Quinoa

Opportunities and challenges in Australia
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Investigation of quinoa production and marketing systems in Australia
to identify opportunities or barriers for greater industry organisation
RIRDC foreword

Quinoa provides great interest and opportunities for consumers. In salads, curries and baked products it has flavour, carries flavour and is a healthy food option. Nutritionally, it is the only seed or grain that contains all amino acids and it is gluten free.

Quinoa provides a new crop option for Australian farmers and potentially, it can be grown in subtropical and temperate cropping regions. However, farmers need information about production systems and prospects to manage risks and opportunities in forward plans. This report presents production and market information on this important and popular emerging crop.

New and emerging plant industries play an important part in the Australian agricultural landscape. In addition to contributing to the national economy, they provide alternative enterprises to rural and regional communities. The objectives of the New and Emerging Plant Industries Program is to conduct research, development and extension for new, emerging and other core funded plant industries that contribute to the profitability, sustainability and productivity of regional Australia.

The program’s objective directly aligns with Australian Government and RIRDC research priorities. ‘New’ refers to small plant industries that, thus far, have achieved limited growth. ‘Emerging’ plant industries have accelerating growth and can be small to medium in size. ‘Core funded’ refers to RIRDC’s investment in plant industries that do not have a levy mechanism in place to contribute matching funds for RD&E. Instead, our research funds for these industries rely, in the main, on budget allocated to RIRDC by the Australian Government. Funding constraints require a targeted approach to funding non-levied programs such as quinoa.

RIRDC investments aim to move quinoa from a novel crop to wider adoption across Australian broadacre farming. RIRDC looks forward to value chains establishing for quinoa, overcoming current bottlenecks of information about seed performance and general supply chain management. Through this investment in quinoa, Australian farmers will be able to make a contribution to growing this emerging food option for consumers.

This report is an addition to RIRDC’s diverse range of over 2000 research publications.

RIRDC’s publications are available for viewing, free downloading or purchasing online at www.rirdc.gov.au. Purchases can also be made by phoning 1300 634 313.

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Quinoa growing at Kununurra, WA. Photo: Mark Warmington
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Introduction

Australians consume more quinoa than is grown in Australia, with most domestic suppliers and retailers depending heavily on imported product for supply.

Many other countries around the world also depend on imported quinoa to meet domestic demand. The major growers and exporters of quinoa to the world are Peru and Bolivia.

The rising popularity of quinoa has attracted plenty of attention, raising the question: does quinoa present a new crop opportunity for Australian farmers? Quinoa production is barely established in Australia, so before embarking on a new enterprise, answers are needed for some critical questions.

Who are you going to sell your quinoa to?
Prospective quinoa growers should investigate the opportunities to replace imported product and increase local demand; and they will need to develop their own customer base and marketing system.

How are you going to process the seed that you produce?
Most quinoa varieties have a seed coat that contains bitter-tasting saponin. The seed must be processed to remove the saponin before consumption. Food manufacturers do not want unprocessed seed and most consumers prefer the convenience of a ready-to-cook product.

Where will you get the seed to sow a crop?
A successful quinoa enterprise needs to be based on seed that will produce a viable crop in Australian conditions that produces seed with marketable characteristics. Quinoa seed for sowing is not yet available commercially in Australia (as at March 2017).

Starting a quinoa enterprise presents the same challenges and risks associated with the production of any other new or novel crop. A few entrepreneurial Australian farmers have developed successful quinoa enterprises; and there are some farmers growing quinoa to supply the entrepreneurs.

As of March 2017, some major challenges exist for prospective growers of quinoa but some of these are being addressed by current research projects.

There are no publically-available varieties of quinoa that have been identified or selected for Australian farming environments; however RIRDC-funded evaluation trials are well underway.

There is no agronomy package for quinoa growers; although experience suggests that the crop is quite like canola to grow. The evaluation trials will also identify key agronomy practices. The most significant agronomy issue is a lack of pesticides registered for use on quinoa in Australia.

Quinoa has no industry organisation to support development, establish product specifications, provide guidance to new growers or generate consumer demand. Many impediments to the growth of emerging industries can be overcome through collaborative efforts of growers, handlers, marketers and end-users.

Challenges aside, quinoa has an amazing story spanning thousands of years and in the last decade or so the crop has taken a phenomenal journey from obscure grain to ‘super food’.
A short history of quinoa

Quinoa was believed to have been domesticated around Lake Titicaca in Peru, up to 10,000 years ago.

Quinoa seed has been found in ancient tombs and burial grounds in Chile; and historians report quinoa being widely cultivated in the valleys of Chile and Argentina, and in the highlands of Bolivia and southern Columbia.

Quinoa is just one of a wide range of food crops that was cultivated in the Andes Mountains for thousands of years. Potato is also thought to have been domesticated in the Lake Titicaca basin around the same time as quinoa. Archaeological evidence indicates that maize has been produced in the region for about 4000 years, and several types of tubers, amaranth, beans and lupins also were important.

Explorers and colonialists of South America noted many varieties of quinoa growing, with the seed ranging in colour from yellow to red to purple and black.

Along with quinoa, the leaves and seeds of other Chenopodium species have been consumed for millennia in other parts of the world. Chenopodium album was cultivated in the Himalayas at altitudes of 1500–3000 metres above sea level, C. nuttalliae, known as huautzontle, was cultivated in the highlands of Mexico and is very similar to quinoa. Another close relative, Chenopodium berlandieri spp. jonesianum, was cultivated by ancient North Americans.

Quinoa was a staple food of the Andean people, along with maize, potatoes and other tubers, throughout the many civilisations that rose and fell in the region. Quinoa remained an important food source during the Incan empire however with increased organisation of agriculture and transport of food throughout the largest of the South American civilisations, maize became the most significant food.

The arrival of Spanish explorers and colonists changed the status of quinoa for centuries to come. Quinoa was considered “food for Indians” and its cultivation was forbidden due to the seed being used to produce an alcoholic drink consumed in indigenous religious ceremonies. Subsequently, the Spanish forced the Incas and other Andean people to grow wheat instead.

In the 1990s, government programs implemented in several South American countries encouraged the resurgence of cultural traditions, which included the cultivation and consumption of quinoa. Further, quinoa was increasingly recognised for its high nutritional value and potential to provide essential nutrition in developing countries. After several decades, the seed is once again a staple food in its traditional environment.

In the 21st century quinoa has become a popular food in developed countries, due to its nutritional qualities, unique eating characteristics and the fact that it is gluten free. The upward-spiralling demand for quinoa has seen a massive expansion of production in its traditional growing regions, as well as the development of new growing regions throughout the world.
Modern popularity

After thousands of years in the fields and on the plates of the Andean people, quinoa has experienced a worldwide surge in its popularity.

Commencing in the 1990s, the FAO promoted the importance of quinoa and other Andean grains as a food source to the South American population. Increased awareness and pride in indigenous Andean culture and South American heritage led to a significant increase in nationally-consumed quinoa, following centuries of wheat being the main food source.

The year 2013 was declared the International Year of Quinoa by the Food and Agriculture Organization of the United Nations (FAO). At that time, FAO Director-General José Graziano da Silva described quinoa as an exceptional crop, which due to its nutritional qualities, diversity and resistance to drought and cold, has been identified as an important alternative to contribute to global food security, especially in areas where the population has no access to adequate sources of protein, or where there are environmental constraints to food crop production.

Super food
During the two decades of reinstating quinoa as a key crop and food source in South America, quinoa became a very popular ingredient for many foods in western diets and there is a large range of unprocessed and processed quinoa products available from health food shops and major supermarkets.

Quinoa is a tasty and easy-to-use base for many dishes, but much of its popularity is driven by the perception that quinoa is a ‘super food’. The marketability of the product is also enhanced by its ‘fair trade’ credentials and South America’s traditional organic production system.

The unprecedented demand for quinoa saw global annual production rise from about 30,000 tonnes in the 1980s to 193,000 tonnes in 2014. Almost all of the world’s quinoa is grown in Peru and Bolivia.

Next new crop
Apart from phenomenal consumer demand, the versatility and genetic diversity of quinoa as a crop has attracted the attention of farmers and scientists over past decades. The attractiveness of quinoa is primarily its notable tolerance of adverse environmental conditions, including salinity, frost and drought.

From a plant scientist’s point of view, its tolerance to adverse conditions makes it a model species to understand the cellular, physiological, biomolecular and morphological basis of stress tolerance in plants generally.

Its adaptability (and underlying genetic diversity) also attracts policy makers and scientists around the world, as quinoa has potential to be a crop well adapted to a world where scarcity of water resources and increasing salinisation of soil and water are primary causes of crop loss, and climate predictions suggest that both conditions will be greater in the future.

For the farmer and agronomist, quinoa offers immediate benefits to crop rotations, by providing a break crop for intensive crop rotations that are often dominated by cereals. Quinoa also offers the potential to be a cash crop with its short growing season that fits easily into cropping rotations. However future growers of quinoa in Australia have a number of challenges to address before benefits are realised.
**Quinoa – the food**

Although quinoa is a seed, it is commonly referred to as a grain, and is cooked and eaten like a grain.

The seeds can be cooked like rice and used in salads, soups and curries. Quinoa may also be used as an alternative to pasta. When cooked, the seed has a fluffy consistency but it is slightly crunchy to bite. The seed has a mild delicate nutty flavour. Other products made from the seed include breakfast cereal and flour. Quinoa leaves are also palatable but they are not commonly consumed.

Quinoa is the edible seed produced by the annual plant, Chenopodium quinoa Willd. Quinoa seeds are disc-shaped and the diameter of the seed ranges from 1.3 to 2.7 millimetres in diameter. The seed is coated in outer layers (pericarp) that contain bitter-tasting saponin. The saponin must be removed before eating, and is generally done so by abrasion or washing, or both, prior to marketing.

Compared with many grains, and cereals in particular, quinoa contains high levels of protein, calcium, phosphorus, magnesium, iron, zinc, potassium and copper. It has relatively good levels of vitamin E and several of the B vitamins. Quinoa is lower in carbohydrate than cereal grains, with starch and dietary fibre content approximately 60% and 13%, respectively; and it has a low glycaemic index of 53. It has an oil content of 4.5–8.7%, which is predominantly made up of linoleic acid, oleic acid and a-linoleic acid.

The seed and leaves of the quinoa plant contain many bioactive compounds that have antioxidant, anti-allergic, anti-inflammatory, antiviral and anticarcinogenic properties.

The nutritional significance of quinoa is that it is the only plant food that contains all essential amino acids — the building blocks of protein. Quinoa contains its amino acids within the seed (in the embryo), which is the consumed portion of the seed. This is unlike other staple grains such as rice and wheat that contain amino acids in the hull of the grain and therefore, they are lost during de-hulling or de-husking.

Quinoa does not contain gluten, which is another feature that has attracted much interest in recent years.

Table 1 shows key nutritional qualities of quinoa and other major grains. A detailed nutritional analysis of quinoa and other grains has also been prepared by the Grains & Legumes Nutrition Council.

Quinoa also has a variety of uses beyond food — it can be used in cosmetic products, as green feed for livestock or in industrial products such as plastics.

**Table 1. Nutritional qualities of quinoa and other grains**

<table>
<thead>
<tr>
<th>Type of grain</th>
<th>Protein (g/100 g)</th>
<th>Vitamin B1 (mg/100 g)</th>
<th>Iron (ppm)</th>
<th>Calcium (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quinoa</td>
<td>13.9</td>
<td>0.39</td>
<td>133.0</td>
<td>1200</td>
</tr>
<tr>
<td>White rice</td>
<td>6.7</td>
<td>0.08</td>
<td>4.6</td>
<td>40</td>
</tr>
<tr>
<td>Maize</td>
<td>9.4</td>
<td>0.30</td>
<td>25.0</td>
<td>100</td>
</tr>
<tr>
<td>Wheat</td>
<td>12.6</td>
<td>0.30</td>
<td>40.0</td>
<td>360</td>
</tr>
<tr>
<td>Millet</td>
<td>11.0</td>
<td>0.30</td>
<td>30.0</td>
<td>201</td>
</tr>
<tr>
<td>Sorghum</td>
<td>11.3</td>
<td>0.34</td>
<td>45.0</td>
<td>260</td>
</tr>
<tr>
<td>Sunflower</td>
<td>22.8</td>
<td>1.90</td>
<td>6.3</td>
<td>38</td>
</tr>
<tr>
<td>Soybean</td>
<td>36.5</td>
<td>0.90</td>
<td>157.0</td>
<td>2770</td>
</tr>
</tbody>
</table>

Quinoa – the plant

The physical appearance of the quinoa plant and its seed is highly variable and is influenced by genetics and growing environment.

Quinoa is an annual plant, generally growing 1–2 metres tall. The plant has a woody central stem, which may be single or branching, and green, red or purple in colour.

The leaves of the plant are broad and lobed, and may be powdery in appearance. An elongated flower head with large clusters of seeds develops at the end of each stem.

Plant structure

The growth habit of quinoa falls into one of four main categories based on branching characteristics, which range from a single-stemmed plant, to a main panicle with branching on the lower parts of the plant, to a completely branched plant with no defined main panicle.

The degree of branching of the quinoa plant affects its suitability for mechanised agriculture, but branching may be managed by sowing density.

Panicle shape and colour

The panicle (seed head) of a quinoa plant has three main forms. The developing seed forms in clusters along the stem of the panicle. The clusters may be globular (rounded) in shape, elongated or somewhere in between. The panicle may also be loose or compact in form.

Prior to flowering, the panicle may be green, purple, mixed or red in colour. As the grain forms and matures, the panicle will change in colour. Colour at maturity varies between and sometimes within lines, with possible seed colours of white, cream, yellow, orange, pink, red, purple, coffee, green, grey, black and mixtures.

Seed colour

Although there is a wide variety of colours of the raw seed, after the seed is processed to remove the outer layers, three main seed colours prevail: white, red (coffee) and black. Quinoa produced in Australia is generally white.

Food manufacturers who use quinoa as an ingredient have specific colour requirements for the seed they purchase.

Seed shape and size

There are four main seed shapes, which can be indicative of chemical make-up and cooking characteristics of the seed. Seeds may be lenticular, cylindrical, ellipsoid and conical in shape. The first two shapes, due to the amylose and amylopectin levels of the endosperm, are well suited for producing custards, puddings and instant sauces.

Generally, the diameter of quinoa seed ranges from 1.3 to 2.7 mm in diameter. Internationally, quinoa seed has been classified into four categories based on seed size: extra large (> 2.20 mm), large (1.75–2.20 mm), medium (1.35–1.75 mm) and small (< 1.35 mm).

Individual buyers of quinoa have specific requirements for seed size, depending on the end use of the seed.
Many types for many places

Due to its high genetic diversity and its adaptability to a wide range of environments, quinoa has potential to be grown in many parts of the world.

There have been wonderful successes and complete failures of quinoa plots and crops in Australia. At the farm level, it has been very difficult to determine if failures are due to a poor season, extreme weather events, or mismatched genetics and environment.

The environmental factors influencing the growth and development of a quinoa crop are:
- temperature
- photoperiod
- water availability (water deficit)
- light (radiation).

International research shows that temperature has the most influence of all environmental factors on the length of different growth stages of the quinoa plant. Trials in Australia have experienced crop failures in seasons that have been extremely hot in northern Australia, as well as seasons that were extremely cold in southern Australia.

Quinoa is essentially a short-day plant, which means key growth stages are triggered by a certain number of minimum daylight hours per day. Short-day plants tend to flower in spring after short winter days, and this is true of quinoa plants that originated in cold dry regions of South America, such as between Argentina and Colombia. However many lines or accessions of quinoa from warmer or humid areas show little or no response to day length, which is typical of plants from north-west Argentina and coastal regions of Chile.

The days to maturity for quinoa varieties held in plant collections in South America ranges from 115 to 220 days. In Australia, days to maturity appears to be around 100–110 days in northern Australia and 130–160 days in southern Australia.

In order to develop publically-available quinoa lines for Australian farmers, a partnership between RIRDC and the Department of Food and Agriculture, Western Australia (see page 16) is coordinating evaluation trials of selected lines of quinoa across the length and breadth of the continent to gain a preliminary understanding of the impact of environmental factors on quinoa in Australia.

There are five main types of quinoa, described primarily on the basis of adaptation to different agro-ecological conditions in the Andes region of South America (Table 2).

As a result of centuries of cultivation and selection, there are varieties of quinoa that are adapted to both local environments, as well as to particular end uses. For example, scientists have described six types of a native quinoa growing on the highlands of Puno on the shore of Lake Titicaca in Peru (Table 3).

Early attempts to grow quinoa in Europe and North America throughout the 1980s failed because seeds were obtained from varieties grown in Peru and Bolivia. These varieties did not reach maturity during the summer when grown at high latitudes. Later attempts showed that varieties of the sea level (or coastal) quinoas from southern and central Chile were better suited to temperate agriculture.

A challenge for Australian quinoa growers is access to varieties suited to their environment and varieties that produce seed suited to the targeted end use.
Table 2. Varieties and types of quinoas adapted to different agro-ecological zones

<table>
<thead>
<tr>
<th>Agro-ecological group</th>
<th>Rainfall (mm)</th>
<th>Min. temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valley quinoas</td>
<td>700–1500</td>
<td>3 °C</td>
</tr>
</tbody>
</table>
| Valleys grown in the inter-Andean valleys with irrigation (Peru and Bolivia) or rainfall (Colombia, Ecuador and Peru).
| Altiplano quinoas     | 400–800      | 0 °C            |
| Altiplano quinoas grown in the highlands north of Lake Titicaca between Peru and Bolivia with a short growing season, over a range of altitudes, with some varieties growing up to 3900 metres above sea level.
| Salt flat quinoas     | 250–400      | -1 °C           |
| Salt flat quinoas grown in the southern highlands of Bolivia, as well as Chile and Argentina, are adapted to saline soils and produce a large seed.
| Sea level quinoas     | 800–1500     | 5 °C            |
| Sea level quinoas grown in the centre and south of Chile, at latitudes south of 30°S, and produce small coloured seed.
| Yunga quinoas         | up to 2000   | 11 °C           |
| Yunga quinoas grown in the subtropical zone on the eastern slopes of the Andes in Bolivia at altitudes of 1500–2000 metres above sea level.


Table 3. Native varieties of quinoa grown on the Puno highlands of Peru

<table>
<thead>
<tr>
<th>Quinoa cultivar</th>
<th>Plant colour/grain</th>
<th>Cold resistance</th>
<th>Main use</th>
<th>Secondary use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. White, janka or yurac</td>
<td>White/white</td>
<td>Average</td>
<td>Broth or soup</td>
<td>Puree or pesque</td>
</tr>
<tr>
<td>2. Chulpi or hialinas</td>
<td>White/transparent</td>
<td>Fair</td>
<td>Broth</td>
<td>Puree</td>
</tr>
<tr>
<td>3. Witullas, coloreadas, Wariponcho</td>
<td>Red/red, purple</td>
<td>High</td>
<td>Kispiño</td>
<td>Meals, torrejas</td>
</tr>
<tr>
<td>4. Q’oitu</td>
<td>White or lead/lead or brown</td>
<td>Fair</td>
<td>Torrejas</td>
<td>Meals</td>
</tr>
<tr>
<td>5. Pasancallas</td>
<td>Bursts easily</td>
<td>High</td>
<td>Mana</td>
<td>Meals</td>
</tr>
<tr>
<td>6. Cuchi willa</td>
<td>Red/black</td>
<td>High</td>
<td>Chicha</td>
<td>Quispiño</td>
</tr>
</tbody>
</table>


Seed or grain?
Quinoa is often referred to as a grain but technically it is a seed. Grain is generally the term that refers to fruit (seed) of plants belonging to the grass family, which includes the commonly cultivated crops such as wheat, rice and maize.

Quinoa is consumed with the whole seed largely intact, i.e. after ‘processing’ it may still be capable of germinating and growing. Traditionally, the processing of cereals removes the germ from the grain rendering it incapable of germination.

Because quinoa is used in the same manner as many cereals or as a cereal replacement, quinoa is often referred to as a pseudo-cereal. In fact, quinoa is more closely related to spinach and beets than it is to cereals.

Due to the level of processing required to remove saponin and make quinoa edible, it is not considered a paleo food (under the strictest requirements to qualify as paleo).

The term ‘ancient grain’ holds true for quinoa (ignoring the seed versus grain issue).

And … is quinoa a super food?
There is no technical or legal definition of the term ‘super food’; it is a term popularised by marketers and media. However, quinoa does have notable nutritional values and health attributes.
The quinoa family tree

By virtue of its family tree, quinoa is related to many plants throughout the world and quite a few that are native to Australia.

The botanical name of quinoa is Chenopodium quinoa Willd and it belongs to the plant family Amaranthaceae, which is a different plant family to most cultivated grains. Wheat, rye, barley, rice, maize, millet and sorghum, for example, all belong to the Gramineae family.

Within the family Amaranthaceae is the subfamily Chenopodioideae and the genus Chenopodium. Plants of the subfamily are collectively referred to as goosefoots.

Quinoa has many relatives throughout the world. There are about 150 species within the genus Chenopodium, mostly found in large areas of America, Asia and Europe as herbaceous annual plants. However, some members of the genus are perennial and tree-like. Many species of Chenopodium have edible seeds and leaves.

Species of the genus Chenopodium are very versatile and adaptable, and concentrated in temperate and subtropical environments. Over time, the genus has adapted and diversified to give rise to a large number of species in order to survive in a wide range of environments, from high altitude to sea level, from arid and saline to high rainfall. Many species originate from hybrids of species within the genus.

There are several Chenopodium species native to Australia, and several closely-related plants such as Rhagodia and Einadia — the climbing and nodding saltbushes, respectively. More distant relatives of quinoa include many other saltbushes and bluebushes native to Australia, including old man saltbush (Atriplex nummularia), which belong to the plant family Amaranthaceae.

A number of Chenopodium species were introduced to Australia, deliberately or accidentally, and now present as a serious problem in agricultural systems. In particular, C. album L., which is known by many different common names throughout Australia, including fat hen, goosefoot, lambsquarters, pigweed and wild spinach. It is a weed of agricultural areas as well as natural environments. In fact, the plant is one of the most widely-distributed weed species in the world and a very successful coloniser of recently-disturbed sites.

Quinoa and other Chenopodium are related to the genus Amaranthus. Like quinoa, some Amaranthus species are historically an important food source for the people of the Andean regions and the highlands of Mexico. Amaranth is another ‘ancient seed’ gaining popularity in modern diets. Several species are cultivated for their seed however, despite having edible grain, some species are considered noxious and invasive weeds of agriculture, for example in North America, Palmer or Palmer’s amaranth (A. palmeri) is a serious weed of annual cropping systems and has developed resistance to glyphosate.
Sourcing seed

Worldwide, there is seed for over 16,000 lines of quinoa and its wild relatives stored in 59 gene banks in 30 countries, including Australia.

Gene banks in the Andean region conserve more than 88% of quinoa lines. According to the 2013 State of the Art Report on Quinoa by the FAO there is little coordination of the management of this genetic resource within countries and between countries. The quinoa seed and quinoa product available in markets around the world are derived from a small set of quinoa types, which means that the genetic potential of the plant is underutilised.

Quinoa growers in Australia have been enterprising. Some growers have simply grown seed purchased from retail stores — and generally with little success. Established growers have invested significant time and resources in seeking and selecting the best lines of quinoa for their location, their production system and their markets.

At the time of publication, sourcing seed was one of the greatest challenges to starting a quinoa enterprise.

Food store seed

It is possible to grow plants from quinoa seed purchased at retail food stores. However, the risk of this approach is that there is no information about the purity or integrity of the seed, and therefore it is not possible to know what sort of crop may result or whether or not it is suited to a particular growing environment.

Variable height, maturity and seed colour, to name a few characteristics, are likely from food store seed. Most of the imported seed available on retail shelves in Australia is from South America, which is sourced from hand-harvested crops and production systems where plant variability is less important than it is in mechanised systems.

Under the correct conditions, quinoa seed can be stored for years and maintain good viability, however in conditions of high temperature and humidity it quickly loses viability. The risk with seed purchased from food stores is that there is no way of knowing storage conditions and expected germination rate of the seed.

Imported agricultural seed

It is possible to purchase quinoa seed from overseas seed suppliers. The seed must be imported according to Australian Government requirements to prevent the introduction of weeds, pests and diseases that could threaten Australia’s natural environment, food security and economy. The Biosecurity Import Conditions System (BICON) provides information about bringing agricultural goods into Australia. International seed suppliers may have licensing requirements for the seed produced.

Quinoa is produced under mechanised systems in a number of countries in the northern hemisphere, and as such, these lines may be better suited to Australian agriculture. However environmental conditions, particularly day length and temperatures at maturity, may not be suited to accessible seed sources.

Benefit of industry organisation

The capacity to support a continued coordinated approach to identifying suitable varieties for Australia and producing seed stock.
Quinoa is grown in more than 70 countries around the world. Over 90% of the world’s quinoa is produced in Peru, Bolivia and Ecuador.

The main quinoa-producing countries outside South America are Canada, United States of America, United Kingdom, the Netherlands, France, Belgium, Germany and Spain. In these countries, many farmers grow quinoa as a cash crop, encouraged by the popularity of quinoa and high prices at retail outlets in the past decade.

Quinoa plantings are proving successful in emerging Asian economies, particularly India; and Kenya in Africa is producing competitive yields as well.

Quinoa production is also being investigated in arid regions of the world, according to the FAO, and studies indicate that quinoa could also be produced in the Himalayas, the plains of northern India, the Sahel Belt in northern Africa, and Yemen.

Total annual production globally throughout the 1990s and until 2007 was around 50,000 tonnes. From 2007 there was a steady doubling of production to 114,000 tonnes in 2013 and then a very sharp increase in production of 193,000 tonnes in 2014.

At the time of publication, further FAO data on production was not available however industry observers and media reports indicated that production in Peru and Bolivia has plateaued (if not dropped off a little) and supply exceeds demand, on a global basis.

Figure 1. Quinoa producing countries across the world.
Global trade
Annual world trade of quinoa grew from less than 5000 tonnes in 2005 to over 30,000 tonnes in 2012. Trade accounts for about 30% of quinoa produced globally.

In 2012, 84% of quinoa exported globally originated from South America, mainly from Bolivia, Peru and Ecuador, with small contributions to trade by Chile and Colombia. About 10% of global export was from the United States of America and 6% from the European Union.

For the same period, the United States of America imported 53% of quinoa traded, followed by Canada with 15%. The other significant although relatively small importers of quinoa were France (8%), the Netherlands (4%), Germany (4%), Australia (3%) and member countries of the Latin American Integration Association (LAIA) (3%).

Up until 2012, world quinoa prices increased sharply due to strong demand, despite increasing production and exports. However, since 2014 there has been a fall of around 40% in quinoa prices at the farm gate and further falls are expected as the massive 2014 South American harvest stays on the market. Market reports suggest that as production settles to meet demand, prices will return to about 2011 levels, however the influence of increasing production in countries other than South America will also affect the supply and demand relationship.

Quinoa is able to be traded relatively freely as tariff protection around the world is low and there are few phytosanitary barriers applying to quinoa seed. In response to phenomenal growth in the trade of quinoa, the World Customs Organization has introduced a tariff opening for quinoa, subheading 10.08.50.

Australian trade
The Australian Bureau of Statistics reported that in 2012, Australia imported 934 tonnes of quinoa at an average price of $3319 per tonne. In the same year, two tonnes of quinoa was exported from Australia for a total value of $18,840.1

Since 2012, imports of quinoa into Australia have been predominantly from Bolivia and Peru, with smaller amounts from Chile and the US. The increasing consumer demand for quinoa is reflected in import figures, with approximately 2000 tonnes imported in 2013 and 2015; and 3000 tonnes in 2014.2

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1 Emerging animal and plant industries—their value to Australia 2014 (RIRDC)
2 pers comm. ABS via J. Semmler
Markets for quinoa

Quinoa is a new crop for Australian farmers and there is not an established supply chain for taking the product from paddock to plate.

In Australia, the pioneering growers of quinoa are fully vertically integrated, i.e. growing, processing and marketing their own product, and a handful of growers grow and supply these vertically-integrated producers, under agreed arrangements and specifications.

Quinoa is sought by consumers who purchase raw seed for use in their own cooking and manufacturers who produce a wide range of baked goods and breakfast, health and snack foods containing quinoa. Consumer demand for quinoa exceeds domestic production, and between 2000 and 3000 tonnes of quinoa are imported into Australia annually.

Retail demand

Australian-grown quinoa is available from delicatessens, health food shops and direct from the grower, either online or at farmers’ markets. As quinoa becomes more ‘main stream’ and production increases, major supermarkets have begun to stock Australian-grown quinoa.

However, to meet demand, quinoa must also be imported into Australia. In part, importation is also driven by consumer preference for the highly-regarded Royal quinoa. Akin to Puy lentils or French champagne, quinoa grown around the high altitude (3700 metres above sea level), dry salt flats (especially Salar de Uyuni and Salar de Coipasa) of Bolivia is considered the highest quality quinoa in the world. Referred to as Royal quinoa, this source is produced organically and has a large, white and round seed; and it is reputed to have superior taste and cooking qualities compared with other types of quinoa. The Bolivian National Association of Quinoa Producers has had a vital role in developing and promoting the quinoa industry, resulting in the processing of large volumes of quinoa for world markets, while ensuring benefits gained from sales of Royal quinoa are invested for the benefit Bolivian farmers and their communities.

Australian quinoa producers are/will be competing predominantly with South American product at two levels. First, Australian quinoa is produced in a high-cost agricultural system (due to high capital investment and high labour costs) whereas most South American quinoa is produced in fairly traditional farming systems. Second, Australian-produced quinoa has to define itself and find a place in a market where there is already a ‘brand’ considered the pinnacle of quinos, i.e. Royal quinoa.

While there is growing consumer demand for quinoa, market research suggests that 80% of Australian consumers have not used quinoa. Therefore consumer education about the product and how to use it is an essential step in the development of a sustainable domestic quinoa industry.

Benefit of industry organisation

A capacity to educate consumers about quinoa to increase ongoing demand is an essential step in the development of a sustainable domestic quinoa industry.

3 pers comm. ABS via J. Semmler
Manufacturer demand

Australian manufacturers of food products containing quinoa almost exclusively import quinoa from South America, as at 2017. While food manufacturers would consider sourcing Australian product, they require product in greater quantity and on a regular basis, as well as having varied and particular product specifications.

While specifications vary between manufacturers, one requirement is consistent — saponin must be removed from the seed.

There are no formal seed standards or specifications for quinoa in Australia. Current Australian producers are vertically integrated and therefore have control and vested interest in ensuring that the seed they produce and sell meets the standards required by their customers.

In a growing industry, the need for seed standards would be important to ensure that Australian-grown quinoa can be sold on its merits, growers are fairly recognised for quality and consumers have product confidence with their purchase.

Table 4. Seed characteristics required by manufacturers and retailers

<table>
<thead>
<tr>
<th>Seed characteristic</th>
<th>Manufacturer/retailer preferences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>Important for shelf and plate appeal. Important for contrast and aesthetics in products where the quinoa seed is mixed or presented with other grains</td>
</tr>
<tr>
<td>Size</td>
<td>For handling and presentation, there is a general preference for larger seed size. Important when seed is blended with other grains to ensure ingredients do not separate when packaged. Less important where the seed is milled to make flour, flakes and other ingredient products.</td>
</tr>
<tr>
<td>Microbial analysis</td>
<td>Essential to ensure food safety and quality</td>
</tr>
<tr>
<td>Insect free</td>
<td>Essential to ensure food safety and quality</td>
</tr>
<tr>
<td>Organic</td>
<td>Requirement for organically-produced seed varies between manufacturers, depending on the style of food product. Most seed imported from South America is organic, which is a reflection of traditional production systems, especially for Royal quinoa, rather than a response to consumer demand</td>
</tr>
<tr>
<td>Processed</td>
<td>For manufacturers and most retailers, saponin removal is a requirement for purchase — manufacturers do not have the facilities to process seed and retailers wish to supply consumers with a ready-to-cook product</td>
</tr>
</tbody>
</table>

Benefit of industry organisation

The ability to develop seed certification and standards for Australian-grown quinoa to recognise quality and give confidence to manufacturers, retailers and consumers.
Saponin

Saponin is the bitter-tasting substance that is found in the outer layers (called the pericarp) of the quinoa seed.

Saponin content varies between varieties and ecotypes of quinoa, and within varieties depending on growing environments and conditions. Saponin content generally varies between 0 and 3% in dry grain, and accordingly, varieties and ecotypes may be classified as bitter, semi-sweet and sweet.

Saponin is not unique to quinoa — many plants (and some marine organisms) contain saponin. The name is derived from the Latin word for soap (sapo) because of the foam that forms when certain parts of the plant are washed or agitated in water, which is observed when quinoa seed is washed.

The saponin-containing layer must be removed from the quinoa seed before consumption. Some quinoa breeding programs in Europe have developed ‘sweet’ varieties, the benefit not only being reduced saponin content but also reduced processing and water usage to remove the saponin. Appropriate crop management over time is required to prevent cross-breeding between sweet varieties and bitter varieties, which would result in higher saponin contents of resulting plants.

The mapping of the quinoa genome, completed in 2016, will make the development of low-saponin quinoa varieties more expedient.

Effects of saponin

While the role of saponin in quinoa is not completely understood, it is believed to be part of a plant’s defence system against pathogens and herbivores. Saponin levels have also been observed to increase when the plant is grown under stressful situations, such as drought or salinity.

Many saponins are bitter and reduce the palatability of vegetation to livestock, while others may impart a licorice taste. Saponins can range from being harmful to not harmful, depending on quantities consumed and the species consuming. Some pasture plants and weeds contain substantial quantities of dangerous saponins and can cause life threatening toxicities for certain animal species. For example saponins in some lucerne varieties are harmful to pigs and poultry; however saponins in oats and spinach increase and accelerate the body’s ability to absorb calcium and silicon, thus aiding digestion. At least 20 different types of saponin have been identified in quinoa.

Traditionally, saponins were considered antinutritional or even dangerous to humans and livestock because of their haemolytic activity — where the saponin reacts with the membranes of red blood cells causing a loss of haemoglobin; however these effects are observed in people with certain blood types. More recently, several health benefits have been identified, with saponins potentially having anti-inflammatory, anticarcinogenic, antibacterial, antifungal and antiviral properties. Based on these properties, saponins have been used in commercial food, cosmetics, and agricultural and pharmaceutical applications. Saponins have industrial applications as detergents and surfactants. Saponin-based vaccines have been introduced commercially.

Saponin removal

The reduction or removal of saponin is important to consumers and manufacturers as both groups generally desire a ready-to-use product.

Much of the quinoa in South America is processed by traditional methods, with abrasion being used to remove the saponin-containing layers. Alternatively, the saponin may be removed by washing the seed with water; or a combination of abrasion and washing may be employed. Removal methods are relatively manual and time consuming, with small quantities (several kilograms) of seed processed at a time to meet family requirements.

As global demand and the commercial value of the crop have exploded, the incentive has risen for growers and millers to develop mechanised and more efficient processing methods. Initially, milling equipment for other grains (rice, wheat, soybean and sorghum) was adapted to mill larger quantities of quinoa destined for consumer and export markets. From the 1980s onwards, the processing of quinoa at a commercial scale became a focus of research and development, particularly in South America.

Sorting out the processing of quinoa is an essential step for new growers, as most customers require processed seed. There is no ‘off-the-shelf’ processing equipment available and access to contract processing will be determined by investigation and availability.
Modern and industrial-scale processing of quinoa is generally based on a combined method of hulling, washing and drying. The hulling or abrasion part of the process must balance the removal of the saponin-containing layers without affecting the seed’s nutritional profile. Physical removal of the outer layers is attractive as it requires less water, and reduces drying requirements for the seed and disposal requirements of effluent (i.e. the saponin dissolved in the waste water).

The combined method also helps maintain the nutritional profile of the seed. Minimising the physical removal of outer layers helps maintain some of the nutrients contained in the inner layers of the seed coating; and less washing helps minimise leaching of nutrients.

New processing techniques have shown that saponin removal improves considerably when warm water or alkaline or acid solutions are used. New techniques that are water dependent may also include steps to recover discarded saponin for use in soaps or detergents.

There is potential economic value in the saponin-rich outer layers of the quinoa seed that could be investigated, and so end-uses for saponin also present an added market opportunity.

The modern combined processing techniques help achieve international requirements for saponin removal and grain quality, particularly for organic Royal quinoa. The 2013 State of the Art Report on Quinoa by the FAO reported that current combined processes enable saponin levels to be reduced to 0.01–0.06%, which is required by the international market and is far below the values detected by the palate. The most effective processing systems remove up to 95% of saponins by abrasion in the huller, with a grain mass loss of approximately 5–7%. The remaining saponin is further reduced by washing, where the grain is in contact with water for less than two minutes or sometimes just seconds.

According to the State of the Art report, current equipment and technology cannot process large volumes of quinoa using the dry method alone, without compromising the nutritional quality and changing the grain shape. However, there are artisanal dry-method prototypes achieving good grain quality. Recent developments in processing technology recognise the value of the saponin-rich outer layers.
Quinoa in a crop rotation

Quinoa has many agronomic characteristics that make it an attractive option for cropping rotations in Australia.

With a relatively short growing season compared with many other crops grown in Australia, quinoa makes it possible to grow two crops in an annual cropping program.

Because it is a broadleaf plant and a different species to pulses and oilseeds, quinoa potentially offers a good disease break in rotations of cereals, canola and pulses.

A crop of quinoa through late spring and early summer in southern Australia offers the opportunity to provide active competition to weed species that may otherwise form the ‘green bridge’ for crop disease from one winter crop growing season to the next.

The quinoa plant has a hollow stem, which breaks down quickly after harvest. Standing stubble provides good soil cover until the next crop is sown but there is not sufficient material to impede direct sowing of a crop immediately after the quinoa is harvested.

Several years ago, quinoa was looking like an excellent cash crop as well. However, as discussed throughout this publication, good returns depend on the stabilisation of the global market, and the development of customer demand and a customer base for Australian-grown quinoa.

Quinoa as a new crop in Australia

Growing interest in quinoa and its apparent suitability to Australian cropping rotations and growing conditions has led to the establishment of stage 2 of the RIRDC-funded project, Quinoa as a new crop in Australia (PRJ-010057). The project will evaluate germplasm and multiply seed from selected lines for use by future Australian growers.

Led by the Department of Agriculture and Food, Western Australia and with the cooperation of other state departments of primary industries, this project has the objectives of:

- transitioning quinoa from a niche/cottage/organic crop to wider adoption across Australian broadacre farming environments by undertaking field testing in a range of environments, which may lead to the development of variety options
- developing and providing knowledge on agronomy, production and seed processing to growers and industry.

The project runs from June 2015 until June 2018, and involves evaluation trials of quinoa in northern Western Australia, southern Western Australia, South Australia, New South Wales and the Northern Territory.

The mapping of the quinoa genome was completed in 2016. This knowledge will enhance the capacity of plant breeders to quickly identify and select for quinoa lines that meet production goals and suit specific production environments.
Growing quinoa

Quinoa is a very diverse species, so there is a cultivar or ecotype to suit almost all arable parts of the world.

There are no established guidelines or recommendations for growing quinoa in Australia. So while a very general statement can be made that quinoa will grow in any temperate or subtropical climate, and that it is similar to canola to produce, the burning issue is where to source the seed to grow the crop.

While there is little documented knowledge of quinoa production in Australia, there are some general principles that can be drawn from anecdotal experience, from existing trial work and from experience overseas, to guide new growers in Australia.

**Soil type**

Generally, quinoa thrives on loamy soils that are high in organic matter and have good drainage. The plant will grow in soils ranging from alkaline (pH 8.5) to acidic (pH 4.8), however a neutral soil pH is ideal.

The Australian experience, at the time of publication, indicated that quinoa grows successfully on sandy soils, loams rich in organic matter and clay soils (in dry seasons).

The family of plants (Amaranthaceae) that quinoa belongs to contains many groups of ‘salt-loving’ plants, including many Australian saltbushes. There is a wide range of tolerance to salinity, at different stages of the growth cycle, between quinoa varieties. Some varieties are able to survive in soils with salinity levels (electrical conductivity) as high as 50 dS/m, which is as saline as seawater. However within the main five agro-ecological types of quinoa (Table 2), there is wide genetic variability in terms of salinity tolerance.

**Growing regions**

Quinoa can be grown in temperate and subtropical regions. The genetic diversity of the species is such that there are lines of the species that grow in winter and others that grow in summer, and lines that have developed at different latitudes and altitudes.

In Australia, quinoa has grown successfully in the north and south of Western Australia, in the Northern Territory, in the South East of South Australia and in northern Tasmania.

**Growing conditions**

Quinoa is tolerant of a range of climates and environmental conditions. The five agro-ecological types of quinoa are generally suited to different conditions, with varieties within these types suited to or tolerant of a range of conditions, including adverse drought and saline conditions.

The optimum temperature for the germination of quinoa seeds is between 15 °C and 23 °C. However some lines can germinate at very low temperatures, with some South American lines germinating at zero degrees.

Generally, the ideal temperature for crop growth is between 15 °C and 20 °C, however the plant can withstand temperatures from –4 °C to 38 °C.

Frost can be tolerated after the plant has established and before flowering.

Quinoa can grow in regions with limited soil moisture through to regions with annual rainfall of 1000 mm. While irrigation of a crop may improve yields, quinoa does not tolerate poor drainage and waterlogging, therefore water application needs to be scheduled carefully.
Crop management

Quinoa has a small seed, therefore its management in terms of sowing and harvesting has been likened to that for canola and chia.

The information in this section is based on first-hand experience from evaluation trials of quinoa in Australia. If considered useful, information about overseas production also may have been included. Due to the fact that quinoa production is a new industry in Australia, this information may not suit every potential production system or production environment. It is provided as a guide only and a means of sharing current experience.

Sowing
Quinoa has the capacity to germinate at very low temperatures, and while some South American lines can germinate at zero degrees, the optimum temperature for the germination of quinoa seeds is between 15 °C and 23 °C.

In a trial in the South East of South Australia in 2015, germination was poor in September-sown plots compared with October-sown plots.

Australian experience has shown that it is critical to sow fresh seed, as seed quickly loses viability, in turn lowering germination rates.

Seed germinates very quickly in moist soil, within 12 hours of watering in northern Australia, and within a few days of watering in southern Australia.

Irrigation after sowing, to ensure a moist seedbed for germination and emergence, has been a key to successful crop establishment. Preliminary research has shown crop failure with sowing into dry soil conditions.

Crop nutrition
Nutrition requirements for quinoa grown in Australia have not been established. Again, the crop has been treated like canola and other major crops, with nitrogen and phosphorus applied at sowing, and then nitrogen applied throughout the growing season.

At a regional level, other nutrients such as potassium or micronutrients such as zinc, that are regularly applied to other crops, also should be applied to quinoa.

Irrigation
Quinoa will grow in a very wide range of environments and tolerate very dry conditions. However, the crop responds well to irrigation and increased soil moisture can significantly increase yields.

Quinoa does not tolerate waterlogging therefore it is essential that water can be quickly supplied to and drained from the irrigation layout.

In northern Australia, under trial conditions, the seed bed was dry at sowing and the field watered up after sowing. The quinoa was irrigated about every two weeks to maintain adequate moisture supply to the crop, especially during the early seed-filling stage. Total water use for the season was about 6.0–7.0 ML/ha (1.0–1.2 ML/ha per watering).

In southern Australia, the quinoa grown in the South Australian trial was irrigated after sowing and watered several times through the growing season, as required.
Weeds
Weeds are problematic for quinoa production. As with any crop, weeds compete with quinoa for moisture, nutrients and light; and present a contamination risk. The greatest difficulty for growers however, is that there are no herbicides registered for use in quinoa in Australia — although some permits have been granted for specific regions.

Good paddock preparation includes pre-sowing weed control as an important first step. Using adequate sowing rates to achieve a good plant density is currently the only way to suppress weed growth during the growing season.

Depending on the crop area and availability of labour, hand weeding may be an option.

Pests
Quinoa may be susceptible to a range of pest species, depending on location and seasonal conditions. The plant is most susceptible to pests in the growth stages leading up to flowering, where the leaves, stems and developing flower heads may be infested. Developing and mature seeds are protected from pest attack by the unpalatable saponin in the outer layers of the seed.

Current experience in northern Australia has shown loopers (various species), heliothis (Helicoverpa spp.) and caterpillars (Spodoptera spp.) affecting quinoa. Heliothis can be effectively controlled in seed-increase crops with readily available pesticides but chemical and biological control options are not registered for crops where seed is destined for human consumption. Rutherglen bug and mirids attacked developing seed in late-planted crops in northern Australia as the crop was senescing. While control options were available for the trial, options are not available for commercial crops.

In southern Australia, Rutherglen bug caused plant damage in a quinoa trial in the South East of South Australia. As the crop was not intended for human consumption, a general pesticide was applied to the trial, which provided control of most expected pests. Aphids and mirids have also been a problem.

In some trial situations in Australia, red-legged earthmite have been a problem after emergence; and webworm has been detected in crops at the end of the growing season.

In South America, a range of moth species are commercially-destructive pests of quinoa, especially the quinoa moth (Helicoverpa quinoa), of which a major infestation of its larvae can wipe out an entire crop. Other moth species that are serious pests include Copitarsia spp., Agrotis sp. and Eurysacca spp. The larvae of moth species attack several parts of the plant, but their feeding on the developing flowers and seeds causes the greatest yield loss.

Assessment and registration processes are required to determine a range of pesticides suitable for use on quinoa crops in Australia, where the seed of the crop is destined for human consumption.

As more understanding is gained of quinoa growth patterns in different parts of Australia and the interaction of crop growth and the lifecycles of likely pest species, integrated pest management strategies can be developed.

Evaluation trials offer an opportunity to identify and select lines of quinoa that show tolerance or resistance to common pest species.

A significant agronomy challenge for growing quinoa in Australia is the lack of herbicides and pesticides registered or permitted for use in most states (as at December 2016).
Disease
In northern Australia, fungal diseases have been observed in quinoa crops. These have been able to be controlled in seed-increase crops with the use of available fungicides however, biological or chemical control options are not possible for seed destined for human consumption.

Downy mildew *Peronospora variabilis* Gaum (formerly called *Peronospora farinose* Fr.) is reported to be one of the major fungal diseases of quinoa on a global scale. Sustained wet periods or periods of relative humidity around 90% favour the development and spread of the disease, which results in high grain yield and poor grain quality. Further, the rapid development of quinoa cropping around the world could facilitate the pathogen’s spread between countries and continents. In the Andean region and North America, some lines of quinoa have shown medium to high resistance to downy mildew.

Minor diseases of quinoa include damping off, green mould, leaf spot (caused by *Passalora dubia* [Riess] U. Braun, *Ascochyta hyalospora* and *A. chenopodii*), brown stem rot, eyespot and bacterial spot. Nematodes and viruses can also cause problems. The incidence and severity of these diseases varies with variety, crop growth stage and environmental conditions.

Assessment and registration processes are required to determine a range of fungicides and other disease control measures suitable for use on quinoa crops in Australia, where the seed of the crop is destined for human consumption.

Benefit of industry coordination
The capacity to support the continuation of evaluation trials to enable the development of agronomic management guidelines for crop nutrition, crop protection and irrigation; as well as to support the process of application and registration of agricultural chemicals for nation-wide and industry-wide use in quinoa.

Readers are encouraged to take advantage of this shared experience but be fully aware that the same results may not be repeatable in their situation. Further, RIRDC would welcome additional information about quinoa growing experiences throughout Australia.
Table 5. Summary of crop management at five trial sites in RIRDC Project PRJ-010057 (2015 and 2016 seasons)

<table>
<thead>
<tr>
<th>Growing season</th>
<th>South East South Australia</th>
<th>Northern Western Australia</th>
<th>Wheat belt Western Australia</th>
<th>Lower south west Western Australia</th>
<th>Katherine Northern Territory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sowing timing</td>
<td>September–October</td>
<td>April</td>
<td>April–June</td>
<td>September–October</td>
<td>May</td>
</tr>
<tr>
<td>Soil temperature</td>
<td>~ 18 °C</td>
<td>~ 35 °C</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Seed bed</td>
<td>Clover paddock</td>
<td>Cultivated to fine tilth</td>
<td>Wheat stubble</td>
<td>Cultivated and levelled</td>
<td>Sabi grass stubble</td>
</tr>
<tr>
<td>Seeding rate</td>
<td>3.0 kg/ha (of 4 rates tested) most successful</td>
<td>3.0 kg/ha for beds (~ 6.0 kg/ha for flat paddock)</td>
<td>4–8 kg/ha</td>
<td>5–10 kg/ha</td>
<td>2–8 kg/ha</td>
</tr>
<tr>
<td>Equipment</td>
<td>Direct drill on small seed settings</td>
<td>Air seeder on small seed settings</td>
<td>Direct drill – air seeder with knife points and press wheels</td>
<td>Direct drill – pasture seeder with knife points</td>
<td>Direct drill – cone seeder with knife points and press wheels</td>
</tr>
<tr>
<td>Sowing depth</td>
<td>—</td>
<td>1–2 mm</td>
<td>10 mm</td>
<td>10 mm</td>
<td>—</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>At sowing DAP @140 kg/ha (25 kg N/ha, 28 kg P/ha)</td>
<td>DAP + zinc @280 kg/ha (50 kg N/ha, 56 kg P/ha)</td>
<td>Agstar extra @80 kg/ha (11 kg N/ha, 11 kg P/ha +Cu +Zn)</td>
<td>Agstar @130 kg/ha (19 kg N/ha, 18 kg P/ha)</td>
<td>DAP @120 kg/ha (22 kg N/ha, 24 kg P/ha) Muriate of potash @50 kg/ha (50 kg K/ha)</td>
</tr>
<tr>
<td>Topdressing</td>
<td>100 kg N/ha as urea</td>
<td>Potential for 100 kg N/ha as urea</td>
<td>30–60 kg N/ha as urea</td>
<td>NS31 @100 kg/ha (33 kg N/ha, 11 kg S/ha) Muriate of potash @50 kg/ha (25 kg K/ha)</td>
<td>60–120 kg N/ha</td>
</tr>
<tr>
<td>Irrigation</td>
<td>Sown dry, irrigated after sowing and several times through the season</td>
<td>Sown dry, irrigated after sowing and several times through the season</td>
<td>Rain-fed only</td>
<td>5–6 weeks in December and January based on evapotranspiration</td>
<td>Frequent as required</td>
</tr>
<tr>
<td>Weeds</td>
<td>Rye grass</td>
<td>General cropping weeds</td>
<td>Rye grass</td>
<td>Fat hen</td>
<td>Sabi grass</td>
</tr>
<tr>
<td></td>
<td>Fat hen</td>
<td></td>
<td>Wild radish</td>
<td>Various others</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Radish</td>
<td></td>
<td>Toadrush</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>General broadleaf weeds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pests</td>
<td>Rutherglen bug</td>
<td>Loopers</td>
<td>Nil</td>
<td>Rutherglen bug</td>
<td>Helioltis in chickpeas next to trial. No damage to quinoa, preventative BT spray</td>
</tr>
<tr>
<td></td>
<td>Aphids</td>
<td>Helioltis</td>
<td>Caterpillars</td>
<td>Other sap sucking insects yet to be identified</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mirids</td>
<td>Rutherglen bug</td>
<td>Mirids</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Windrowing</td>
<td>Due to plant height (1.7 m) and to achieve complete drying</td>
<td>If variety prone to lodging or shattering</td>
<td>Chemical desiccation</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Harvest</td>
<td>Conventional grain harvester</td>
<td>Conventional grain harvester</td>
<td>Conventional grain harvester</td>
<td>Conventional grain harvester</td>
<td>Conventional grain harvester</td>
</tr>
<tr>
<td>Yield</td>
<td>2.7 t/ha</td>
<td>2.5 t/ha</td>
<td>0.0–0.4 t/ha</td>
<td>3.0 t/ha</td>
<td>1.2 t/ha</td>
</tr>
<tr>
<td>Stubble management</td>
<td></td>
<td></td>
<td></td>
<td>Stems are light and hollow and break down quickly, presenting no issues for subsequent crops</td>
<td></td>
</tr>
</tbody>
</table>

Notes: 1 Record cold winter and spring impacted on seed production
Harvest

The timing of harvest for quinoa (when the plant reaches physiological maturity) is recognised by the colour change in the plant.

Australian experience to date is that plants will change from green to a reddish pink, orange or yellow colour. Overseas, depending on ecotype and/or variety, quinoa crops also may turn reddish yellow, purple or black.

Plant maturity may also be confirmed by the hardness or resistance of the grain when pressed under a fingernail. The ideal time to harvest is when a dent is left in the seed after being pressed.

The crop must be harvested as close to maturity as possible to avoid seed loss during the harvest process, seed loss in high winds and deterioration of grain quality in rain or storms. The seed readily germinates and at high temperatures and high humidity can germinate on the seed head.

The seed head of the quinoa plant matures at the same time along the length of the head.

At maturity, moisture content of the seed is 10–13% and in the plant, 16–20%. Experience in northern Australia shows that seed stores well at 12% moisture.

Timing of harvest
In Australia, experience in evaluation trials indicates that quinoa is ready for harvest about 100 days after sowing in northern Australia, which is generally July; and about 160 days after sowing in southern Australia, which is about November or December. Leading up to grain maturity, the leaves change from green to red or yellow, and the seed heads lose colour.

However, time to maturity can vary with line and environment. Overseas, some lines take up to or more than 200 days to mature.

Direct heading or windrowing
Quinoa plants in trials in northern Western Australia and the South East of South Australia grew to 1.7 metres tall and therefore windrowing was necessary to enable harvest of the seed.

Some lines tested in Australia also have a tendency to shatter when mature, so windrowing is effective in preventing seed losses at harvest. Windrowing ensures a quick and even dry down of the crop prior to harvest.

In northern Australia, some varieties have retained sap in the head causing ‘gumming up’ of the header, which was difficult to remove — regardless of how dry the crop was. In this situation, windrowing enables total dry down of the head, which enhanced seed removal and cleanliness of the harvested seed.

The use of desiccants may be another approach to achieving a uniformly dried crop before harvest.

Direct heading of crops with the harvester has been successful for lines/varieties that do not shatter and have shorter-statured and even-sized plants.
Machinery
Standing quinoa crops are successfully harvested with a conventional grain harvester. Settings are similar for other small-seeded crops such as canola or chia, and a small seeds sieve will be necessary. The seed is light so fan settings should be such that seed is not blown out the back of the header.

Direct-headed and windrowed crops are successfully harvested with a conventional grain harvester, using small seed settings and sieves.

Harvested seed is managed the same as canola seed, being transferred from header to field bins, before being transferred to storage or a processing plant.

Seed must remain dry during transport and storage, as mature seed can germinate within 24 hours if exposed to moisture.

Yield
In Australia, yields of 2–3 t/ha have been recorded in trial crops in favourable seasons, with irrigation, in southern and northern Australia. Dryland experience indicates yields of around 1.0 t/ha are possible.

Overseas, yields vary greatly with production systems — organic or non-organic cultivation and traditional or mechanised crop operations. In Bolivia for example, production systems remain organic but new agronomy methods (variety selection, nutrient management, pest management and mechanisation) have lifted yields from around 0.5 t/ha to 1.5–2.5 t/ha.
In Peru, recently identified mutant lines have yielded up to 3.5 t/ha.

Benefit of industry coordination
The capacity to support the continuation of evaluation trials to enable the development of management guidelines for crop harvesting and post-harvest handling.
Processing and storage

Following harvest, seed may be transported directly to storage or to a processing plant and then storage, depending on marketing arrangements.

Consumers and processors of quinoa are after a product with:
- seed integrity (including shape)
- good nutritional value
- low saponin content.

At the time of publication, there were no receival depots or ready markets for quinoa, as there are for other grains produced in Australia. At this very early stage of quinoa production in Australia, pioneering growers of quinoa have not only determined production systems for the crop, they have also invested in and developed their own seed processing facilities, as well as developed a supply chain for their product.

Cleaning and storage
As with grain production across Australia, quinoa seed requires cleaning before storage to remove impurities such as chaff, plant material (flowering parts, stems and leaves), small stones, dust and other contaminants from the paddock. These impurities may account for up to 15% of harvested grain weight. Grading may also be required to remove damaged, germinated, unripe and other unsuitable seeds.

Experience in northern Australia indicates that quinoa seed stores well at 12% moisture. If the seed requires drying before storage, the settings and sieves of grain dryers used for small-seeded crops, such as canola, are also suitable for quinoa. In the US, seed is often cleaned after harvest using a fanning mill and gravity separator.

Storage facilities must be clean to prevent contamination by insects or other biological matter.

Processing
Before quinoa seed can be consumed it must be processed or washed to remove the bitter-tasting substance called saponin (see page 14). Even after saponin is removed most retail brands of quinoa recommend further washing of the seed before use.

At the producer/processor level, the saponin may be removed by physically agitating the seed, which is similar to processes used to remove hulls from rice or bran from wheat and barley. Alternatively, the seed may be washed with water or steam, which will also remove a large proportion of saponin. In South America, large-scale processing facilities employ a multi-step processing system of abrasion, washing and drying (see page 14 for more detail).

Once processed, quinoa must be stored in a clean, dry and ventilated area to prevent infestation by insects and deterioration of quality.

Benefit of industry organisation
Enables a coordinated approach to identify a process to achieve uniform seed quality to meet consumer requirements and maintain the reputation of Australian-grown quinoa.
Seed standards

Quinoa is an emerging crop in Australia, and therefore industry-determined guidelines and standards for seed quality are yet to be established.

There are ‘in-house’ standards established by existing growers and processors in Australia, to ensure their own product meets the requirements of the particular markets they supply, however there are no industry-wide standards to guide new growers.

In Bolivia, the world’s largest quinoa exporter, standards for quinoa sold on local and world markets have been established and are administered by the Instituto Boliviano de Normalización y Calidad (IBNORCA). These define suitable quality characteristics in terms of seed size and impurities, as well as a range of chemical and biological aspects, such as nutritional qualities and toxicology.

To achieve market quality, the key steps in post-harvest processing of quinoa seed are:
- removal of impurities and preliminary sorting of size (larger and smaller than 2.2 mm in diameter)
- saponin removal — hulling or washing
- drying
- sorting by size
- separation of different coloured grains
- removal of residual impurities.

Benefit of industry organisation

Enables a coordinated approach to develop a process to guarantee seed integrity (certification) for the benefit of future enterprises and the reputation of Australian-grown quinoa.
Quinoa is an interesting crop and there is plenty of reading about its background, its current popularity and attempts to grow the crop beyond South America.

If you are reading a printed version of this publication, go online to RIRDC publications (www.rirdc.gov.au) to access the online version and links to the references listed on this page.

General international references
- Quinoa Food and Agriculture Organization of the United Nations
  A comprehensive and detailed report with a lot of discussion on the genetic diversity, utilisation and potential of quinoa. Excellent for general background knowledge and understanding of the plant, and provides a good appreciation of the need for identifying and purifying lines of quinoa to grow in Australia.
- Quinoa: An ancient crop to contribute to world food security (FAO 2011)
- Why the price of quinoa has fallen The Economist, May 2016
- Global quinoa imports continue to grow, although at a slower pace Mercadero, January 2017
- The genome of Chenopodium quinoa Nature, February 2017

North American references and articles
- Quinoa ... The Next Cinderella Crop for Alberta? Alberta Agriculture, Food and Rural Development, Canada
- Growing quinoa on the Prairies Grainews, Canada, January 2014
- Growing Quinoa in Colorado Local Food Shift, regional food magazine, February 2016
- US farmers make foray into quinoa as demand for grain grows Phys.org™ web-based news service, October 2016

Australian references
- Farm Diversity – Quinoa Farm Diversity website
- Gluten Free Grains: a demand-and-supply analysis of prospects for the Australian grains industry RIRDC 05-011 Grant Vinning and Greg McMahon Asian Markets Research Pty Ltd, Project no. AMR-10A
- Quinoa and the Australian Consumer RIRDC 08-15 Robert Vogel and Dean Vogel, January 2008, RIRDC Project No. VOG-1A
- Emerging commodities: quinoa NAB Economic report, January 2015

Australian news about quinoa
- Ancient seed ABC Landline, October 2013
- Australia’s first quinoa crop cuts food miles GRDC Groundcover, May–June 2014
- Quinoa washing plant up and running at Kindred The Advocate (Tas), January 2015
- Quinoa shows potential for high profit crop RIRDC News, July 2015
- Quinoa trial convinces Kununurra locals of crop’s viability ABC The World Today, July 2015
- Grower caution for early quinoa crops Stock Journal (SA), January 2016
- On a winner with quinoa The West Australian, March 2016
- Quinoa gamble wins big for Wheatbelt farmers The West Australian, April 2016
- Coles backs WA produced quinoa Farm Weekly, April 2016
- Bitter chemical coating leads to quinoa success Phys.org™ web-based news service, July 2016
- Quinoa research explores potential for a ‘superfood’ crop in the Northern Territory ABC Rural, September 2016
- Researchers decode quinoa genome, allowing them to learn why it thrives in harsh environments ABC Rural, February 2017