

Viticulture R&D for the Australian Wine Industry

Future Directions : 2012-2017



April 2011

Executive Summary

The Australian wine industry is one of the most technologically advanced in the world but faces major production challenges and increasing competition in the global marketplace. Viticulture R&D can provide the knowledge and tools to equip the industry to meet these challenges and to remain at the forefront of innovation in the future.

For viticulture R&D to benefit the industry and provide for future innovation, it needs to deliver across four major areas :

1. Improving production efficiency and profitability.
2. Producing targeted fruit composition to deliver desired wine styles.
3. Ensuring long term sustainability of vineyards and adapting to climate change.
4. Positioning for the future - developing new germplasm and innovative vineyard technologies.

CSIRO is Australia's premier research organisation and has been carrying out R&D in support of the Australian grape and wine industries for more than 90 years. Improved knowledge of grapevine performance and vineyard management will continue to deliver benefits in terms of more efficient and sustainable production in existing vineyards. However, the greatest impact of R&D on improving the future profitability and sustainability of the Australian wine industry will be achieved from improved varieties, rootstocks and management systems that require lower input costs, have an improved yield per unit area while also meeting desired quality specifications, and produce a unique and consumer desirable product that cannot easily be replicated by competitors. These goals can be achieved by a concerted effort on improving our knowledge of the genetics, physiology and management of important vine and wine traits through the use of advanced technologies and development of improved grapevine germplasm.

This document outlines a range of research and development issues that we believe are priorities in the area of viticultural research over the next five years. These research areas and associated outcomes will be critical to the future of the Australian wine sector :

- Bud fruitfulness, flowering & fruitset – the basis of grape yield
- Pests & diseases – protecting yield
- Managing the vineyard – maintaining yield, managing quality, maximising efficiency
- Ripening & fruit composition – the basis of wine style
- Rootstocks & scions – germplasm for industry renewal
- Vineyard sustainability, adaptation to climate change and a carbon constrained future
- Biosecurity – protecting the production base
- The wine value chain – enhancing returns

With appropriate co-investment from industry, CSIRO expects to deliver benefits including consistency of yield with desired fruit composition, reduced chemical usage through disease resistant vines, improved pest resistance through new rootstocks, improved soil health and vineyard sustainability, improved monitoring and management of vines and vineyard variability, tools, knowledge and options to manage climate challenges, high flavour wines at lower alcohol levels, better management of flavour in the vineyard and optimisation of harvest timing and winery intake logistics.

1. Background

The Australian wine industry is one of the most efficient and technologically advanced producers in the world. However, the increase in the value of the local currency, global oversupply of wine and competition from lower cost producers are all intensifying competition in both established and developing markets. To remain competitive, the Australian industry will need to continually improve production efficiency and deliver wine styles that match changing consumer expectations in a range of markets. Preferred wine styles vary across different market segments and over time, so the challenge is to grow grapes 'fit for purpose', to produce targeted wine styles suited to different market segments. This will require the industry to efficiently grow grapes that have the potential to produce wines that 'over deliver' to the consumer across a range of attributes. Australia must differentiate its wine based on consistent high quality, environmental production integrity and a competitive price and value proposition relative to its competitors.

The Australian wine industry faces major challenges over the next 5 years and for many grapegrowers and winemakers, the current focus is on survival of their businesses in an era of overproduction and low profitability. Viticulture R&D can support the industry through this downturn by providing knowledge, information and practical solutions to manage existing vineyards and to provide a platform for renewal when the upturn gains momentum. However, there also needs to be a strategic R&D element to continue innovation and position the industry for new opportunities in the future and to address factors such as climate change. International competitors are investing significantly in development of new germplasm and management techniques and there is a risk that focusing only on the near term issues of survival will leave the Australian wine industry in a weakened position, where it is not globally competitive in the future.

For viticultural R&D to support the industry and provide for future innovation, it needs to deliver across four major areas :

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2. Producing targeted fruit composition to deliver desired wine styles.
3. Ensuring long term sustainability of vineyards and adapting to climate change.
4. Positioning for the future - developing new germplasm and innovative vineyard technologies.

CSIRO is Australia's premier research organisation and has been carrying out R&D in support of the Australian grape and wine sector for more than 90 years. CSIRO supports a co-investment model through joint projects with the wine sector investment body, the GWRDC, to provide benefit to Australia. Over the past three years, CSIRO has contributed more than \$4M per annum in funding to R&D in support of the wine sector. Our winegrape research capability has recently been consolidated at our Waite Campus site in collaboration with our partners in the Wine Innovation Cluster (WIC). The germplasm at Merbein will be transferred to our recently upgraded Koorlong Farm, near Mildura and we will maintain our involvement with the warm irrigated grape production industries through this site and active field trials in collaboration with industry in the Sunraysia, Riverland and MIA regions. CSIRO has a wide range of capabilities in plant science, soil science, viticulture and climate change which can support both strategic and applied R&D. Collaboration with other research partners will become increasingly important particularly in relation to new high throughput technologies. However, much of the international research is carried out in cooler regions or regions with different challenges and so it is important to maintain a focus on building knowledge and skills pertinent to the Australian industry. Through co-investment with industry and collaboration with research partners in Australia and globally, these capabilities can be harnessed to provide R&D that will address the current and future viticulture needs of the Australian wine industry.

2. Viticulture R&D Opportunities in the Next Five Years

Knowledge about grapevines and vineyard production systems will develop rapidly in the next 5-10 years through the impact of new technologies. Microarray analysis of gene expression and next generation DNA sequencing allow high throughput investigation and are already changing our understanding of grapevine development and response to external stimuli. These new technologies will dramatically enhance our capacity to discover new genes and biochemical pathways involved in disease resistance, flowering, fruit set, fruit ripening, fruit composition and adaptability to abiotic stress. The completion of the first grape genome sequence is having important scientific impacts and these will flow through into practical outcomes, particularly with the sequencing of the genomes of other varieties and North American species which is now underway in a number of other countries. This information, coupled with advances in protein and analytical chemistry will ensure that the knowledge base will continue to expand providing the impetus for new developments.

The development of new analytical technologies will provide the ability to measure metabolites in grapes with increasing sensitivity, higher throughput and at lower cost, providing information about grape composition along the production and processing chain. This will provide the tools and information to more effectively manage fruit composition in the vineyard to meet target wine style specifications. Development of new sensors, imaging technologies and vision systems together with wireless sensor networks and advanced robotics will provide new ways of managing vineyards. Coupled to improved understanding of the effects of the vineyard's biophysical environment on vine performance, these new technologies will allow monitoring of vineyard and vine parameters in real time, allowing more precise management of vineyards.

Such advances in knowledge and application of new technologies have the potential to improve the efficiency of vineyard management, decrease input costs and provide greater control over fruit composition. New germplasm will provide the potential for step change in grape production and wine style. The challenge for the Australian wine sector is to remain at the forefront of technology developments and translate these into innovation that will maintain the competitive position of the sector in the global marketplace.

Priorities for future viticulture R&D to deliver to the wine industry will need to address a number of key areas across the grape and wine value chain, as outlined below.

- **Bud fruitfulness, flowering & fruitset – the basis of grape yield**

Grapevine development determines the basis of grape yield. Conditions between the initiation of bunch primordia in one season and harvest around 16 months later determine bunch number and the number and size of berries per bunch, which are the key determinants of yield. Generally, 60% of the seasonal variation in yield of major winegrape varieties can be accounted for by the number of bunches which can be linked to bud fruitfulness, where both the number and size of the inflorescence primordia are determined in the previous season. Grapevine development from budburst through flowering to fruitset then determines the realisation of the potential yield established the previous season. Whilst we have a reasonably good knowledge of the developmental processes involved, the ability to monitor and control this process is still a significant issue, especially against the background of variability in vineyards and increasing temperatures. Grapegrowers need an improved ability to estimate and manipulate yield to more effectively tune production to demand and to optimise fruit composition for target wine styles. There is also a limited capacity to monitor and manage year to year variability in yield, which would be of major benefit in managing production. We have a limited understanding of the influence of

environmental factors such as temperature, light, humidity and soil properties on these critical phases of grapevine development and this will become increasingly important with future changes in climate and more variable weather patterns. Recent advances in developmental and molecular biology provide new tools to investigate the key processes involved and to develop improved methods for monitoring bunch primordia initiation and fruitset and for estimating and managing potential yield. There is also a need for improved understanding of the impact of climate and vineyard management on bud fruitfulness, flowering and fruitset. This will also form the basis for developing predictive modelling of grapevine development, particularly under varying and changing climatic conditions. Recent advances in modelling in other plant crops could be applied in viticulture.

Key areas for R&D include :

- Understanding the impacts of environmental factors on bud fruitfulness.
 - Increasing understanding of floral development and fruit set.
 - Developing improved biological models for bunch primordia initiation, flowering and fruitset.
 - Identifying genes and germplasm that provide stable yields under variable climates.
 - Developing improved methods for estimating yield.
 - Developing improved methods for altering potential yield.
 - Managing year to year variation in yield.
 - Understanding and managing the impact of climate change and increase in CO₂ levels on yield.
- **Pests & diseases – protecting yield**

Pests and diseases have the potential to decrease yield and significantly compromise fruit quality. A recent review commissioned by GWRDC estimated that 76% of the economic cost of endemic pests and diseases to the Australian Grape & Wine Industry could be accounted for by three diseases – powdery mildew, downy mildew and botrytis. Whilst improvements in the application of fungicides have been made, there is probably limited scope for further gains in efficiency in the Australian industry through chemical control. There will also be increasing pressures on Australian growers to reduce fungicide applications as major wine export markets in Europe seek to ban the use of many of the chemicals currently used in our industry to control these diseases. A number of other grape-growing countries have recognised this and are actively pursuing breeding programs to develop new winegrape cultivars with genetic resistance to powdery mildew and downy mildew introduced from wild grape species in North America and Asia. CSIRO recognised the need for the development of new disease-resistance winegrape germplasm in the late 1990's and developed research collaborations with INRA in France and, more recently the USDA, which currently places us as global leaders in this area of research. Although it is a long-term project, the benefits of developing grapevines that can be cultivated with little or no application of fungicides are so great that it will provide a step change in grape production in the future.

Key areas for R&D include:

- Identifying and testing novel genes for resistance to mildews.
- Developing strategies to provide resistance to bunch rots.
- Developing grapevines with durable resistance to fungal pathogens.

- **Managing the vineyard – maintaining yield, managing quality, maximising efficiency**

Improved vineyard management will increasingly be required to minimise inputs and maximise production efficiency while producing fruit with a composition targeted to meet the requirements of the end product. This requires a whole of chain approach to manage inputs (water, nutrients, soil, pruning, canopy management, crop control, harvesting etc) and a multidisciplinary approach from R&D, using a diverse range of skills from molecular biology and micro-meteorology through to whole vine physiology and vineyard management.

New technologies such as high throughput measurement of gene expression, the use of molecular markers and advanced weather prediction will add significantly to our ability to monitor vine performance and predict response to abiotic stress. CSIRO has expertise across all of the required capabilities. Being able to predict irrigation water requirements in advance and understanding the interaction between vineyard irrigation systems and soils will be the basis for managing water and nutrients in the vineyard to maximise the efficient use of these resources and respond to abiotic stresses such as heat, frost, drought and salinity. It will be critical to tailoring management to specified grape end use, and also to the minimisation of water loss by soil evaporation and the maintenance of soil health. Pruning and canopy management are also critical factors and there is a strong interaction between vegetative production of the vine, grape yield and fruit composition. As these are the critical management tools for the vineyard, it will be important to understand the interactions between them and improved models of vine growth and fruit production would provide valuable information to optimise vineyard management. There is also a poor understanding of grapevine root biology, the temporal and spatial dynamics of root growth in vineyards and how this is influenced by soil type, structure and below ground environment. A better understanding of what happens below ground and its impact on canopy performance through root to shoot signalling will be critical to improving management of the vineyard floor and soil health. The impact of spatial variability in vineyards and climate change will also be important factors for vineyard management in the next decade.

Key areas for R&D include :

- Developing better water management strategies to minimise soil evaporation, maximise yield and reliably produce target fruit composition.
- Developing tools for prediction of vineyard irrigation requirements up to a week in advance.
- Improved ability to manage abiotic stress such as heat, frost, drought and salinity.
- Using a whole of system approach to manage vineyard production.
- Better understand the spatial and temporal dynamics of the grapevine root system and environmental influences upon them.
- Understanding rootstock responses under abiotic stress (water and salt).

- **Ripening & fruit composition – the basis of wine style**

Grape composition is a critical contributor to wine style. Unlike most other agricultural commodities, the value of grapes varies very widely (more than 50-fold) according to perceived quality and end use. To produce grapes 'fit for purpose' to achieve desired wine styles, we need objective measures of fruit composition, particularly flavour and tannin, and methods to manage fruit composition and hence wine style in the vineyard. There is great potential to control the composition of fruit based on management

practices and harvest timing. There is also a need to improve the streaming of fruit and the parcelling of grapes at the winery. CSIRO research underpinning these industry outcomes has already demonstrated that berry ripening can be manipulated with plant growth regulators, and that marker compounds linking fruit composition to certain wine sensory attributes can be identified. These tools will enable a better understanding of how the berry responds to management and the environment and how to control secondary metabolism in the berry. Identification and validation of the key compounds in grapes that contribute to wine flavour and aroma has the potential to provide an objective measure of 'fruit flavour potential'. Such a measure would lead to a step change in viticultural management by providing growers with measurable signals of grape composition that will predict wine sensory attributes. This will also provide the means to determine how environmental factors and vineyard management influence grape composition, leading to improved management of flavour potential and tannin profile in the vineyard and optimisation of vineyard harvesting strategies.

Secondary metabolism in grapes is complex and needs to be more fully understood to provide objective measures of fruit quality, links between fruit composition and wine style and the ability to manage wine flavour, aroma and taste in the vineyard. This will allow growers and winemakers to optimise harvest timing and better manage logistics of harvesting, transport and processing in the winery. There are clear indications that there is the potential to manipulate ripening to improve fruit composition and extend the window of harvest through the targeted use of plant growth substances. By better understanding the links between primary metabolism and secondary metabolism it may be possible to break the nexus between 'sugar ripeness' and 'flavour ripeness' to produce wines with good fruit flavour characteristics at lower alcohol levels while maintaining adequate levels of organic acids. There is also a need to better manage tannin in the vineyard and improve the tannin composition of grapes to deliver better mouthfeel in wine.

New extraction technologies can also contribute to improved wine style. For example, Pulsed electric field (PEF) processing is an emerging processing technique that can improve juice extraction efficiency. It causes rapid breakdown of microbial or plant cell membranes to release intracellular material. Proteins and small molecules are generally not affected so extraction of valuable metabolites such as polyphenols or pigments can be enhanced. CSIRO has demonstrated that PEF processing can enhance extractability of polyphenols and anthocyanins from grape pomace during vinification of red grapes.

Key areas for R&D include :

- Determining how to optimise harvest timing.
 - Developing improved objective measures of fruit composition.
 - Learning how to manage fruit composition in the vineyard.
 - Improved methods of streaming and batching parcels of fruit.
 - Understanding the nexus between sugar and flavour during ripening.
 - Methods to delay or advance ripening to manage fruit composition and harvesting and winery logistics.
 - Managing the tannin composition of grapes in the vineyard.
 - Developing improved methods of managing berry acid composition and pH.
- **Rootstocks & scions – germplasm for industry renewal**
Unlike many other crops, there has been limited improvement in grapevine germplasm and the majority of production is from a small number of classic cultivars that have been vegetatively propagated for hundreds of years. However, there is now a much

greater interest in alternative varieties and the influence of ‘terroir’ on varietal character. The next generation of wine consumers will be more open to changes in wine style and the introduction of novel products. The sequencing of the grapevine genome and development of molecular markers provides the opportunity for a revolution in breeding and evaluation of grapevine rootstocks and scions. Development of the ‘microvine’ by CSIRO has provided the basis for a rapid breeding system that could produce completely new grape varieties which combine novel wine styles with enhanced disease resistance. Rootstock breeding and evaluation will also be critical to addressing issues such as vine vigour, water and nutrient use efficiency, salinity, boron toxicity and resistance to soil pests such as phylloxera and nematodes. CSIRO has led rootstock breeding and evaluation in Australia and has strong links to breeding programs in the USA, Germany and France. In the longer term, these new genetic tools could be used to develop ‘direct producer grapevines’ – which have all the desired properties of both rootstock and scion in one plant.

Key areas for R&D include :

- An expanded Australian germplasm collection containing varieties and *Vitis* species with unique traits for research.
 - Improving the rigour and reliability of selection and evaluation procedures for specific scion and rootstock traits.
 - Molecular markers to more effectively screen scion and rootstock material for key traits.
 - Understanding rootstock-scion interactions and ensuring long term consistency of rootstock performance.
 - Understanding the impacts of rootstocks on fruit quality attributes.
 - Development of ‘novel and efficient’ superior grape varieties for emerging markets.
- **Vineyard sustainability, adaptation to climate change and a carbon constrained future**
 The areas of soil health, salinity and soil carbon will be particularly important for vineyards in the next decade. The management of soil health and soil salinity are crucial components in a sustainable production system and further work is required in these areas. Grape production and fruit composition are also highly dependent on soils and climate and this is the historical basis for many of the great wine regions of the world. Even relatively small increases in temperature will significantly impact on the timing of budburst, flowering, ripening and harvest and as well as grape composition and wine style. Frosts can also impact on vines, reducing yields and paradoxically, frost risk could increase with climate change in southern Australia requiring more effective tactical and strategic responses. Climate change has the potential to alter almost all aspects of grapegrowing and winemaking and the capital intensive nature of both vineyards and wineries will require greater adaptation than for many other agricultural enterprises. As vineyards take several years to come into full production and can be utilised for decades, forward planning will be required if the wine industry is to respond to these challenges. This will require climate modelling at the sub-regional scale and knowledge of the physiological responses of different varieties to a range of climates as a step towards developing effective management adaptations. A critical issue will be managing what are likely to be increasingly scarce and costly water resources requiring responses both on-farm and off-farm. Climate extremes can have above and below ground impacts, but much less is known about below ground impacts. For example, heat waves can significantly increase temperature in the top 30 cm of soil, which can have a range of impacts on plant performance. This has implications for vineyard design and cooling strategies.

Associated with climate change is a carbon constrained future. Understanding the cycling of carbon and especially greenhouse gas emission in vineyards is critical in understanding the potential cost impacts of a carbon constrained future. There are also opportunities for viticulturists in sequestering carbon or feeding bioenergy plants. The methods for sequestration such as turning crop residues into biochar and the impact of these and export of biomass off farm need to be understood. There is widespread industry concern that pH levels in must are increasing, leading to problems of wine stability and the increasing use of acid adjustment during winemaking processes to correct the problem. There is a research need to understand the underlying causes and develop solutions to the problem. This will involve a better understanding and management of mineral composition, particularly potassium uptake, organic composition of berries and cation balance within the berry.

Key areas for R&D include :

- Better measures of soil health and improved management of soils.
 - Development of an effective suite of climate adaptation options including to climate extremes, their effects above and below ground and implications for vine performance.
 - Temporal consequences of high temperature events on vines under mild water deficit.
 - Capacity of the perennial grapevine to re-distribute accumulated salts during the seasonal growth cycle and during recovery from salinity.
 - The impacts of a carbon constrained future on viticultural production and opportunities for crop residue use in carbon sequestration and bioenergy.
 - Managing potassium uptake to minimise the need for pH adjustment during winemaking.
 - Use of interactive models to enhance understanding of Genotype x Environment x Management interactions (G x E x M) and varietal differences in response.
- **Biosecurity – protecting the production base**
There are numerous pests and diseases that have the potential to seriously effect grapevine production in Australian vineyards which are currently not present in this country (eg. Pierce's disease, Fan leaf virus) or are restricted in their distribution (eg. Phylloxera). While maintaining their exclusion is the first line of defence, we also need the capability to monitor R&D in other countries and to deal with incursions should they occur. Skills in some of these areas (eg classical plant pathology, virology, entomology, nematology) are in decline and the ability to respond to future biosecurity risks may be limited. We need to maintain the ability to recognise and accurately identify the cause of disease outbreaks in order to establish the best means of control and eradication.

Key areas for R&D include:

- Maintaining capability in key areas of pest and disease pathology.
- Developing and maintaining collaborative links with international research institutes with skills and experience in dealing with these exotic pests and pathogens.
- An expanded Australian germplasm collection containing varieties with unique traits for research.

- **The wine value chain – enhancing returns**

CSIRO has a strong capability in viticulture R&D but can also contribute to broader aspects of the wine value chain. There is an opportunity to better integrate CSIRO sensory and consumer science capability to achieve an understanding of consumer appreciation of wine quality, determine consumers' perceptions of wine, and to understand dynamics of wine choice and acceptance. This research has examined leading Australian red wine brands, regional wines, and wines from different price points to determine optimal relationships / match between wine consumer, wine product, and wine sensory character to maximise perceived quality. The research has developed new approaches to understanding changes in wine liking over time, and how product experience informs consumer preferences. Further research will enable Australian wine to market position its products, and ensure maximal consumer acceptance, so that consumers will preferentially purchase higher value Australian wine domestically and/or in export markets, and Australian wine in preference to other wines as their wine drinking experience evolves.

The market share for foods with a health benefit are predicted to grow substantially in the coming years. The scientific evidence needed to justify that benefit is key to consumer credibility. Furthermore, any potential health claims regarding foods are subject to regulatory processes which although constrained in some countries including Australia at present, are likely to be legitimised in the future. The science to satisfactorily demonstrate a health benefit to one or more target functions in the body, beyond adequate nutritional effects is termed "substantiation". There is an opportunity to focus CSIRO's considerable expertise in this area to substantiate the potential health benefits of grape and wine products.

Key areas for R&D include:

- Wine and the consumer – better positioning of products in key markets
- Developing objective measures of the cross modal impacts of bouquet, fruit flavour and tannins on acceptance.
- Demonstration of the anti-oxidant effects of polyphenols extracted from wine and processing co-products
- Investigation of the potential benefits of incorporation of resveratrol in the diet
- Wine and grape components and heart health

3. CSIRO's Capability

CSIRO is one of the largest and most diverse scientific organisations in the world. It has over 6,600 staff located across 56 sites throughout Australia and overseas. CSIRO is a trusted source of creative ideas and practical technologies to deliver impact for the nation. By igniting the creative spirit of our people, we deliver great science and innovative solutions for industry, society and the environment. We seek to make a difference and generate impact by focusing on the nation's big challenges and opportunities.

CSIRO has broad capabilities across a wide range of research areas including plant science, soil science, entomology, water management, climate adaptation, consumer and sensory science, extraction technologies and information technologies. Our research delivers :

- integrated solutions to help address major national challenges
- technologies to transform or create new markets for Australian industry
- innovative technologies to improve the competitiveness of existing industries
- advice, information and research to meet specific community needs
- knowledge-based services to governments and businesses

CSIRO Plant Industry is one of the world's leading research centres for plant science, with an annual budget of \$104 million and around 570 staff at eight sites around Australia. CSIRO Plant Industry conducts basic and applied research to promote profitable and sustainable agrifood, fibre and horticultural industries, develop new plant products and improve natural resource management. One of CSIRO Plant Industry's primary aims is to translate research into practical applications for all Australians that can be extended internationally. CSIRO Plant Industry's research consists of 58 per cent long-term strategic research and 42 per cent short-term applied research. This balance delivers practical research outcomes underpinned by a platform of fundamental science that can produce technology driven solutions well into the future. Fitted with advanced and unique equipment, CSIRO Plant Industry's facilities support a broad range of plant science allowing it to deliver research results across the whole value chain of production.

- Laboratories – the most sophisticated for plant sciences in Australia for research from molecular biology and gene function through to yield, plant form and physiology.
- Glasshouses – the largest and most advanced range of glasshouses and controlled environment facilities in the Southern Hemisphere – suitable for tissue culture through to crops.
- Field sites – on dedicated research stations, in natural landscapes and on farm sites Australia-wide to take advantage of different environmental conditions and industry linkages.

CSIRO's National Research Flagships tackle Australia's major research challenges and opportunities through large-scale multidisciplinary partnerships. The CSIRO Climate Adaptation Flagship is a world-leader in developing with stakeholders, options for dealing with climate variability and change. The Flagship will equip Australia with practical and effective options to adapt more effectively to climate change and variability and draws on skills from across CSIRO to deliver its interdisciplinary science. The CSIRO Sustainable Agriculture Flagship aims to secure Australian agriculture and forest industries by increasing productivity and reducing carbon emissions. The Flagship brings together many different scientific disciplines to address the economic, environmental and social sustainability of agriculture and forestry. The CSIRO Food Futures Flagship aims to transform the international competitiveness of the Australian agrifood sector by applying frontier technologies to high potential industries.

The CSIRO Clinical Research Unit located in Adelaide undertakes clinical studies in many areas to establish the health potential of diets, food products, nutrients, supplements and food related pharmaceuticals. Staff are accredited in Good Clinical Practice procedures and the Clinic has established a broad portfolio of biomarkers of disease risk which can be used noninvasively in human clinical trials.

4. National and International Collaborations

CSIRO has a national capability with the majority of its viticulture R&D now located on the Waite Campus near Adelaide in collaboration with our partners in the Wine Innovation Cluster. The Cluster sees four leading grape and wine research agencies (AWRI, CSIRO, SARDI and the University of Adelaide) coming together with a single goal in mind : in collaboration, to achieve results that would not be possible working as standalone agencies. With new research facilities on the Waite Campus, world-leading personnel and networks right around the globe, the Wine Innovation Cluster will deliver results effectively and efficiently. Between them, the collaboration partners possess the major share of Australian research, development, extension and education capabilities over the whole of the grape and wine value chain.

Further details are available on the WIC website :

<http://www.wineinnovationcluster.com/>

An extensive collection of grapevine germplasm is maintained at our Koorlong Farm, near Mildura, and on the SARDI Research Station at Nuriootpa. Much of our field work is carried out in collaboration with industry partners, utilising vineyards in a wide range of grapegrowing areas including the Riverland, Sunraysia, the MIA, Adelaide Hills, Clare Valley, Barossa Valley, Langhorne Creek, McLaren Vale, Coonawarra and Padthaway.

We have international collaborations with key viticultural research groups in the USA, France, Germany, Italy, Spain, Chile, South Africa, the UK and Japan. This includes long standing collaborative arrangements with national agencies such as the USDA, New Zealand Plant & Food and INRA in France. CSIRO is a major participant in the International Grapevine Genome Program and our staff regularly attend international meetings relating to grapevine physiology, pathology, breeding, genetics, soils and vineyard management.

5. Pathway to Delivery

CSIRO conducts research across a broad range of capability areas to produce knowledge, tools and germplasm that can be delivered to industry to improve the management of vineyards, decrease production costs, improve efficiency and profitability and provide sustainable production systems. This is illustrated on the following diagram :

Pathway to Delivery

