Quinoa in the Riverina

David Troldahl[1], Richard Snowball[2], Harmohinder Dhammu[3] and Mario D'Antuono[2]

[1] NSW Department of Primary Industries, Yanco Agricultural Institute, Yanco, NSW 2703. www.dpi.nsw.gov.au, david.troldahl@dpi.nsw.gov.au
WA Department of Primary Industries and Regional Development, 75 York Rd, [2] South Perth and [3]Northam, WA 6401. www.dpird.wa.gov.au

Abstract
Quinoa can potentially be grown in Australia as a summer or winter crop and as a complementary crop within existing cropping programs depending on soil type, rainfall and environment. A national project "Quinoa as a new crop in Australia" co-funded by the AgriFutures and state Departments of Primary Industry (DPI) and Agriculture (DA) explored this potential at experimental sites in South Australia (Naracoorte), Northern Territory (Katherine and Alice Springs), Western Australia (Cunderdin, Eradu, Esperance, Geraldton, Katanning and Kununurra) and New South Wales (Leeton Field Station). The paper reports on the experiments at Leeton Field Station in the Riverina region of NSW .

Variety evaluation experiments were conducted in two years to determine a range of agronomic recommendations for growing quinoa in the Riverina. Preliminary research highlighted a sowing window between December and March, a sowing density of around 7kg/ha and identified key varieties that matched local industry needs.

Key Words
Quinoa, agronomy, variety, plant density, temperature effect.

Introduction

Quinoa (*Chenopodium quinoa* Willd) is an Amaranthacean cultivated as a seed crop in the Andes in Argentina, Bolivia, Chile, Equador and Venezuala for several thousand years (Aloisi et al., 2016; Jacobsen, 2003; Tagle & Planella, 2002). Unlike cereal monocot plants quinoa is a dicot plant and is considered a pseudo-cereal or pseudograin due to it being grown and consumed as a seed crop (Cusack, 1984). Consumers in Europe and North America are recognising its exceptional nutritional qualities and this has led to quinoa being considered a "functional food" that aims at lowering the risk of a number of diseases (Vega-Galvez et al., 2010).
The wide adaptability and multiple uses of quinoa seeds has led to an increase in demand for quinoa worldwide and its versatility due to the fact it can be consumed as a whole seed or processed into a range of food products. Since the 1990s there has been a resurgence of growing quinoa and other traditional crops in South America due to government support in this area. The worldwide production of quinoa has climbed from 23,000 tonnes worldwide in 1990 to nearly 200,000 tonnes today. This could be due to the elevation of the status of this plant to "superfood", and as a gluten free substitute for other cereals.

A national project "Quinoa as a new crop in Australia" was funded in response to increased demand for quinoa in Australia and transitioning from a niche, cottage crop to a wider adoption across Australian broadacre farming environments. The purpose of quinoa experiments at Leeton Field Station were to investigate the viability of growing quinoa in the Riverina as an irrigated summer crop and to assess the best time of sowing and agronomy practices to achieve this. Assessments were based on establishment counts, plant heights and yield for all experiments. The results of these preliminary experiments with limited data are reported on in this paper.

Methods

Five irrigated quinoa experiments were conducted at Leeton Field Station in the Riverina. Soil tests were carried out and 110kg/ha of Granulock Z (N 11%, P 21.8%, S 4.0% and ZN 1.0%) was applied pre sowing in all five experiments. Seed was sown with a precision cone seeder in four rows at 30cm centres and dropped on soil surface and covered with trailing chain and followed by press wheels on a 1.8m raised bed. Experiments were then watered using furrow irrigation wetting up the whole bed. Timing of subsequent irrigation was calculated using evapotranspiration figures.

The two initial experiments were sown in March 2017, the first to identify suitability of varieties for growing at the Leeton Field Station site and secondly to investigate sowing using irrigation on beds in the Riverina

environment. These quinoa seed for all varieties was supplied from Western Australia. The other three experiments were conducted in late 2017 and focused on sowing dates.

Weed control was attempted pre- and post-sowing. Glyphosate 360 was used pre sowing and Dual Gold® post sowing to treat weeds before emergence of the quinoa. Additional grass weed control was with Verdict™520 after crop emergence.
The young quinoa plant is susceptible to Flea beetle *Chrysomelidae Alticini* which eats the leaves of the emerging plant and can kill or delay the development of the plant. Flea beetles were a serious issue in the experimental plots at Leeton Field Station and were sprayed with Firepower® if damage was seen on emerging crop.

Establishment counts were carried out on 1 m by four rows per plot. This 1m was pegged and used for hand harvest to collect yield and harvest index data. Flowering dates and plant heights were also recorded. Each trial was analysed separately with GenStat 18.

Three key agronomic parameters were evaluated in separate experiments. These were:

-*Variety suitability* compared thirteen varieties to assess their performance in the Riverina environment under irrigation. One variety (V2) had limited seed and was sown as an unreplicated plot. The experimental design was randomised by splitting the 12 varieties into 2 beds and these were replicated 3 times. The variety experiment was sown at 4kg/ha due to limitation in amount of seed.

- *Sowing density* was evaluated on two varieties (BEW and JC1) using three sowing rates of 2kg/ha, 4kg/ha and 8kg/ha. Four replicates of each rate were conducted within the one trial site. Both the variety and density experiments were sown on 16 March 2017 and watered on the 17 March. These two experiments were hand harvested 27 July and machine harvested 24-25 August

-*Time of sowing* experiment was conducted using six varieties that were selected based on results from the variety experiment. Each plot was sown at 7kg/ha at three different sowing times; 27 October 2017, 20 November 2017 and 19 December 2017 . They were hand harvested 24 and 26 April 2018 for the first two sowing dates and 16 May 2018 for the third sowing date. The plots that were not senescing were desiccated using Reglone® and machine harvested 7 June 2018.

Results

Variety suitability
The variety experiment results gave an indication of those varieties that were suited to the growing conditions at Leeton Field Station and those that were not. Variety V2T was significantly affected by frosts at flowering whereas most of the other varieties had finished flowering by the time the frosts occurred. Average yields taken from the replicated plots of the varieties and V2 from an unreplicated plot are featured in Figure 1.

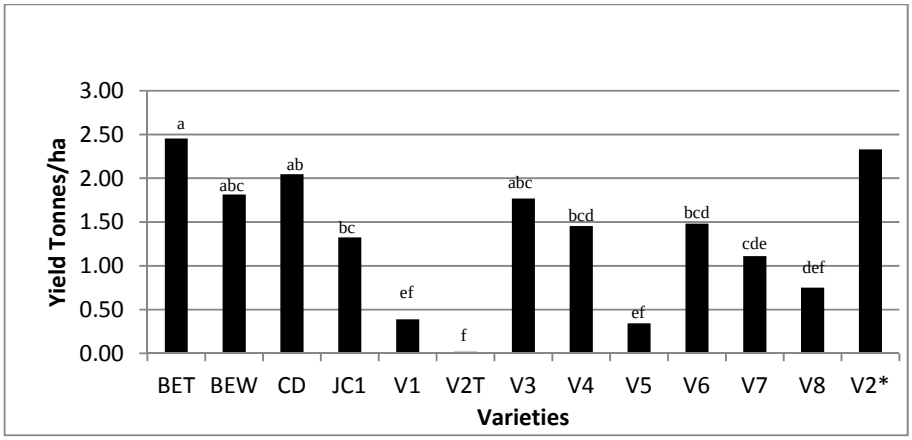

Figure 1. Yield (Tonnes/ha) of thirteen quinoa varieties (V2* not replicated). Significant difference is indicated by different letters (*P*<0.05).

Sowing density

JC1 and BEW at the lowest rate of 2kg/ha did not differ significantly in plants per metre length of bed (data not shown). JC1 and BEW at 4kg/ha and BEW at 8kg/ha did not differ significantly in plants per metre of bed. JC1 at 8kg/ha was significantly higher than all other treatments including BEW at 8kg/ha.

The yields of the experiment showed a significant difference between the 2kg/ha sowing rate of both varieties compared to the 4kg/ha and 8kg/ha Figure 2.

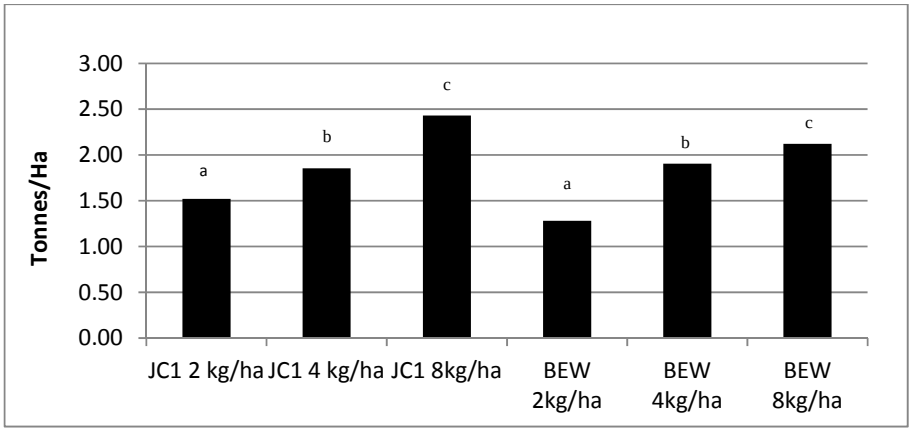

Figure 2. Plant density yield (tonnes per hectare) from different sowing rates. Significant difference is indicated by different letters (*P*<0.05).

Time of sowing

From the initial variety experiment, six varieties were selected on their yield performance and pureness. These varieties were then sown at three different times to examine a sowing window recommendation for quinoa in the Riverina. The yields achieved in these experiments varied enormously Figure 3 and Table 1.

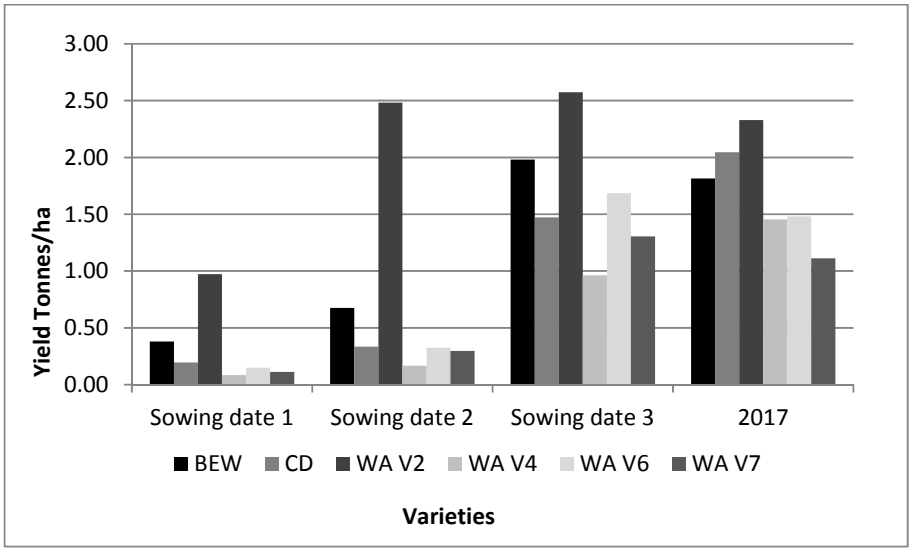

Figure 3. Time of sowing yields with 2017 yields as a comparison.

Variety	BEW	CD	V2	V4	V6	V7
Sowing date 1	0.38 **b**	0.19 **bc**	0.97 **a**	0.08 **c**	0.15 **bc**	0.11 **bc**
Sowing date 2	0.68 **b**	0.33 **b**	2.48 **a**	0.17 **b**	0.32 **b**	0.29 **b**
Sowing date 3	1.98 **ab**	1.47 **bc**	2.57 **a**	0.96 **c**	1.68 **bc**	1.31 **bc**

Table 1.Grain yield tonnes/ha. Significant differences within sowing dates are indicated by different letters (*P*<0.05).

Preliminary results indicate quinoa is susceptible to low and high temperatures at flowering. The three sowing dates in the 2017/18 experiments encountered differing numbers of days above 34^0 Celsius which is thought to be the temperature above which flowering abortion occurs. The number and timing of consecutive days over 34^0 Celsius may have been the difference between the floret damage in sowing dates 1 and 2 and the lower floret damage in sowing date 3. Further investigation would help to make this clearer. The higher yield of V2 could suggest a tolerance to the higher temperatures experienced during the experiment, further investigation needs to be carried out to better understand and verify this and the yield difference.

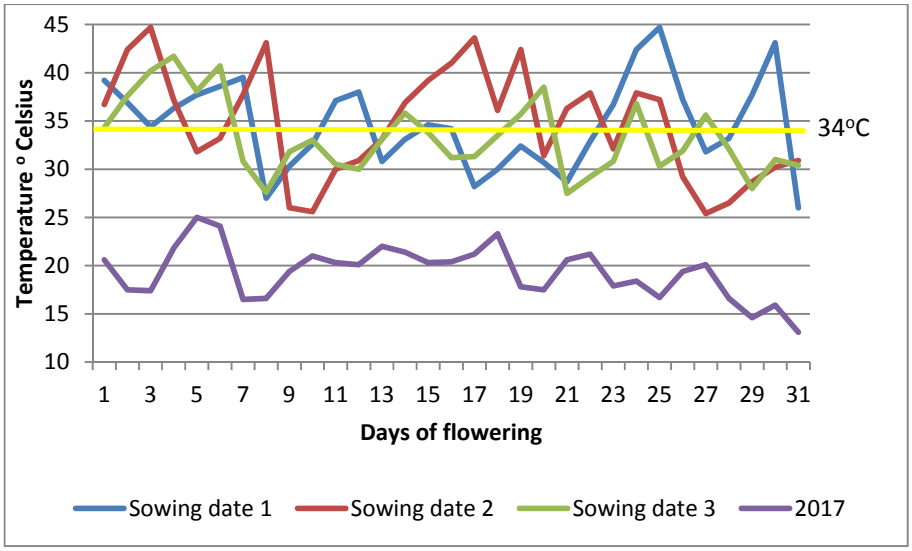

Figure 4. Maximum temperature during flowering for each sowing date, and the sterility threshold temperature of 34 °C

Conclusion

The data from these experiments is from one season only and would need to be repeated to be confident in any recommendations. Preliminary evidence for suitability of quinoa production as a summer irrigated crop in the Riverina is available. The preferred window for sowing quinoa to achieve best yields based on limited research experiments undertaken in NSW appears to be between late December and February to avoid extreme temperatures during flowering. This may also coincide with later water allocations which are too late to be of benefit for many other crops.

The experiments have also identified varieties that appear to be more tolerant to both high and low temperatures and would therefore be more suited to the Riverina region. Temperature variations will need further investigation to identify whether it is temperature levels, length of exposure or timing to higher temperatures have the greatest influence on the floret damage and reduced yield.

References

Aloisi, I., Parrotta, L., Ruiz, K. B., Landi, C., Bini, L., Cai, G., . . . Del Duca, S. (2016). New Insight into Quinoa Seed Quality under Salinity: Changes in Proteomic and Amino Acid Profiles, Phenolic Content, and Antioxidant Activity of Protein Extracts. *Frontiers in Plant Science, 7*(656). doi:10.3389/fpls.2016.00656

Cusack, D. F. (1984). Quinua: grain of the Incas. *Ecologist, 14*(1), 21-31.

Jacobsen, S. (2003). The worldwide potential for quinoa (Chenopodium quinoa willd.). *Food reviews international*. Vol.19, NOS 1&2, pp.167-177

Tagle, B., & Planella, M. T. (2002). La quinoa en la zona central de Chile. Supervivencia de una tradición prehispana. *Santiago: Editorial IKU*.

Vega-Galvez, A., Miranda, M., Vergara, J., Uribe, E., Puente, L., & Martinez, E. A. (2010). Nutrition facts and functional potential of quinoa (Chenopodium quinoa willd.), an ancient Andean grain: a review. *Journal of the Science of Food and Agriculture, 90*(15), 2541-2547. doi:10.1002/jsfa.4158