Executive Summary
Quinoa as a new crop in Australia
Stage 2

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Executive Summary

What the report is about

Quinoa (*Chenopodium quinoa* Willd) is a new ‘superfood’ in Australia that has attracted grower interest. This report summarises results from 25 field, two glasshouse and various laboratory experiments that examined the performance of current quinoa varieties, advanced breeding lines and germplasm lines across a range of Australian agroecological zones between 2015 and 2018. A major outcome of the research was the development of Australia’s first public quinoa variety ‘Kruso White’, along with its agronomic package, which is due for release in 2021.

Australia, like many countries outside South America, is witnessing the production, trade and consumption of quinoa grow from a very low base. Market research suggests that 80 per cent of Australian consumers are yet to use quinoa and demand for the grain in Australia is expected to increase (Kealey, 2017).

As of May 2017, Australian plantings of quinoa were estimated at 50 hectares, producing 45 tonnes, with Tasmania and Western Australia the main producers. The WA company Three Farmers (Australian Grown Superfood Pty Ltd) is the leading grower and retailer in WA (AgriFutures Australia, 2017). Data from UN Comtrade indicates that Australia imported 2,863 tonnes of quinoa worth $7.42m in 2017. At an average 0.9t/ha yield, this equates to 3,181 hectares of production. Currently, Australian food manufacturers prefer to import quinoa because the supply, quality and price of locally produced quinoa has not yet stabilised.

The development of the new quinoa variety, Kruso White and its agronomic knowledge, will help fill the gap between locally-produced and imported quinoa by providing farmers with the opportunity to grow quinoa and increase production for local and international markets.

This report focuses on the following points:

- Where and how quinoa could be grown across Australia to lift local production to better meet consumer demand.
- The seed quality attributes (seed colour, size, protein content) present in available quinoa germplasm.
- Herbicides for pre-emergent and post-emergent weed control in quinoa crops.
- A proposed list of seed quality specifications for farmers, processors and marketers to consolidate the quality standards of the emerging industry.
- The availability and suitability of seed processing methods in Australia to remove saponin from the seed coat of quinoa post-harvest.
- The economics of producing rainfed quinoa in relation to established crops like wheat and barley.

Who is the report targeted at?

The report is targeted at the Australian grains industry including grain growers, processors and marketers, research organisations and funding bodies for flow-on research projects and consumers.
Where are the relevant industries located in Australia?

The field investigations were carried out at sixteen locations across Australia and the results have implications for farmers, processors, marketers and consumers in the following regions:

- Northern Australia – Northern part of Western Australia (Kununurra), Northern Territory (Katherine) and Queensland (Walkamin).
- Central Australia – Alice Springs
- South-Western Australia - wheatbelt and south-west region
- South-Eastern Australia - Bool Lagoon area of South Australia and Riverina region of New South Wales.

Background

Quinoa, a dicotyledonous pseudo-cereal, is native to the Andes Mountains of South America where it has been a staple food for at least 5,000 years. The grain is gluten free, high in protein (average 15%, range 7.5-22% in germplasm) with an excellent amino acid profile and a low glycaemic index score. Current world production is only about 150 thousand tonnes mainly from Bolivia, Ecuador and Peru but global food trends are creating demand due to the grain’s perceived health benefits. Preliminary work in Australia and elsewhere has demonstrated that quinoa is adapted to a wide range of environments and it is currently grown in 70 countries. Quinoa could provide a high value alternative break crop for farming systems across Australia.

Aims/objectives

- 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 with the aim of developing variety options.
- Developing and providing knowledge on agronomy, production and seed processing to growers and industry.

Methods used

Germplasm evaluation

To evaluate the quinoa germplasm and determine optimum times of sowing and seeding rates, 21 field trials and a glasshouse trial were carried out across 16 Australian locations from 2015-2018. The quinoa germplasm tested included three commercial varieties, three advanced lines and nine USDA lines (three Bolivian and six Chilean lines). Several SARDI lines selected from the advanced line ‘JC1’ were also included in South Australian trials during 2016 and 2017.

To facilitate germplasm exchange with collaborators and other organisations, twelve material transfer agreements and six subcontracts were signed during the course of the project. Just over 50 per cent of trials were located in WA with the remaining 50 per cent located in SA, NT. NSW and Qld. The trial sites covered a range of agroecological regions and soil types. The trials were established using either a randomised complete block (RCB) or split-plot/factorial design balanced in two directions with 2-4 replicates. Measurements included crop emergence, plant height, days to flowering (selected trials) and seed yield.
Seed quality assessments

To assess seed quality attributes, harvested seed of several quinoa lines from seven national field trials was used during 2016 and 2017. The traits assessed were seed germination, 1000-seed weight, seed size and colour, and protein. Physical testing was done on both unwashed and washed seed. The field trial and seed quality data were analysed using either the ANOVA or REML procedures in the GenStat Statistical Program.

Weed control

To identify herbicides that could potentially be used for selective weed control on locally adapted quinoa advanced lines, four field trials and a glasshouse trial were carried out at five locations across WA. The field trials were carried out using either randomised complete block (RCB) or criss-cross design with 11-27 pre- and post-emergent herbicide treatments and 3-4 replicates under weed free conditions (except Kununurra 2018). All trials were assessed visually for herbicide damage using a scale from 0-100% (where 0% = no visible injury and 100% = complete plant death). Seed yield was determined by machine harvesting the field trials. The trial data were analysed using the analysis of variance (ANOVA) component of the GenStat Statistical Program.

Quinoa quality specifications

To develop a proposed list of quinoa quality specifications, 20 grain samples from the national field trials were assessed using a nutritional panel organised by Agrifood Australia and various laboratory methods. Physical traits were assessed using both clean unwashed and washed samples and included seed weight, seed size, seed colour and germination. Protein analysis of washed samples was done using Leco Nitrogen analyser in a commercial laboratory (Chemistry Centre). Quinoa seed coat colour (colour difference index) was measured with a Minolta CR-310 colorimeter. Amino acid profiling was carried out on four of the samples.

Results/key findings

Germplasm evaluation and agronomy

Among the advanced and introduced germplasm lines tested, BEW and the Bolivian line PI 634918 achieved the highest seed yield of more than 3t/ha when sown on 2 June 2017 under rainfed conditions at Geraldton, WA at a plant density of about 70-90 plants/m². Among the quinoa varieties, Medusa achieved the highest seed yield of 3.1t/ha when sown under rainfed conditions at Bool Lagoon, SA on 10 November 2016 with plant density of 102 plants/m². The seed yield across all varieties and advanced lines ranged from 0.3-3.2t/ha with an average seed yield of 1.5t/ha.

BEW (precursor of Kruso White) performed better in northern Australia and the northern WA Wheatbelt, while Medusa and JC1 performed better in the south-west of WA (Manjimup) and in South Australia (Bool Lagoon).

Two Chilean lines PI 433232 and PI 614885, and the Bolivian line PI 433232 Tall yielded significantly more than BEW, JC1 and Medusa in first time of sowing (12 May 2017) at Katherine, NT but this relative yield ranking was not observed in any other trial. Time to flowering for the Katherine-sown varieties was relatively early (40-51 days) and seed yield was lower (0.4-1.4t/ha) than the national average (1.5t/ha).

Winter-sown quinoa lines took 35-51 days to flower in northern Australia (Kununurra and Katherine), around 67-90 days in the northern WA wheatbelt (Geraldton and Eradu) and about 116-138 days in the south-eastern wheatbelt (Esperance). Spring-sown quinoa lines in south-western WA (Manjimup) flowered at about 72 days after sowing and between 64-96 days after sowing at Bool Lagoon in South Australia. Autumn sown quinoa lines (mid-March) at Leeton in NSW took 45-60 days to flower.
Quinoa germplasm and varieties were sensitive to chilling temperatures (6-12°C), frost, temperatures above 34-35°C between flowering and seed development and seed sprouting at maturity. When sown in spring/summer, the Bolivian line PI 470932 tolerated high temperature periods better than other lines at Leeton, NSW during 2017/2018.

BEW seed was found to be whiter than Medusa, Titicaca and JC1, but not as white as Organic White Peru (a standard variety). Seed size ranged between 1.13-1.74mm and 1000-seed weight between 1.06-3.86g across quinoa lines and locations.

Protein content ranged from 11.3-15.8% between BEW, Medusa, Titicaca and JC1. When sown in autumn at Leeton during 2017, the Chilean line PI 433232 achieved the highest protein content of 18.4% followed closely by another Chilean line PI 614888 at 17.9% and 14.8% in BEW. The lowest protein contents of 11.3-11.8% were recorded in winter-sown quinoa at Katherine during 2017.

Washing quinoa seed tended to decrease the colour difference index and seed weight significantly.

The following quinoa sowing windows were established as optimal for the different trial regions during the national project:

Northern Australia:
- Kununurra (WA), Katherine (NT) and Walkamin (Qld): mid-April to late May.

Western Australia (wheatbelt and south-west):
- Northern wheatbelt (Geraldton, Dongara, Eradu, Mingenew): end of May to early June.
- Central and southern wheatbelt (Cunderdin, Katanning and Esperance): mid-June to end of June.
- South-West (Manjimup): late September to early October.

South-Eastern Australia:
- South Australia (Bool Lagoon): first fortnight of November.
- New South Wales (Leeton/Riverina region): mid-December to mid-March.

A seeding rate of 2-5kg/ha with a greater than 85% germination rate (to achieve a plant density of 50 to 100 plants/m²) was found to be optimum for yield. Increasing the seeding rate did not significantly increase quinoa seed yield in most of the trials. As there are currently no registered herbicides for quinoa it would be best to seed at rates towards the higher end of 4-5kg/ha. This will enable better competition against weeds and also ensure optimum crop stand under poor seed-bed conditions.

Sowing larger quinoa seeds (1.7-2.2mm) at 0.5cm depth into sandy loam soil at 1/3 field capacity moisture level resulted in significantly higher plant emergence than sowing smaller seeds (1.18-1.4mm) at the same depth with 1/6 or full field capacity (glasshouse trial results).

**Herbicide tolerance**

The pre-emergent herbicide Pyramin (chloridazon) at 3.5 and 7kg/ha and the post-emergent herbicides Brodal (diflufenican) at 100, 200, 300 and 400mL/ha and Broadstrike (flumetsulam) at 25g/ha for broadleaf weed control applied at the 2-10 leaf stage had no significant negative effect on seed yield of BEW, JC1 and Regalona. Similarly, the pre-emergent herbicide Dual Gold (s-metolachlor) at 0.5 and 1L/ha for grass weed control was found to be safe to use on the quinoa lines and varieties. Minor use permits for these herbicides on quinoa are not yet available and need to be pursued for the industry.
While a permit (PER80723) for the pre-emergent herbicide trifluralin is in place, the research reported here found trifluralin (480) at 1-2L/ha or higher and incorporated either by seeding (rainfed) or power harrowing (irrigated) caused significant reductions in quinoa plant population and seed yield compared to untreated plants.

**Commercial release of a new variety**

Kruso White (tested as BEW) has been nominated by DPIRD for launching nationally in 2021. At the national quinoa project meeting in South Perth, WA on 18 April 2018 all project collaborators recommended Kruso White be released based on its performance in field trials across mainland Australia. About 700kg of good quality seed of Kruso White was produced at Kununurra during 2018. Tenders for selecting seed multiplication/commercialisation licences are expected to be announced by November 2019. The key features of Kruso White are outlined below:

- First public quinoa variety in Australia.
- Suitable for both rainfed and irrigated conditions.
- Suitable for winter and spring-autumn sowing.
- Wide adaptability with good yield and seed quality.
- Protected by Plant Breeders’ Rights.

**Quality specifications**

There are currently no standard quinoa quality specifications available in Australia with different quinoa companies following different standards. To address this, we have proposed a set of integrated seed quality specifications based on existing specifications used in Peru, USA and Australia, with additional specifications developed via the seed quality assessments of the national project field trials. The specifications tend to be broad with the aim that they are not excessively restrictive while still maintaining acceptable quality of Australian produced seed. Physical and chemical trait specifications are relevant at both the entry and exit points of grading and de-saponification plants. As the industry matures, specifications can be tightened to allow for improved seed quality and premium pricing. It is proposed that quality traits not included in the proposed specifications, such as amino acid score and important minerals, can also be added in future.

**Seed processing technologies**

Saponins contained on the outer surface of quinoa seed need to be removed before consumption due to their bitter taste and negative effects on human health. Commercial methods for removing saponin involve scarification followed by washing and drying. Due to the cost of washing and drying, attempts have been made in recent years to develop methods of scarification that remove sufficient saponin while avoiding the need for washing and drying. Several scarification options are available to quinoa growers and processors for domestic and export markets:

- Access the state-of-the-art processing plant at Three Farmers, Narrogin, WA.
- Purchase a machine from Peru (Vulcanotec scarifier, www.vulcanotec.com).
- Purchase a machine from Germany (contact Peter Damen, Kindred Organics for details).
- Access a Peru-based machine from quinoa grower Sam Carbone in NSW.
- Export unprocessed seed.
The national project examined a novel scarification approach that involved soaking seed in water for 30 minutes followed by rapid drying to improve the subsequent removal of saponin by abrasive/scarification. This approach represents a reversal of the currently-used commercial method for saponin removal. The new approach has the potential to reduce the cost of both the washing and scarification processes.

In addition to the saponin-removal research, a new technique known as the “surface tension water droplet method” was developed via the project to quantify saponin content of quinoa. The technique uses a digital camera to capture the size and shape of droplets of quinoa ‘wash-up’ samples and processes captured data using specific computer software. The currently available test-tube foam or afrosimetric method only determines the presence of saponin via a rating of either ‘acceptable’ or ‘unacceptable’.

**Economics**

The research reported here found that quinoa is best suited to frost-free areas under both rainfed and irrigated conditions and that it can yield 0.5 – 3t/ha with an average seed yield of 1.5t/ha. With a farmgate price of ~$1,000 per tonne (1t/ha yield) and similar production costs to wheat ($364/ha) and canola ($411/ha) under rain-fed conditions in the Geraldton port zone (high rainfall zone), quinoa therefore represents a highly profitable alternative crop for Australian cropping systems. The gross margin of quinoa can be as high as $615/ha compared with $309/ha for wheat (at 2.9t/ha) and $285 for canola (at 1.5t/ha).

**Communications**

The project research and development activities were publicised through presentations at two international/national conferences and two field days. In addition, eight newspaper and newsletter articles and a press release were written, and eight radio and telephone interviews given. Two trial visits were also organised with the Agrifutures board and the NSW Minister for Agriculture.

**Implications for relevant stakeholders**

The proposed 2021 release of the publicly available quinoa variety Kruso White along with an agronomic package (developed through this project), will provide interested farmers with the opportunity to grow quinoa and increase production for local and international markets. Kruso White has performed relatively well nationally compared to local varieties like Medusa and Regalona, however these varieties belong to private companies and have restrictions on their production.

The proposed seed quality specifications through this project will help to standardise the seed quality parameters that are relevant at both the entry and exit points of grading and de-saponification plants.

Health and wellbeing benefits of the project will arise from the increased use of quinoa in Australian diets. Increased local production will help to make quinoa available at an affordable price to all Australians. It is expected that increased quinoa production will also generate more employment via the processing and marketing sectors.

**Recommendations**

The following issues need further research and testing to improve the agronomy, seed processing and marketing/promotion of quinoa in Australia:

**Agronomy**

- Poor establishment of winter-sown quinoa under rain-fed conditions in WA. Investigations are required into the impacts of soil texture, soil moisture, stubble levels and precision seeding machinery on plant establishment and seed yield.
• Investigations are needed into the impact of nitrogen fertiliser on seed yield and protein content.

• Screening of diverse quinoa germplasm is required to select lines tolerant of frost and waterlogging.

• Assessment of the performance of locally-adapted quinoa varieties and advanced breeding lines performance under saline conditions is required.

**Weed Control**

• Minor use permits or registration of herbicides for broadleaf weed control in quinoa are required. Weeds were a major problem during the project and while five minor-use herbicide permits are in place mainly for grass weed control (three pre-emergent and two post-emergent), no herbicide permit/registration is available for broadleaf weed control. Several herbicides were identified as safe/suitable on locally-adapted quinoa varieties/lines for broadleaf weed control in this project, but these need further testing on a range of soil types and climatic/agronomic conditions to obtain permits or registration for use in Australia.

• Research is required into shielded spraying using non-selective herbicides and inter-row cultivation of quinoa planted in wide rows.

**Seed processing technologies**

• While food companies like *Uncle Toby*’s are interested in locally-grown quinoa there are no processing facilities available for the critical step of saponin removal. For small-to-medium scale processing, the effectiveness of scarification machines identified through this project like the Vulcanotec de-huller from China (Cinoaix), and others from Peru and Germany to remove saponin need to be fully investigated.

• A novel approach developed via the project resulted in promising levels of saponin removal by soaking seed in water for 30 minutes before scarification. This approach would be worthy of future consideration by industry.

**Marketing**

• During the national project meeting at South Perth on 18 April 2018, the lack of marketing channels was identified as a major issue for future quinoa production. The Three Farmers group could act as a marketing channel for domestic and/or export market. There is a need to establish a quinoa industry association consisting of growers, seed companies, processors, marketers, exporters and value-adding food companies. Such an organisation could also participate in research and development.

**References**


Further information

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