMENT OF PRIMARY INDUSTRIES

The New South Wales Department of Primary Industries (NSW DPI) have an extensive range of staff and facilities. NSW DPI run a number of programs relating to plant sciences throughout NSW. The Department

currently has 17 agriculture research facilities across NSW, with three of these having the capacity to conduct R&D relative to horticulture/nursery industry. These research facilities contain various controlled growing environments, plant laboratories and extensive field areas. The research stations of relevance are the Dareton Agricultural Research and Advisory Station, the Yanco Agricultural Institute, and the Gosford Primary Industries Institute, Ourimbah. These research facilities have significant capacity and capability to conduct relevant R&D to the nursery industry. Facilities include:

- Dareton Agricultural Research and Advisory Station
  - 243 hectares of irrigated farmland
  - 17 staff members
- Yanco Agricultural institute
  - Six-bay controlled temperature greenhouses
  - Air-conditioned polyhouses
  - Soil, plant pathology and entomology-specific laboratories
- Gosford Primary Industries Institute, Ourimbah
  - Greenhouses and controlled growing environments.

A number of highly qualified staff are located across these facilities; they have a diverse set of skills that relate to plant protection and management, production and extension. The NSW DPI are currently conducting a range of RD&E programs that have relevance or are able to benefit the nursery industry. They are as follows:

Sourcing and evaluation of new genetic material

NSW DPI manage a long running variety and rootstock evaluation program for the citrus industry. The program prospects the world for citrus germplasm that may be of value, bring it to Australia, guide it through quarantine and then evaluate it for a range of production factors such as salinity tolerance, fruit yield and quality at their satellite sites across Australia. Key features of this program are:

- Great international linkages in countries such as Asia, Spain, Florida and California which the program can utilise to source new genetic material
- Coordinated industry linkages – deal with one large commodity and one large industry body (Citrus Australia). Good linkages between the R&D program and commercial providers of germplasm.

Although this program is currently focussed on citrus with funding and direction from the Australian nursery industry, the research team has the capability to expand to running a similar program for the nursery industry.

Export market development

NSW DPI commonly run up to five programs with ACIAR which provides great linkages and insight into SE Asian countries such as Vietnam and Cambodia. They also have an international engagement unit which are responsible for fostering trade and establishing new markets. This has included work on cherries, which has allowed re-entering markets they had been excluded from.

Extension

NSW DPI have a network of ten development officers who cover all the major horticulture crops. Key features of the extension approach include:

- Development of extension officers guided by an industry steering committee who determine what their work program will be

- Use of an apprenticeship scheme which uses funding from industry partners for three years after which time the department employs them (bananas and blueberries)
- National focus rather than regional.

Protected Cropping

NSW DPI has joined a potential CRC for future food systems which will have a protected cropping focus. This is largely driven by the universities with industry input from NSW Farmers Federation.

AGRICULTURE VICTORIA - DEPARTMENT OF ECONOMIC DEVELOPMENT, JOBS, TRANSPORT AND ROADS (DEDTJR)

Agriculture Victoria conducts a range of research relative to diverse agricultural industries throughout Victoria. Research is conducted at seven research stations across Victoria. Of these research stations, three have historically conducted research that is of relevance to the horticulture/nursery industry. They are DEDTJR Tatura, DEDJTR Mildura and AgriBio, located at La Trobe University (Bundoora campus). These research stations hold varying amounts of capacity and capabilities to conduct R&D. Facilities at Mildura and Tatura, consist primarily of irrigated production lots and deliver research focussing on citrus, grapes and various vegetable crops. AgriBio is a joint initiative of the Victorian government and La Trobe University. It is the main research centre for Agriculture Victoria and has significant capacity for conducting R&D in a state-of-the-art facility. The facility hosts of a total of 400 DEPI and La Trobe staff members, made up of various scientists with a major focus on improving productivity, fighting plant diseases and reducing environmental impact. Facilities of the centre include:

- Extensive controlled growing environments
- Well-equipped laboratories.

Agriculture Victoria is not currently conducting any research directly related to the nursery industry, however the research that is being conducted in broad-acre grains and dairy, may have some relevance and show capabilities. This work includes research on sensor technologies that are able to be transferred to some horticultural crops.

UNIVERSITY OF WESTERN SYDNEY

The University of Western Sydney's Hawkesbury Institute for the Environment conducts the majority of the university's horticulture and nursery-related R&D. The Institute contains capacity to conduct R&D of relevance to the nursery industry in the areas of urban greening and protected cropping. The university has a history of collaborating with international R&D organisations, including Wageningen University & Research. It employs a diversity of research professionals with skills relating to plant pathology, ecology, entomology and a number of other relevant plant science qualifications. The Institute for the Environment has significant capacity and capability to deliver nursery-related R&D. Along with the skills of individuals within the institute, there are also a number of dedicated facilities that have the ability to support a range of research.

FACILITY	FUNCTION
Labs and growth chambers (PC2 compliant)	▪ Next generation sequencing laboratories ▪ Climate-controlled growth chambers ▪ Analytical instruments including elemental/chemical lasers and spectrophotometry equipment
National vegetable protected cropping centre – a working collaboration with Wageningen University & Research	▪ Funded through Hort innovation and the Australian Government ▪ 1800 square meters of greenhouses ▪ Offers protected cropping training programs

The most recent projects conducted by the institute relevant to the nursery industry include:

- Green cities initiative (in collaboration with Macquarie University)
- Developed/revised the industry QA standard for nursery tree stock.

UNIVERSITY OF TASMANIA, TASMANIA INSTITUTE OF AGRICULTURE

The Tasmanian Institute of Agriculture (TIA), a subgroup of the University of Tasmania, provides a wide-range of support to the Australian horticulture industry, conducting significant amounts of RD&E throughout Tasmania. The research conducted by the institute focuses on a variety of fruit and tree crops, vegetables, and a variety of industrial and extractive crops, including hemp, pyrethrum and poppies. The institute employs 130 researchers, educators and technical staff who contribute to the diverse research the institute conducts. As well as research, the institute also offers a range of undergraduate and postgraduate degrees relating to agriculture and the environment. The institute currently operates two research farms and production facilities:

- University of Tasmania's Cambridge Farm - 340 hectares
- Forthside Vegetable Research Facility - 54 hectares

The university has greenhouse, growth chamber, micro-propagation and laboratory research facilities at the Hobart and Burnie campuses. All facilities are used for conducting a wide-range of commercial and university research trials, including a range of product developments and PhD research. TIA also conducts a wide range of research trials on commercial farms, orchards and vineyards, often in close collaboration with industry.

Although there are no current projects that directly deliver to the nursery industry, TIA are currently conducting a series of horticulture related R&D projects that have some level of relevance to the nursery industry. These include:

- Biofumigation for potato production
- Soil-borne disease control
- Surveillance for Tomato Potato Psyllid
- Getting nitrogen application right
- Supply chain management research.

UNIVERSITY OF SYDNEY

The University of Sydney offers a breadth of expertise in various agricultural disciplines. This includes conducting extensive research in plant physiology and plant pathology, as well as robotics technology to assist with production efficiency. The university has ample capacity and capability in agricultural sciences, housing world-class researchers who have skills relating to a diverse range of agricultural and environmental topics. The University's Institute of Agriculture delivers research in the areas of:

- Plant breeding and production – improving the plants farmers have access to
- Environmental issues relating to agriculture – sustainably managing water and soil
- Quality food – ensuring high food safety standards.

Along with extensive laboratory facilities located at the Camperdown campus and the Australian Technology Park, which facilitate a range of plant-related research, the University of Sydney also has a number of farms which conduct horticultural research located in Camden, Nowly, Narrabri, and Arthursleigh. These facilities include extensive in-field and protected cropping systems, which support a range of research. The university also collaborates with industry partners to deliver projects. As well as research, the university also offer a range of undergraduate and postgraduate degrees that are conducted throughout the university's various campus' and farms.

The university also has capacity to conduct research in relation to agriculture robotics, which focus on assisting with a range of production-related tasks. The Horticulture Innovation Centre for Robotics and Intelligent Systems which is part of the University of Sydney's Australian Centre for Field Robotics has been developing robots to assist with horticultural production, focussing on both vegetable and tree crops. Both of these robots work to aid in a range of decision-related tasks on farm.

UNIVERSITY OF SOUTHERN QUEENSLAND (USQ)

The University of Southern Queensland (USQ) has focus on a small range of agriculture-related topics that vary in scale and transferability to the Australian nursery industry. Although many are not directly transferable to the industry, they have some relevance and may benefit some sectors. The majority of relevant research is conducted through the USQ's National Centre for Engineering in Agriculture (NCEA) researchers which is focused on intelligence-based technologies and solutions for agricultural and horticulture, including precision agriculture, robotics and automation as well as modelling and decision support systems. Project examples include:

- The new era of farming – driverless tractors
- Minimising environmental footprint through agricultural modelling
- Improving water use and food security for South Asian farmers
- Integrated management of nematodes for grain growers
- Genetic detection against wheat crown rot.

Machine vision technology enables drones to perform crop scouting operations, with the drone automatically recognising and reporting back to the grower about emerging crop issues. This involves automated analysis of drone imagery from low-cost colour cameras as well as other camera technologies that can see beyond what is human visible, e.g. thermal and multispectral.

Researchers have developed real-time adaptive control and low cost camera-based sensing systems that can reduce labour in plant growth monitoring and improve and potentially optimise the irrigation of field grown

crops. NCEA is evaluating camera-based crop growth and fruiting monitoring and variable-rate irrigation on cotton, dairy, horticulture and sugarcane crops.

Machine vision approaches are developed to spot spray weeds in fallow field as well as cropped fields. There different types of cameras available and used for this application as well as software techniques used to analyse the images from the cameras.

Researchers are also working on automating a small John Deere tractor. This is primarily a research concept to serve as an autonomous mobile sensor platform for deployment in research trials, demonstrate how existing auto steer technologies can be augmented for autonomous control functionality and serve as a platform for sensor developments relating to autonomous vehicles. The concept involves equipping the tractor to have the same functionality of a much larger John Deere tractor and exploiting embedded technologies to make it driverless.

As well as conducting various research projects, USQ offers agriculture-related degrees in the areas of plant sciences and engineering.

UNIVERSITY OF NEW ENGLAND (UNE)

Agricultural science research at the University of New England (UNE) encompasses a range of fields and disciplines. A core area of research is the application of new technology in agriculture. Established in 2002, the Precision Agriculture Research Group (PARG) develops new technologies that address current challenges in agriculture, horticulture and natural resource management using expertise from a range of fields. PARG is a multidisciplinary group of researchers developing innovative, low cost and accessible technology for industry and farmers. PARG uses the latest sensors and positioning technology to improve efficiencies and cost effectiveness.

The Precision Agriculture Research Group finds ways to integrate technology with farming practices to achieve optimal production. Current projects include:

- SMART Farms - Plant, Soil, Climate Sensing
- Remote Sensing for Crop, Pest and Disease Management
- Intelligent and Autonomous Systems.

UNE's SMART Farm serves as a test-site for researching new technologies, including broadband connectivity in an effort to improve productivity, environmental sustainability, safety, workflow and social/business support networks on Australian farms.

NURSERY INDUSTRY ASSOCIATIONS

The Australian nursery industry is represented by state and national organisations that direct and participate in RD&E investments to facilitate delivery of beneficial outcomes for their members (commercial producers, retailers and suppliers). They manage a number of programs addressing industry related issues such as:

- Biosecurity
- Climate change
- Business improvement.

The peak national body, Nursery and Garden Industry Australia (NGIA), represents production and retail nurseries throughout Australia. Although not directly involved in RD&E, they play a large role in advising the

direction of RD&E funding to ensure good outcomes for producers. While NGIA and their state-based partners (such as NGIV, NGIQ have limited capacity in terms of research extension, they have a high capacity in:

- Communication of industry wants and needs
- Providing direct industry-related experience and knowledge to guide future funding
- Ensuring projects are sufficient to meet the demands of the industry.

NGIA also focus on initiatives to ensure greater financially viable and unified industry, including the Certified Nursery Professional program – the nursery industry's professional recognition program set up to acknowledge the skills of individuals within the industry.

5.1.1 PRIVATE RD&E PROVIDERS

A range of private consultancy companies around Australia are able to provide services and RD&E partnerships to the nursery industry in the following areas:

- Consumer and market research
- Supply chain management and logistics
- Industry data analysis
- Business management/efficiency/benchmarking
- Resource use efficiency (water, nutrients, land, energy) and waste management
- Application of technology
- Biosecurity
- Environmental management
- Quality assurance
- Extension and training
- Research review and planning, strategic planning
- Monitoring and evaluation
- Communication

Appendix 4: Recent projects (< 5 years) relevant to the Australian nursery industry delivered by international R&D providers.

Projects are arranged according to the key issues and RD&E drivers identified in Table A-4.

ISSUES	R&D DRIVERS	R&D PROGRAM	PROVIDER
I. Environmental stewardship and sustainability	Assist the nursery industry to mitigate and adapt to climate change	**Performance testing to identify climate-ready trees** This study describes a five-step process to identify and evaluate the performance of promising but infrequently used tree species. This approach can serve as an international model for cities interested in climate adaptation through urban forestry.	USDA Forest Service in collaboration with the University of California
		Assessment of the suitability of 'climate ready trees' for use along road-side areas	Technical University of Munich
	Reduce the environmental footprint of green infrastructure and plant production through reduced/better managed input usage	The main objective of the **FERTINNOWA** thematic network is to create a meta-knowledge database of innovative technologies and practices for the fertigation of horticultural crops. FERTINNOWA will also build a knowledge exchange platform to evaluate existing and novel technologies (innovation potential, synergies, gaps, barriers) for fertigated crops and ensure wide dissemination to all stakeholders involved of the most promising technologies and best practices.	European collaboration
		Alternative substrates This research evaluated green waste compost (GWC) and green waste vermicompost (GWV) as peat substitutes in growing media used for the production of geranium *(Pelargonium zonale L.)* and *calendula (Calendula officinalis* L.).	Beijing Forestry University
		Alternative substrates Peat-based growing media are not ecologically sustainable and peat extraction threatens sensitive peatland ecosystem. In this study, olive-stone waste (OSW) and paper waste (PW) were used in different ratios—as growing media—for ornamental crop production, as peat (P) substitutes.	Cyprus University of Technology
		Alternative substrates A greenhouse experiment was conducted to assess the performance of biochar obtained from pyrolysis of conifer wood as a substrate component for growing potted Rosa rugosa plants.	CREA Research Centre for Plant Protection and Certification (Italy)

ISSUES	R&D DRIVERS	R&D PROGRAM	PROVIDER
		Alternative substrates The Institute of Horticulture at HSWT has conducted intensive development work on the preparation and application of peat substitutes and other raw materials and additives for horticultural crop substrates and potting mix. Due to opportunities for plant cultivation experiments paired with excellent laboratory equipment and analytical know-how, the institute today serves both nationally and internationally as a contact for all matters relating to substrate.	Centre for Research and Continuing Education at Weihenstephan-Triesdorf University of Applied Sciences (Germany)
		SCEPTREplus - Research for sustainable plant protection products for use in horticulture (2017 – 2021) The aim of this project is to deliver applied research on high priority pest, disease and weed problems in fresh produce and ornamental crops in order to identify effective treatments, support approval of new products and devise and develop IPM programs.	AHDB (UK)
		Water Use Classification of Landscape Species (WUCOLS IV) WUCOLS IV provides evaluations of the irrigation water needs for over 3,500 taxa (taxonomic plant groups) used in California landscapes. It is based on the observations and extensive field experience of thirty-six landscape horticulturists (see the section "Regional Committees") and provides guidance in the selection and care of landscape plants relative to their water needs.	California Centre for Urban Horticulture (CCUH)
		Water and Nutrient Use The Greenhouse Horticulture unit at the University of Wageningen has an active research program investigating emissions, more accurate nutrient supply, nutrient and water recycling, improvements to soil resistance, and the development of new hydroponic systems.	University of Wageningen
		Energy and Climate Management The Greenhouse Horticulture unit uses advanced computer models to calculate new cropping concepts and study the effects of changes in climate and energy consumption. They also study innovations in climate and energy control in practice, working in close cooperation with growers and the input supply industry.	University of Wageningen
		Re-use and Recycling of Plastic Wageningen Food & Biobased Research is focused on the development of renewable materials such as bioplastics (thermoplastics and thermosets), natural fibre-based materials (such as composites), coatings and adhesives. Their projects cover a number of areas that may have relevance to the nursery industry including: ▪ The BioactiveLayer project will lead to a unique alternative to the existing solution of Modified Atmosphere Packaging for dried products. The partners in the project aim to successfully	University of Wageningen

ISSUES	R&D DRIVERS	R&D PROGRAM	PROVIDER
		introduce a completely renewable and biodegradable packaging solution that will maintain freshness of dried food products and will reduce high levels of packaging waste. ▪ SEABIOPLAS (Seaweed from sustainable aquaculture as feedstock for biodegradable bioplastics) is an EU Seventh Framework Programme (FP 7) funded project which aims to introduce sustainably cultivated seaweeds as feedstock for biodegradable bioplastics. ▪ Biobased, biodegradable and sprayable cover material for horticulture and agriculture: The project's objective is to develop a sprayable mulch formulation to be used for weed control and acceleration of plant growth. This liquid formulation should be able to form a polymer network that is impenetrable for weeds but permeable for moisture and is biodegradable with time in/on soil following EU standards currently under development.	
		The carbon balance of potted roses Carbon foot-printing at the product level is one way to make a subset of environmental sustainability measurable and traceable. This project collected data via surveys and collecting business information, and used secondary industry data in the event of data gaps from recognized databases.	Technical University of Munich
		This project aimed to quantify the **Product Carbon Footprint (PCF)** of *Euphorbia pulcherrima* (poinsettias). Data was collected as primary data from the participating companies (young plant producers, production nurseries, supply chains) via questionnaires and collecting business information and used secondary data in the event of data gaps from recognized databases. In many sectors of the economy, the PCF is often used as an indicator of sustainability.	Technical University of Munich
II. Improving systems and practices	Improving production efficiencies (both in the field and within protected cropping systems)	**Cultivation and Production Systems** The Greenhouse Horticulture Unit is developing new complete concepts and integrated designs of production systems with mobile cultivation systems, revolutionary greenhouse designs or systems for the early detection of plant diseases. They are also developing parts of production and selection systems, such as innovative sensors, vision systems and robots.	University of Wageningen
	Improving supply chain efficiencies and logistics		
	Improving pest management	**Application and Management of Biopesticides for Efficacy and Reliability (AMBER)** AMBER aims to identify practical ways for growers to improve the performance of biopesticides in their crop protection programs.	Warwick Crop Centre: School of Life Sciences, University of Warwick, UK
		“eyeSpot” – leaf specific herbicide applicator for weed control in field vegetables (2014 – 2018)	University of Reading, UK

ISSUES	R&D DRIVERS	R&D PROGRAM	PROVIDER
		For field vegetable crops grown in rows, the project aims to prove the concept of weed management by leaf-specific herbicide application.	
		As the introduction of invasive insects and diseases has impaired the ability of California's nursery industry to do business, growers have used **best management practices (BMPs)** in combination with IPM approaches to exclude and prevent the spread of several major pests. This online tool allows growers/shippers to create a set of BMPs unique to their nursery based on county locations and the pests/pathogens under quarantine or of concern in those counties.	CANGC
		Crop Protection The Greenhouse Horticulture Unit develops strategies and techniques for sustainable crop protection. Biological pest control; conscientious application of agents with the appropriate technique; and the utilisation of soil and crop resistance, the climate, and the environment are all examined individually and as a total system, and then optimised.	University of Wageningen
	Reduce production costs through automation and uptake of new technology	**GROWBOT: A Grower-Reprogrammable Robot for Ornamental Plant Production Tasks (PhD Studentship)** This project will explore the use of new, human-robot interactive, soft robotic systems and their application for semi-automated propagation of multiple varieties of ornamental plants. It will investigate ways in which non-expert users (i.e., those without technical expertise in robot programming and control), but that are nevertheless skilled in plant processing, can use robots in their work, to relieve them of the more repetitive, labour-intensive tasks encountered.	Kings College London, UK
		SPECTRA: Whole plant spectral response models (2016 – 2019) This project will fundamentally underpin understanding of the effects of light quality on a wide range of greenhouse crops. This will directly support the development, design, roll out and selection of LED systems by lighting designers and in particular growers.	University of Lincoln (UK)
		Biofeedback control of supplemental lighting By measuring chlorophyll fluorescence and calculating the above parameters, the HPL can design a biofeedback system to control LED lights.	Horticulture Physiology Laboratory, University of Georgia
		Putting Technology to Work for Horticulture: Process Control and Automation Engineering The main objective of this program is to design automation technology in an indoor environment for the greenhouse sector. The automation program will be further enhanced within Vineland's new research greenhouse, creating a large pre-commercial setting for constant innovation and collaboration. The team is currently working on the following projects: ▪ Development of Gripper Tools for Automated Handling of Horticultural Produce	Vineland Research

ISSUES	R&D DRIVERS	R&D PROGRAM	PROVIDER
		▪ Development of Wireless Irrigation Sensing and Decision-Making Systems ▪ Development and Commercialization of an Automated Planting System ▪ Development and Commercialization of an Automated Potted Plant Packaging System.	
		Company based in the Netherlands which provides UV light to disinfect, modify plant growth and protect against disease.	CleanLight (Wageningen)
		Root growth measurement technologies This research combined high-frequency in situ observations of fine roots and ectomycorrhizal (EM) fungi with data from multiple soil sensor arrays to examine the biophysical interactions influencing soil CO_2 production for one year in a mixed conifer forest. Using structural equation modelling a hypothesized model to test for causal interactions among environmental factors, biotic factors, and soil CO_2 dynamics throughout the soil profile was constructed.	University of California
		Advancements in Root Growth Measurement Technologies and Observation Capabilities for Container-Grown Plants This review delves into the expanding technologies involved with expertly measuring root growth of plants in containers, and the advantages and disadvantages that remain.	North Carolina State University
		Automation – Distribution and collection of nursery containers Harvest has developed a new approach to automating a variety of traditionally manual labour tasks based on mobile robot technology. Teams of small, highly intelligent machines work safely with laborers to perform the most physically demanding parts of these tasks, and at a significantly reduced cost.	Harvest Automation
		Automation – Automatic tray sowing machine There are several machinery companies (predominantly throughout Europe) that specialise in nursery production systems such as Vissa, Javo, Fleeder, Mayo, and Demtec.	Conic System
		Automation – Pruning and maintenance Lommers has created a wide range of pruning and maintenance machines for the nursery industry.	Lommers
	Better industry data	Charlie Hall at the Texas A&M University has been involved in a number of studies of the economic contribution the nursery/green industry to the Texas economy and to the broader American economy (although these were conducted in 2007/8).	Texas A&M University
III. Biosecurity	Improve quarantine/biosecurity efficiencies	**Developing Diagnostics for Quarantine and Quality Diseases in Plants (2017 – 2020)** As part of this project inspection services are gaining experience with Next Generation Sequencing under the guidance of Wageningen University and Research. They are currently	University of Wageningen

ISSUES	R&D DRIVERS	R&D PROGRAM	PROVIDER
		working on a device that allows you to analyse data in the field using your mobile phone, after which you can download a diagnosis directly from the cloud. These kinds of technologies will be developed within at least five years.'	
	Prevent and manage the introduction of new pests	A New Zealand Plant Producers Incorporated (NZPPI)-led team has worked and consulted with plant producers, plant buyers, horticulture and forestry sectors, MPI and other stakeholders to design the **Plant Production Biosecurity Scheme (PPBS)** and the design proposal is now complete. The draft scheme includes a biosecurity standard and manual; a hazard management checklist and; a myrtle rust module. A scheme overview document and the draft scheme rules completes this suite. The proposed Scheme is intended to increase the awareness among plant producers of the risks that exotic and endemic pests pose to their nursery and grow producers' adoption of good biosecurity practice to help manage the risk of pest and disease spread. By protecting their nurseries, they also protect customers, the environment and the New Zealand economy.	New Zealand Plant Producers Incorporated (NZPPI)
IV. Increasing the demand for plant nursery products	Create better plants	New developments in **molecular techniques for breeding in ornamentals** add new possibilities to direct the breeding process. Notably, gene editing (also called genome editing) using Crispr/Cas may be used to increase the pool of functional variation, but there are challenges to apply it in ornamentals, in terms of the availability of sequence information for the candidate genes and the existence of transformation and regeneration protocols.	University of Wageningen (The Netherlands)
		In **ornamental crops the development of genetic and molecular tools** for breeding has been slow because of the large number of ornamental species, many of which are genetically complicated for breeding, being outbreeding crops, polyploid, and/or having a large genome. This is changing due to three recent developments: (i) next-generation sequencing can now generate large numbers of single nucleotide polymorphism (SNP) markers based on genomic or transcriptomic sequences, (ii) efficient and automated SNP detection systems render genotyping into an automated and relatively cheap process, and (iii) methods and software now exist to analyse these data, also in polyploid crops, to find associations with traits and to generate tools for marker-assisted breeding. The challenge for the coming years will be to implement these tools to speed up breeding.	Flanders Research Institute for Agriculture, Fisheries and Food (ILVO)
		Euro-Trials is a collaboration between eight countries in Europe focussed on the **evaluation of woody nursery plants**. An independent organisation in each country plans, establishes, grows and assesses the trials. By growing and assessing plants over a wide geographic range, it is possible to assess the plants' performance and suitability to a range of local climates.	Multiple European collaborators

ISSUES	R&D DRIVERS	R&D PROGRAM	PROVIDER
	Improve understanding by industry of end-user needs/desires	**Consumer-led development of new processes and products** Using a multi-disciplinary approach, this project will develop valuation models based on the carbon footprint for sustainability in the ornamental plant value chain. In conjunction, ethnographic studies will assess the usage contexts and environmental conditions of consumers. Based on this, new production methods for stress-adapted ornamental plants are to be tested in cultivation experiments. In cooperation with partners from production and retail, sustainable product concepts are to be developed and their acceptance examined in a consumer study. Through the companies involved in the project, the findings can be immediately put into practice.	Technical University of Munich
		A collaboration of researchers at a number of universities in the United States (primarily Michigan University and Texas A&M University) has investigated **consumer preferences and purchasing behaviour.**	United States Universities
	Improve horticultural literacy (understanding of plants)	**Plant California** is a CDFA grant funded online gardening resource aimed at educating and inspiring Californian's to plant something. The Plant California's Learning Centre provides garden tips which offer information on planting fundamentals like Healthy Soil and Irrigation: When & How Much to Water. How-to videos offer novice gardeners guidance on building low-cost garden projects like Patio Drip Irrigation and information on How to Be a Water Wise Gardener. Once inspired, Plant California helps gardeners to find a local nursery or garden centre.	California Association of Nurseries and Garden Centres (CANGC)
		Industry software for horticulture Creation of an up-to-date overview of horticultural software products. The listing is aimed at producers, trade and service, gardeners, apprentices, and students. The overview offers different user categories such as costing, merchandise management, determination aids, cultivation planning, information systems, accounting and a few more. The search result can be further limited by cultivation direction, trade or final sale.	Centre for Research and Continuing Education at Weihenstephan-Triesdorf University of Applied Sciences (Germany)
	Influence policy makers and the public on the value of green-life and nursery products		
	Develop green infrastructure	**Greening the Canadian Landscape:** Based on research trials conducted throughout Ontario and Alberta by Vineland Research and Innovation Centre, the Greening the Canadian Landscape Program brings together findings on soil remediation and species selection for improved tree survival and growth in challenging urban and suburban environments. The unique availability of a soil remediation calculator and tree species selector on this website will enable tree planting projects to succeed, even on difficult sites. By considering key factors that influence tree survival,	Vineland Research and Innovation Centre

ISSUES	R&D DRIVERS	R&D PROGRAM	PROVIDER
		especially soil quality and health, as well as selecting an appropriate and diverse suite of tree species, you can grow healthier trees for more resilient and greener landscapes.	
	"Green society and health" Therapeutical use of plants	**Evaluation of the influence of garden therapy on subjective well-being within a neurological rehabilitation centre.** Garden therapy is more and more used in Europe. Estimates are that there are currently more than 400 therapy gardens in Germany, and the trend is rising. Practice shows that therapy gardens are often planned and built without the knowledge of therapeutic or health effects. Added to this is the lack of communication between those involved, so that the potential of the therapy gardens can often not be fully exploited. In view of the marked discrepancy between the widespread use of such facilities and the low level of scientific knowledge about the effects and possibilities of their optimisation, there is a considerable need for interdisciplinary research. With a randomized control study at the Klinikum Osnabrück in the Department of Neurology, Department of Neurological Early Rehabilitation an interdisciplinary research group examined whether the garden therapy has a positive effect on the subjective well-being of patients.	Hochschule Osnabrück 2016
V. Skills and workforce management		With rising costs and uncertainty about future access to labour, AHDB Horticulture developed a program of knowledge exchange activity to help businesses deal with this challenge through improving management practices and supporting skills development. This included the use of LEAN management principles and the development of a champion supervisor model and training programme to improve the selection and training of key staff.	AHDB (UK)

Appendix 5: Capacity and capability of international RD&E providers

WAGENINGEN UNIVERSITY & RESEARCH THE NETHERLANDS

Wageningen University & Research (WUR) provides some of the worlds most specialised horticultural expertise and is known as one of the worlds' premier institutes for plant-related R&D. Containing over 6,500 employees, WUR conducts a range of research, both fundamental and applied, relating to three core areas:

- Food and food production
- Living environment
- Health, lifestyle and livelihood.

The research facilities and amenities located on the WUR campus are home to some of the most advanced in the world. As well as the main WUR campus, there are also 25 research and experimental facilities located throughout the Netherlands. Along with the diverse institutions located throughout the Netherlands, WUR are involved in research programmes throughout the world with a range of international partners. As well as a major focus on research, WUR offers 19 undergraduate programs, 30 masters programs and contains 6 graduate schools throughout the Netherlands. Although the majority of focus is on undergraduate and postgraduate degrees, WUR also offers a wide variety of training and education programs to professionals in the agricultural sector to improve their skillsets

WUR contains most of its capacity for nursery R&D within its Research Institute of Plant Research which conducts research in the following areas:

- Agrosystems
- Biointeractions and Plant Health
- Biometrics
- Bioscience
- Field crops
- Greenhouse horticulture
- Plant Breeding.

WUR is currently conducting a wide range of projects of relevance to the Australian nursery industry. Of particular interest is their work on:

- Protected cropping
- Resource use efficiency and environmental sustainability
- Quarantine diagnostics.

As part of the project 'Developing Diagnostics for Quarantine and Quality Diseases in Plants' various inspection services are gaining experience with Next Generation Sequencing (NGS) under the guidance of WUR. 'The European Plant Protection Organisation (EPPO) has asked WUR to collaborate with them on further developing NGS for diagnostics. It is expected that it will be the go-to standard for diagnostics within a few years. The project is currently developing a device that allows analysis of data in the field using a mobile

phone, after which you can download a diagnosis directly from the cloud. These kinds of technologies will be developed within the next five years.

JULIUS KÜHN INSTITUTE - FEDERAL RESEARCH CENTER FOR CULTIVATED PLANTS (JKI) - GERMANY

The Julius Kuhn Institute (JKI) is a Federal Research Institute under the authority of the German Federal Ministry of Food and Agriculture with headquarters in Quedlinburg and several locations across Germany. The JKI includes the following institutes and research areas relevant to nursery production:

LOCATION	KEY RESEARCH AREAS
Institute in Quedlinburg	▪ Epidemiology and pathogen diagnostics ▪ Resistance research and stress tolerance ▪ Safety of biotechnological processes in plants.
Institute in Brunswick	▪ Application technologies in crop protection ▪ Epidemiology and pathogen diagnostics, also in Quedlinburg ▪ Crop production and soil science ▪ Plant health and plant protection in horticulture and forestry.
Institutes in other locations	▪ Ecological chemistry and plant analysis in Berlin and Kleinmachnow ▪ Biological crop protection in Darmstadt ▪ Breeding research on horticultural crops and fruit in Dresden-Pillnitz and Quedlinburg.

LEIBNIZ INSTITUTE FOR VEGETABLE AND ORNAMENTAL PLANT RESEARCH- GERMANY

The Leibniz Institute is based in Großbeeren and Erfurt. Their mandate is to create the scientific basis for economically successful production in vegetable and ornamental crops, based on yield and quality of products, and at the same time support the sustainable use of limited resources. The institute has greenhouse and laboratory facilities. Research is conducted by five departments:

- Modelling and knowledge transfer
- Plant Nutrition
- Plant health
- Plant propagation
- Quality.

HOCHSCHULE WEIHENSTEPHAN- TRIESDORF, UNIVERSITY OF APPLIED SCIENCES – HORTICULTURE INSTITUTE - GERMANY

The Horticulture Institute conducts research relevant to the nursery industry in the areas of:

- Resource protection and use efficiency (energy and water use efficiency in greenhouses)
- Production and quality management (substrates)
- Innovation, technology and information management (software development, expert networks)

- Urban horticulture and “Green Balance” (regulate the urban microclimate through urban greenery cooling of buildings and use of recycled water for ‘green roofs’).

The institute has many modern research greenhouses and nursery field trial areas.

FREIE UNIVERSITAT BERLIN - DAHLEM CENTRE OF PLANT SCIENCES (DCPS) - GERMANY

DCPS covers a broad range of plant sciences, answering complex research topics using holistic approaches to reach new insights. Research areas relevant to ornamental plants include:

- Urban ornamental plants
- Indoor plants
- New ornamental plants
- Quality of ornamental plants.

Project examples are:

- Sterile in vitro-culture methods for the establishment of healthy mother plant stocks for organic ornamental plants
- Innovative cultivation of aquatic plants (for urban and garden landscapes)
- Development of innovative thin-layer greening solutions for sustainable, economic use on structures in cool, temperate climates
- Alternative growth regulation of plants using controlled vibration technology as a replacement for chemical inhibitors.

HOCHSCHULE OSNABRÜCK, FACULTY OF AGRICULTURAL SCIENCES AND LANDSCAPE ARCHITECTURE- GERMANY

The Faculty of Agricultural Sciences and Landscape Architecture has a wide range of "green" teaching areas, which are of fundamental importance for agricultural and naturopathic applications. They also conduct research in the field of ecotrophology (the nature experience approach) in the context of the inclusion of people with learning or intellectual disabilities.

Existing modules are not yet sufficiently interlinked in order to open up new fields of tertiary qualification. However, under the umbrella of "Green Care" this becomes possible, allowing the faculty to respond in a sustainable manner to social problems and use its "social" potential.

What does Green Care mean?

- It includes client-specific landscape and nature-based offerings in the field of agriculture, horticulture and home economics to meet individual or group-specific needs for promoting mental health, physical health and social behaviours.
- It connects the world of plant production and life and thus creates the conditions for their experience in rural and urban structures.
- It is not an independent form of therapy, but supports and integrates different preventive and curative, nursing or therapeutic approaches.

Research focuses on interdisciplinary approaches combining the knowledge of horticulturist, landscape architects and health practitioners. The current focus is on neuroscience and aged care.

LANDWIRTSCHAFTSKAMMER LWK (HORTICULTURE CENTRE) SCHLESWIG-HOLSTEIN- GERMANY

Landwirtschaftskammer is the name for the agricultural state departments in Germany. These organisations conduct the majority of applied research and field trials.

The Landwirtschaftskammer Schleswig-Holstein is located in the main production region of woody ornamentals and tree nurseries in Germany. The Competence Centre for Nursery is a core area of the horticultural centre Schleswig-Holstein. At the centre, trials are conducted on approximately 30,000 m^2 outdoor area, 5,500 m^2 container cultivation area and 3,000 m^2 greenhouse area. Research conducted at the Centre focuses on:

- Deciduous trees
- Rose and fruit trees
- Forest, landscape and native shrubs
- Plant propagation (seedlings, vegetative methods), and
- Sustainable tree production.

Main research areas are:

Production – in particular propagation using rapid vegetative methods, grafting to overcome soilborne disease, cultivation and maintenance of woody plants. Testing alternatives to chemical growth regulators in the production of woody plants in pots and containers. For example, mechanical touch stimuli but also moderate water stress are used to produce woody plants in a compact and branched manner. Use of biological predators (such as entomopathogenic nematodes) and plant tonic preparations are investigated as a replacement for growth regulators.

Nutrition for production of woody plants in pots including:

- Assessment of new and existing fertilisers
- Development and testing of new fertilisation strategies
- Assessment of alternative substrates for production of woody plants such as the fermentation residues from biogas plants.

Technology

- Assessment of materials such as lava, floral mat and Delta-Terra XX mat for facilitation of substrate drainage for production and overwintering of woody plants in containers.
- Assessment of the suitability and plant compatibility of various processes for irrigation water treatment or disinfection (such as UV irradiation, chlorine dioxide plant and slow sand filter).

Soil management

- Research into the cause, rapid testing and management of soil sickness or re-plant disease in nurseries, cooperation with Universität Hannover

EURO-TRIALS - EUROPE

The initiative to start the Euro-Trials was taken by the Royal Dutch Horticultural Society (KVBC) and it is still the coordinator of the Euro-Trials. Euro-Trials for woody nursery plants were first established in 2004. These plant evaluation trials are a collaboration between eight countries in Europe; Netherlands, Germany, France, Britain, Austria, Iceland, Finland and Ireland.

An independent organisation in each country plans, establishes, grows and assesses the trials. By growing and assessing plants over a wide geographic range, it is possible to assess the plants' performance and suitability to a range of local climates. The plant species are selected by the Euro-Trials committee each year. All new plants are propagated in one location and distributed to all trial sites for planting in the field. Trials are hosted by local government sites or commercial nurseries.

The plants are assessed between the second and fourth years. Judging panels consist of growers, traders and end users. Euro-Trial members meet a number of times during the year at different trial locations. Assessment criteria vary depending on local preferences however floriferousness, hardiness and disease resistance are some of the most important features.

Eurotrial Partner organisations include:

- Germany - Bund Deutscher Baumschulen (BdB), Ellerhoop, in cooperation with LWK Schleswig Holstein
- Finland - LUKE, Piikkiö
- France - Agro Campus Ouest, Angers
- Netherlands - Royal Boskoop Horticultural Society (KVBC), Boskoop
- Austria - Höhere Bundeslehr- und Forschungsanstalt für Gartenbau (HBLFA), Vienna
- Great Britain - Royal Horticultural Society (RHS), Wisley
- Ireland - Teagasc, Kildalton College, Dublin
- Iceland - Agricultural University of Iceland.

AGRICULTURE AND HORTICULTURE DEVELOPMENT BOARD (AHDB) - UNITED KINGDOM

The Agriculture and Horticulture Development Board (AHDB) is a levy paid organisation for primary producers in the United Kingdom. The primary aim of the AHDB is to increase the productivity and sustainability of farmers and growers in the UK. The organisation is represented by a number of experienced individuals with skills in the fields of animal and plant sciences. AHDB is not specifically a research provider but does have some level of involvement in designing, directing and delivering projects. A large part of the work conducted by the AHDB is contracted out to third-party research organisations while AHDB manages the projects. Although the capacity and capability of AHDB to conduct research is relatively low, they do play a large role in ensuring research is conducted and delivered well. There are a total of seven relevant current programs by AHDB focussing on a range of horticulture-related topics; these are as follows:

NAME	PROVIDER	TOPIC
FERTINNOWA	European collaboration	Creation of a database to share knowledge and evaluate current innovative technologies and practices in relation to fertigation of horticultural crops
AMBER	University of Warwick	Improving the performance of biopesticides
GROWBOT	Kings College London	Semi-automated robot for propagation of ornamental plants
EyeSpot	University of Reading	Leaf specific herbicide applicator for weed control in field vegetables
Labour Efficiency	AHDB	Knowledge exchange program to help businesses improve management practices
SPECTRA	University of Lincoln	Understanding the effects of light quality on greenhouse crops
SCEPTREplus	AHDB	Research for sustainable plant protection products for use in horticulture
SmartHort	AHDB	Investigation of technology (automation) and LEAN management to reduce labour pressure

MARKET BASED AND CONSUMER ANALYSIS – USA

A collaboration of researchers (based in American Universities) have conducted and published research into consumer purchasing behaviour and supply chain analysis. Recent papers published in HortScience by these researchers have included:

- Consumer Involvement with and Expertise in Water Conservation and Plants Affect Landscape Plant Purchases, Importance, and Enjoyment
- Consumer Perceptions, Attitudes, and Purchase Behaviour with Landscape Plants during Real and Perceived Drought Periods
- Do Real and Fictitious Plant Brands Differ in Brand Recognition, Awareness, Purchase Intention, and Visual Activity?
- Consumer Response to Novel Indoor Foliage Plant Attributes: Evidence from a Conjoint Experiment and Gaze Analysis
- The Effects of Individual Environmental Concerns on Willingness to Pay for Sustainable Plant Attributes.

Details on the universities, and key researchers within these organisations, conducting research of relevance to the Australian nursery industry are provided below.

MICHIGAN STATE UNIVERSITY - USA

The Floriculture and Greenhouse Crop Production Team at Michigan State University is composed of extension educators and outreach specialists with responsibilities in commercial greenhouse crops, staff at Diagnostic Services, and faculty members in the Departments of Horticulture, Entomology, and Plant, Soil, and Microbial Sciences. The Team has a strong relationship with the greenhouse industry in the state. The goals of the team are:

- To enhance the ongoing growth and profitability of Michigan's floriculture/greenhouse industry.
- To deliver research-based information, educational programs, and scientific and marketing expertise to the greenhouse industry in Michigan and beyond.

- To improve greenhouse crop production through research that identifies new production techniques, new crop production protocols, energy conservation strategies, control of insect and disease pests, and enhanced postharvest longevity techniques.
- To coordinate greenhouse grower tours and experiences that broaden Michigan growers' perspectives and help identify opportunities that can advance their businesses.
- To provide training and professional development opportunities for MSU Floriculture Team members.

Dr. Bridget Behe is a member of the Floriculture and Greenhouse Crop Production Team investigating the consumer perspective of the horticulture industry for crops both edible and ornamental. Bridget has conducted studies and published results on branded transplants, sustainable/local/organic products, the perceived value of good landscaping, the market for a hypothetical blue geranium, and contributed to the understanding of how age and ethnicity influence American gardening purchases and participation. Most exciting is her recent collaborative work with eye-tracking glasses to better understand what consumers see and what they ignore in ads, displays, and the shopping experience. Bridget also gives talks to state, regional, and national businesses and associations involved in many aspects of horticulture, helping to better their marketing and management practices to improve profitability and sustainability.

TEXAS A&M UNIVERSITY - USA

Aggie Horticulture and the other servers of the Aggie Horticulture Network are information providers of the Texas A&M University System Horticulture program, including the College of Agriculture and Life Sciences at Texas A&M University, Texas A&M AgriLife Research, and the Texas A&M AgriLife Extension, referred to collectively as Texas A&M AgriLife. The Aggie Horticulture network offers a vast amount of practical information for horticultural crop producers on topics including the Texas Master Gardener and Jr. Master Gardener programs, Ornamental production, and more. Their factsheets, guides and databases are based on years of testing and practice. More than 50 teachers, scientists, and extension specialists contribute their work to this website.

Dr Charlie Hall is a Professor in the Department of Horticultural Sciences at the Texas A&M University and also holder of the Ellison Chair in International Floriculture. His major areas of specialization include innovative management and marketing strategies, financial analysis and benchmarking, and the situation/outlook for nursery and greenhouse crops. He is an invited speaker at numerous regional, national, and international meetings of various industry-related associations and organizations.

PURDUE UNIVERSITY - USA

The floriculture and ornamentals extension, research, teaching faculty and professional staff at Purdue University include individuals from agricultural and biological engineering, botany and plant pathology, entomology and HLA. Purdue University conduct a number of major floriculture extension programs. These include:

- Development of websites such as the floriculture website (http://flowers.hort.purdue.edu), a green industry resources website (http://www.btny.purdue.edu/Extension/GIWG/) to provide commercial growers with Purdue-generated trade and scientific articles, bilingual floriculture bulletins, production guides, podcasts and links.
- The new e-Gro Alert for greenhouse growers. e-Gro Alert will notify growers of insect, disease, nutritional, environmental and physiological problems as they develop during the bedding plant production season. It

will help growers know what to be on the lookout for in their own crops. To view e-Gro Alert, visit www.e-gro.com.

- Educational tours for small and medium-sized greenhouse operations and other horticultural professionals. Attendees get a first-hand look at new floriculture plant releases and interact with breeders and producers to learn how to use the material in containers and in the landscape.
- Creation of an educational module series in Indiana and New Hampshire, respectively. This series is specifically aimed at the most critical employees that are often under educated. The goal of the educational series is to confront current industry issues and offer a series of two-hour sessions over the course of the bedding plant production and marketing season. Each session is focused on one topic (e.g., fertility, properties of growing substrate and substrate selection, temperature and light management, water quality, pH and alkalinity management, height control, disease and insect management, and marketing strategies).
- To help growers make informed decisions and tackle the issue of sustainable greenhouse production and certification, a collaborative research and extension effort called the Floriculture Sustainability Research Coalition (FSRC) was formed. The group is currently conducting research on energy efficient crop production, plant nutrition, and efficient irrigation methods. As research is generated, articles are published in scientific and trade journals and talks are given around the country. In collaboration with OFA, the group is developing a website that will be a central location for articles and information related to sustainable greenhouse production. The goal is to educate greenhouse growers on how to successfully implement sustainable production practices and to identify consumer segments that are willing to pay premium prices for sustainable floriculture crops.

KANSAS STATE UNIVERSITY - USA

Individuals from the horticulture, entomology and plant pathology departments contribute to the floriculture working group at Kansas State University. Floriculture research conducted by this group include:

- **Physiological disorders.** A series of research projects focuses on understanding the mechanisms behind the physiological disorders of oedema and intumescences on greenhouse-produced crops such as ivy geranium and tomato.
- **Plant nutrition.** One aspect of this project focuses on adapting organic fertilization to greenhouse cropping systems. This includes developing techniques to manage nutrition provided by organic fertilizers in hydroponics and soilless substrates, evaluating organic fertilizer impact on plant architecture, and investigating the impact of organic fertilization on microbial activity in soilless substrates. Another focus of this research includes use of calcined minerals as a component of soilless substrates to increase their nutrient retention, reduce water use and minimize nutrient leaching.
- **Ornamentals.** In conjunction with commercial growers, research has been conducted investigating different PGR applications for controlling height of different bulb crops, including amaryllis and calla lily. Other research investigating forcing specialty bulbs for greenhouse forcing production is also being conducted.
- **Insect and mite pest management.** A research program for greenhouse-grown floricultural crops associated with management of the major insect and mite pests including spider mites, western flower thrips, whiteflies, fungus gnats and mealybugs. Currently, research emphasis includes: 1) incorporatiing entomopathogenic or beneficial fungi (e.g., *Beauveria bassiana, Isaria fumosoroseus* and *Metarhizium anisopliae*) into rotation programs against the western flower thrips (*Frankliniella occidentalis*) in order to avoid the potential for resistance and preserve existing insecticides; 2) understanding the effects of systemic insecticides against the citrus mealybug (*Planococcus citri*) and how feeding behaviour may affect efficacy of these types of insecticides; 3) using barriers applied to the growing medium to prevent

emergence of fungus gnat (*Bradysia* spp.) adults and reduce egg-laying by females; and 4) investigating the use of the rove beetle (*Dalotia coriaria*) as a biological control agent against fungus gnats and their susceptibility to pesticides (e.g., insecticides and fungicides) and plant growth regulators. In addition, new compounds are evaluated in pesticide efficacy trials throughout the year.

- **Plant trials include:**
  - Poinsettia trials. Each autumn, over 50 poinsettia cultivars from several major breeding companies are trialled at Kansas State University.
  - Prairie Star program. Prairie Star Flowers is the Kansas State University flowering plant field trials research program. The comprehensive Prairie Star Flowers program evaluates annuals (Prairie Star), perennials (Prairie Bloom) and flowering woody shrubs in field research trials. Successful Prairie Star trial plants are internationally recognized by plant breeders and distribution companies through notations in their catalogues and at displays at industry events, such as the California Pack Trials. The independent, research-based information provided by the Prairie Star Flowers program has benefitted Kansas greenhouse growers, garden centres, landscapers and home gardeners.
  - All-America Selections Trials. The All-America Selections' (AAS) mission is to promote new garden seed varieties with superior garden performance. Each year, Alan Stevens and Robin Dremsa conduct AAS flower trials at the Kansas State University Horticulture Research Center. Cary Rivard also conducts AAS vegetable trials. Field days and open house events are coordinated, inviting growers and producers, along with the general public to view the trials.

UNIVERSITY OF CALIFORNIA - USA

Within the University of California (UC) system, there are many Agricultural Experiment Station (AES) faculty, specialists and advisors who assess the needs of the industry, conduct both traditional and applied research on ornamental plant production issues and extend the results to growers and allied pest management professionals.

The publications, research, education and outreach offered by the Department of Plant Sciences and the entire University of California system benefit the floriculture, nursery and landscape industries in California and the United States, particularly in the areas of water and drought management, salinity, pathogens, pollutants and lighting technology.

University of California Nursery and Floriculture Alliance

UCNFA is an education and outreach partnership based at the University of California Davis campus and is composed of a diverse range of researchers, growers, and industry associations. The organisation contains academic staff with skills in entomology, nematology, and various plant and environmental sciences from universities throughout the United States and Europe. As well its academic participants, the organisation's growers and industry-member participants have in-depth knowledge of production systems, markets and consumer related issues. Due to the breadth of this organisation, the UNFCA have medium-high capacity and capabilities to deliver focussed projects to benefit the nursery industry. Facilities of the organisation extend throughout the University of California's Davis campus, as well as other universities throughout the US. Research conducted by this group includes:

- Developing and implementing IPM strategies for the ornamental plant production industry with an emphasis on biological controls. They focus on understanding the relationship of the pest to the crop (including its unique production practices) to the environment and to its natural enemies.

- Examining how slow sand filtration and other natural water treatment systems remove plant pathogens, including *Phytophthora ramorum*, the organism that causes Sudden Oak Death disease, and other pollutants from nursery irrigation runoff. The treated water could then be safely reused for irrigation.
- Understanding and managing the light brown apple moth and *Phytophthora ramorum*. These two pests have severely impacted the nursery industry in his coverage area by closing markets, increasing costs and significantly increasing pesticide use.
- Optimization of nutrient use efficiency for nursery and greenhouse crop production and the development of Best Management Practices (BMPs) for ornamental plant production, including irrigation efficiency, fertilizer use efficiency, infrastructural considerations and integrated pest management (IPM).
- Use of light-emitting diodes (LED) as light sources for controlled environment production. While it is well known that LEDs are efficient at producing light, it is not clear how specific light wavelengths affect plant growth. Questions regarding LEDs that are being examined include: can LEDS be used to control photoperiod, are they effective in indoor hydroponic fruit production, can they be used for greenhouse supplemental lighting, and can LEDs influence stomatal control?
- Examining plant salinity tolerance using microcalorimetry, landscape water conservation, biological water treatment methods and the characterization of runoff water in urban and plant production settings. The work that is conducted will develop information to help growers and landscape managers use water more efficiently and reduce waste when irrigating plants.
- In a collaborative USDA project led by Sarah White of Clemson University, UC researchers Pitton, Oki and Haver are managing the California aspects of a large nationwide project called “Clean WateR3” (www.cleanwater3.org) to model water movement in nurseries, characterize nutrient and pathogen contents in runoff, and identify key control points and treatment methods to mitigate the contaminants. To study water movement, they are installing monitoring equipment in nurseries to measure and record water applied as irrigation and the runoff that is generated. Equipment is also used to automatically collect samples so that we can examine them for pathogens and other contaminants. The research team will develop a decision support tool to assist growers in selecting water treatment methods and management practices to reduce runoff and contaminant content.

California Centre for Urban Horticulture (CCUH)

CCUH is an extension organisation part of the University of California, Davis, and has a main focus on water conservation and management in urban landscapes. The centre has two staff members, both located at UC Davis. The research centre is small and lacks capacity to conduct large-scale research projects, the centre is however conducting one project that has relevance to the nursery industry. The project, titled Water Use Classification of Landscape Species, is part of an initiative to match water supply to plant needs to increase water use efficiency.

HORTICULTURE PHYSIOLOGY LABORATORY, UNIVERSITY OF GEORGIA – USA

The University of Georgia’s Horticulture Physiology Laboratory conducts a range of research, both fundamental and applied, with the main aim of advancing horticultural science. The research laboratory’s biggest focus is optimising the efficiency and cost-effectiveness of growth lighting in protected cropping environments. Most recent projects from the laboratory include:

- Biofeedback control of supplemental lighting
- Building irrigation controllers
- Water Requirements for greenhouse and nursery Crops

- Irrigation control for greenhouse and nursery crops
- Whole plant CO^2 exchange
- The use of recycling subirrigation systems in greenhouses
- Fertilisation in greenhouses.

VINELAND RESEARCH AND INNOVATION CENTRE – CANADA

Vineland Research and Innovation Centre is one of North America's premiere institutes for horticultural research. With a major focus on improving the productivity and viability of Canada's horticulture sector, research focuses on a wide-range of broad, cross-disciplinary topics that involve a diversity of partners. The majority of the research conducted at the centre covers four broad areas of research:

- Applied Genomics
- Consumer insights
- Horticultural Production Systems
- Robotics & Automation.

These research areas are led by teams of research scientists and students who have a broad range of skills relating to the horticultural field. Research is conducted throughout the Centre's extensive research laboratories, as well as their Collaborative Greenhouse Technology Centre. There are currently a range of projects being conducted that have relevance to the horticulture and nursery industries. These fall in the Centre's ten research program areas consisting of:

- Canada's National Hardy Rose Program
- Enhancing Flavour and Production Traits of Canadian Greenhouse tomatoes
- Global Reach, Local Touch: New Vegetable Varieties
- Greening the Canadian Landscape
- New Market Opportunities: Driving Growth with New Plant Varieties
- Putting Technology to Work for Horticulture: Process Control and Automation Engineering
- The Customer Comes First: Putting Consumer Intelligence to Work for Horticulture
- The Right Tools: Integrating Biocontrol Systems for Impact
- Value-Added Traits for Horticultural Crops
- Feeding Diversity: Bringing World Crops to Market.

NEW ZEALAND PLANT PRODUCERS INCORPORATED (NZPPI) - NEW ZEALAND

New Zealand Plant Producers Incorporated (NZPPI) grew from the former Nursery and Garden Industry (NGINZ), to allow other members including industry partners, such as suppliers, research organisations, retailers or any organisation with an interest in plant production in New Zealand2. The changeover occurred around 2016/20172.

Since then they have been building towards a more cohesive approach within the industry. Their main areas are engagement, influence, providing results and services to members, innovation, and image (an industry of professionals).

As part of this they have been developing a biosecurity strategy as well as a workforce strategy. Some of the main points from the workshop (May 2018) around workforce strategy were:

- qualifications and training courses are not aligned with the needs of the industry

- perceptions of a low wage, high turnover labour force
- promote pathways for people to develop their careers
- define common roles across the industry.

SCION RESEARCH – NEW ZEALAND

Scion Research (a Crown research institute or government-owned company) is conducting research towards biodegradable and/or compostable pots. They are particularly interested in biobased pots that meet biodegradable standards. They have previously produced biodegradable bioplastic vineyard net clips containing red grape pomace.

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Document review and authorisation

Job Number:

Doc Version	Final/Draft	Date	Author	Reviewed by	Quality checked	Release approved by	Issued to
1.0	Final Report	7/12/2018	Kristen Stirling, Hugh Wardle, Doris Blaesing	Anne-Maree Boland	J. Davison	K. Stirling	Hort Innovation
2.0	Final Report	31/01/2019	Kristen Stirling, Hugh Wardle, Doris Blaesing	Anthony Kachenko, Peter Vaughan, David Mathews	J. Davidson	K. Stirling	Hort Innovation