SA Industrial Hemp Trials 2017/18

PRELIMINARY REPORT

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SA Industrial Hemp Trials 2017/18 – Preliminary Report

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Disclaimer

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- Mickey Wang
- Gary Grigson
- Brian Dzoma
- Amanda Pearce
- Ian Ludwig

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Executive Summary

The key findings in the report are:

- The trials have clearly shown that industrial hemp will grow very successfully in South Australia.
- Some of the key practices which help achieve good production include:
    - Planting in free draining soil;
    - Using good quality irrigation water (<1500 parts per million (PPM) / <2700 electrical conductivity units (EC));
    - Achieving a high plant density (>50 plants/m^2 in leafier varieties such as ECO_16AH, Han_NE and Frog 1, and higher still in less leafy varieties such as Ferimon 12 and ECO_50GC) assists in controlling weeds through early canopy closure.
- Performance of different varieties varies between Loxton and Kybybolite, and between different times of sowing. More research is required to clearly identify best variety and timing combinations.

A final report will be released once all of the grain quality data, and fibre/hurd yield and quality data, is finalised.

A second round of trials is now underway at Loxton and Maaoupe (near Coonawarra) to add to the available information.

Background

The passing of the Industrial Hemp Act by the SA Parliament in April 2017 to legalise the production of industrial hemp crops within South Australia, and the agreement by state and federal governments to allow the sale of hemp products as food in November 2017, created the need for a solid research footing to support the development of a hemp growing industry within South Australia.

Experience in Victoria suggested that the prime market for industrial hemp is in grain production, especially given the legalisation of hemp seed and hemp seed oil as food products. The bast fibre and hurd from the crop is of relatively low value, and facilities and expertise to extract them are currently scarce and scattered. As a result it is not likely to be economical to grow hemp primarily for fibre and hurd in the short term, rather fibre and hurd production is expected to be a by-product of grain production.

Previous South Australian hemp growing research carried out in 1995 (Potter and Hannay 1996) gave variable results, but clearly indicated that production under rain-fed conditions in the mid-north and on Yorke Peninsula was not viable. Irrigated production at Kybybolite in the South East proved successful, however the focus was on fibre production, and no seed was allowed to set. No further research has been carried out in South Australia since that time.

With the legalisation of hemp growing in other states over recent years, variety breeding and selection has occurred elsewhere in Australia, as well as across the world, providing a wider range of varieties worthy of evaluation under South Australian growing conditions.

It was therefore timely to carry out trials of some of the most promising varieties, across some of the potential production areas within South Australia, and test aspects of the timing and agronomy required to grow commercial crops of hemp for grain production, and to also assess the yield and quality of fibre and hurd produced as a by-product.

Project Scope

The focus of this project is on the cultivation of industrial hemp in South Australia, specifically on production of hemp grain. Development of processing and markets is outside the scope of this project. However, it was important that the grain, fibre and hurd produced in this trial was assessed as to its suitability for a range of uses.

As a result, the broader project comprises multiple components:

- SARDI is conducting trials comparing varieties and times of sowing;
- University of Adelaide is assessing the quality of the grain produced;
- CSIRO is assessing the yield and quality of the bast fibre and hurd produced.

This preliminary report covers results from the SARDI field trials, and some initial results from the University of Adelaide’s analysis of the grain grown in the SARDI field trials. Full results from the grain, fibre and hurd analysis will be included in a final report to be released at a later date.

Materials and Methods

The first season of industrial hemp field trials were established at two SARDI Research Centres, at Loxton and Kybybolite. These sites represent different climatic conditions in terms of rainfall, temperature and humidity, and also vary in terms of soil type and chemistry and irrigation water quality. Some parameters of the two sites are detailed in Table 1.

Five varieties were selected through initial prescreening of 20 varieties readily sourced within Australia, for a range of factors contributing to the food value of hemp grain. The varieties selected for planting at the field trial sites are summarised in Table 2, along with some details about their characteristics.

All varieties were subjected to the same five "Time of Sowing" (ToS) treatments. Due to the logistics associated with two geographically separated trial sites, the ToS treatments were applied to the two sites within a few days of each other, as detailed in Table 3.

Table 1 Details of trial site parameters

Site	Latitude	January average daily max temp	January average daily min temp	Soil type	Irrigation water salinity
Loxton	-34.4°	32°C	15°C	Sandy loam	~300 mg/L (~540 EC)
Kybybolite	-36.9°	30°C	12°C	Clay	~2000 mg/L (~3600 EC)

Table 2 Varieties chosen for 2018 field trials

Variety	Origin	Season	Type	Primary Use	Reported THC (%)
ECO-16AH	Australia	Late	Dioecious	Grain/Fibre	0.27
Ferimon 12	France	Mid	Monoecious	Grain	0.03
ECO-50GC	Australia	Early	Dioecious	Grain	0.03
Frog One	Australia	Late	Dioecious	Grain/Fibre	<0.3
Han-NE	China	Mid-late	Dioecious	Grain/Fibre	<0.3

Table 3 Dates of Time of Sowing (ToS) treatments at each trial site

Site	ToS 1	ToS 2	ToS 3	ToS 4	ToS 5
Loxton	20/10/17	10/11/17	30/11/17	20/12/17	15/1/18
Kybybolite	23/10/17	7/11/17	29/11/17	18/12/17	11/1/18

Each combination of variety by ToS was replicated four times at each trial site. In order to minimize the potential for mature plantings to impact on younger plantings, each ToS was planted as a contiguous block, with varieties randomized within the block. Further, the first ToS treatment was planted at the southernmost edge of the trial site, with subsequent plantings being always to the north of the last planting, to avoid shading of new plantings by larger plants from previous ToS treatments.

The Loxton trial site was irrigated using overhead sprinklers on 2.5 m tall risers, spaced at 10 x 12 m. Irrigation at the Kybybolite trial site was applied using a travelling irrigator. Irrigation scheduling was determined by the manager at each site, in response to rainfall and climatic conditions.

Fertiliser applications were also managed by the local site managers, according to soil conditions at the trial sites. The timing and amount of major nutrients applied to each trial site are summarized in Table 4. In summary, both sites received similar amounts of Nitrogen, but differed in the amount of Phosphorous applied. Kybybolite also received an application of Potassium, whilst Loxton received Sulphur.

Table 4 Type, amount and timing of fertiliser applications

Site	Timing	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)
Loxton	At sowing	18	25		
	Post emergence	100			20
Kybybolite	At sowing	63	70		
	Post emergence	37		110	

Crop growth stage was monitored using the decimal code developed by Mediavilla, Jonquera et al. (1998), to accurately compare development of different treatments.

Sampling for THC testing was carried out at 50% female flowering. Eight flower heads were collected across each variety by ToS treatment at Loxton (excluding the fifth ToS treatment), and from the first four ToS treatments of the variety ECO-16AH at Kybybolite. The samples were dried and forwarded to the Southern Cross University's Analytical Research Laboratory for grinding and THC testing.

Results and Discussion

A selection of data is displayed in the following graphs. In each case the graph for the Loxton trial site is on the left, and a separate graph for the Kybybolite trial site is on the right. However, all details of the graphs are identical, including scaling of the axes, to assist in comparing data between the two sites.

The depth of water applied to the trial plots is shown in Figure 1. The values represent all water applied, both irrigation and rainfall. The values vary between treatments as they are the sum of applications between sowing and harvest. As a result the earlier sown and later harvested treatments accumulated more applied water than treatments sown later or harvested earlier.

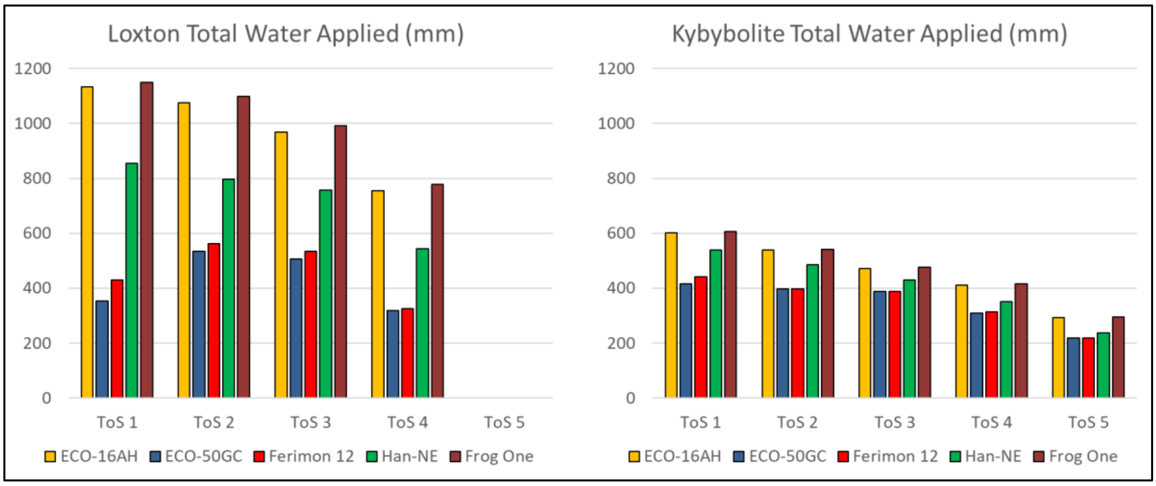

Figure 1 Depth of water applied from sowing to harvest

Differences between Loxton and Kybybolite reflect both a cooler climate at Kybybolite, and also different management of the sites. Irrigation management at Kybybolite was difficult due to its remoteness and the lack of staff located onsite, and as a result it appears that irrigation was possibly sub-optimal.

Figure 2 displays plant counts carried out between three and four weeks after sowing, to assess the density of plants established in each trial plot. The target plant density was 75 plants/m^2 in every case, and seed sowing rate was calculated according to the germination percentage provided for each batch of seed, plus an expectation that 80% of germinated seeds would result in established plants.

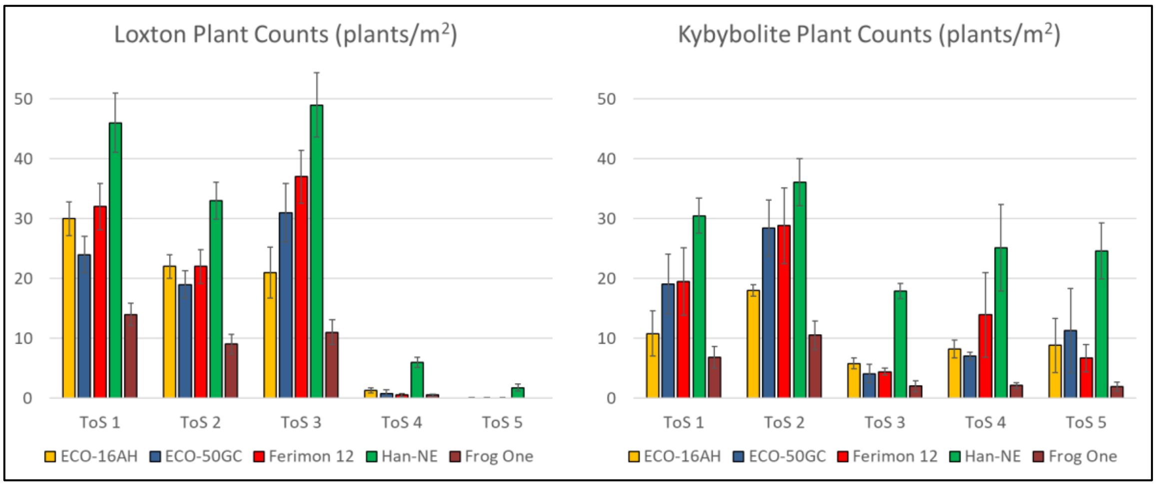

Figure 2 Average plant count at establishment (error bars are SE)

It is clear from Figure 2 that crop establishment was much lower than expected, with the maximum establishment density less than 50 plants/m^2. Major differences can also be seen between the early ToS treatments and later ToS treatments, especially at Loxton. This particularly reflects extreme weather conditions immediately following sowing of the ToS 4 and 5 treatments at Loxton. In the week following sowing of ToS 4 at Loxton there were two days with maximum temperatures of 38.7 and 40.0°C respectively, and in the week following sowing of ToS 5 there were four days above 40°C. These conditions severely impacted on the small seedlings emerging from the sandy soil, with the heat impacting the seedlings directly, and also indirectly by making it extremely difficult to maintain soil moisture in the sandy soil of the shallow seed bed, given that hemp seed is sown quite shallow (< 25 mm).

At Kybybolite in the week following ToS 4, temperatures were milder, with the maximum not rising above 30°C. However, conditions at Kybybolite were severe following ToS 5, with two days above 40°C, so the better performance here than at Loxton at this ToS is perhaps due to the heavier soil not drying out as quickly under these severe conditions. However, at Kybybolite some of the later ToS treatments suffered from salt burn due to the high salinity of the irrigation water, and the lack of rainfall to assist with leaching salt from the rootzone at these later sowing times. It was noted that Han-NE appeared more tolerant of salt than other varieties, which is reflected in the plant counts for these later sowing dates.

The life cycle information in Figure 3 demonstrates the variation in growth habit between varieties, which are essentially split into two groups. In the first group (ECO-50GC and Ferimon 12) flowering and harvest were staggered between ToS treatments, with similar intervals between sowing, flowering and harvest independent of when they were sown. The second group (ECO-16AH, Frog One and Han-NE) showed more consistency in the timing of flowering and harvest between ToS treatments, irrespective of sowing date.

The key difference between these two groups was the trigger for flowering. In the first group flowering did not appear to be linked to day length, but this may reflect the fact that these varieties were developed in higher latitudes, where day length in summer is much longer than in South Australia. In the second group flowering did not occur until day length began to decline, after the New Year. There were also clear differences in timing within this group, with Han-NE flowering in response to day length change quite quickly, followed by ECO-16AH, and Frog One was the slowest to respond.

The late flowering of Frog One resulted in harvest occurring in late May and early June, well after normal season breaking rains. In the very dry spring of 2018 this was not a problem, but in a more “average” year conditions could be expected to be quite wet at this time of year, which would make harvesting the crop much more challenging.

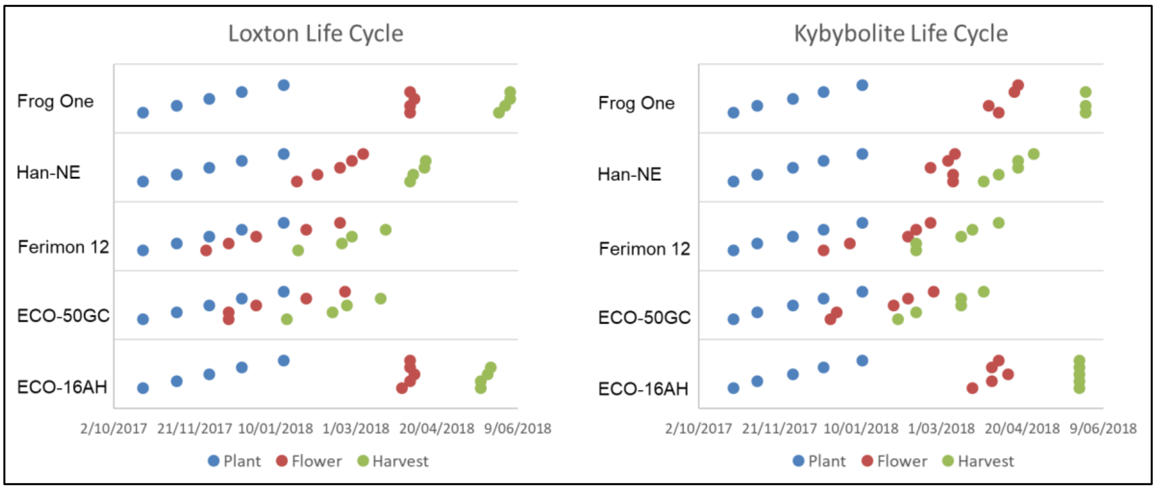

Figure 3 Timing of key growth stages

One result of the difference in flowering between the two groups of varieties was the final size of the plants (Figure 4). When ECO-50GC and Ferimon 12 flowered their vertical extension slowed dramatically, as the plants put energy into flower rather than vegetative growth. As a result these plants only reached a little over one metre tall. On the other hand, ECO-16AH, Frog One and Han-NE continued to grow until they flowered, and in the earlier ToS treatments reached around 3 m tall at Loxton, and 2.5 m tall at Kybybolite. Interestingly they did not continue to grow much beyond 3 m, and Figure 4 shows a levelling out of height at Loxton at around 3 m. Figure 4 presents data from ToS 1 only, but plants in ToS 2 and 3 at Loxton also reached 3 m in height before harvest.

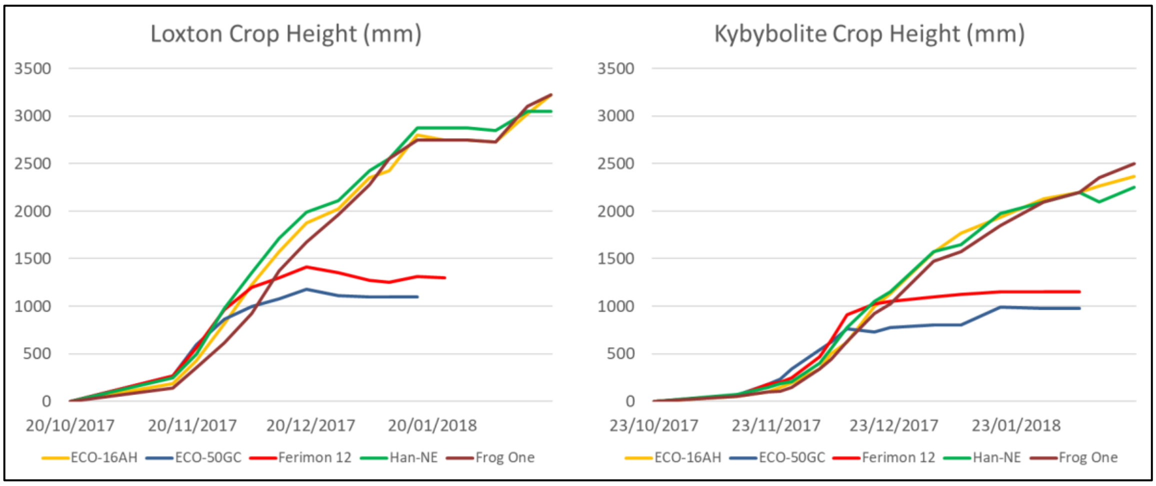

Figure 4 Average plant height over time in ToS 1

THC testing results are displayed in Table 5. There is a difference between the early flowering varieties (ECO-50GC and Ferimon 12), which accumulated only low levels of THC, and the longer season varieties, which accumulated at least double the THC concentration in most cases. This could be due to intentional breeding for very low THC in these varieties, or may be related to the very short growing season of these early varieties, limiting cannabinoid production.

Samples collected at Loxton were below the mandatory 1% limit. There is a clear difference in THC in variety ECO-16AH between Loxton and Kybybolite. At each ToS treatment the THC levels at Kybybolite were around double the levels at Loxton, and ToS 4 was much higher, just above the 1% limit. ECO_16AH was the only variety sampled at Kybybolite, due to logistical limitations, but it is highly likely that a similar pattern of higher THC occurred in all varieties.

Table 5 THC content (% w/w) results

Site	Variety	ToS 1	ToS 2	ToS 3	ToS 4	Average
Loxton	**Frog One**	0.26	0.37	0.30	0.26	**0.30**
Loxton	**Ferimon 12**	0.16	0.17	0.16	0.17	**0.17**
Loxton	**Han-NE**	0.47	0.42	0.42	0.80	**0.53**
Loxton	**ECO-50GC**	0.17	0.16	0.17	0.19	**0.17**
Loxton	**ECO-16AH**	0.44	0.37	0.40	0.28	**0.37**
Kybybolite	**ECO-16AH**	0.77	0.80	0.93	1.01	**0.88**

Reasons for the difference in THC between sites are complex, but there is evidence that the levels of active substances in a range of medicinal plants, including hemp, are raised by stress (Latta and Eaton 1975, Pate 1999, Kleinwachter and Selmar 2015). It is possible that the significantly lower irrigation amounts applied to the Kybybolite site, potentially combined with the high salinity of the water, resulted in plant stress, promoting greater production of cannabinoids, including THC.

The yield of grain harvested from a small subplot within each trial plot (converted to t/ha) is shown in Figure 5. Yield was variable even within ToS treatments, and performance of individual varieties was influenced by both time of sowing and site. Note that no plots from ToS 5 at Loxton were harvested due to the extremely poor crop establishment (Figure 2).

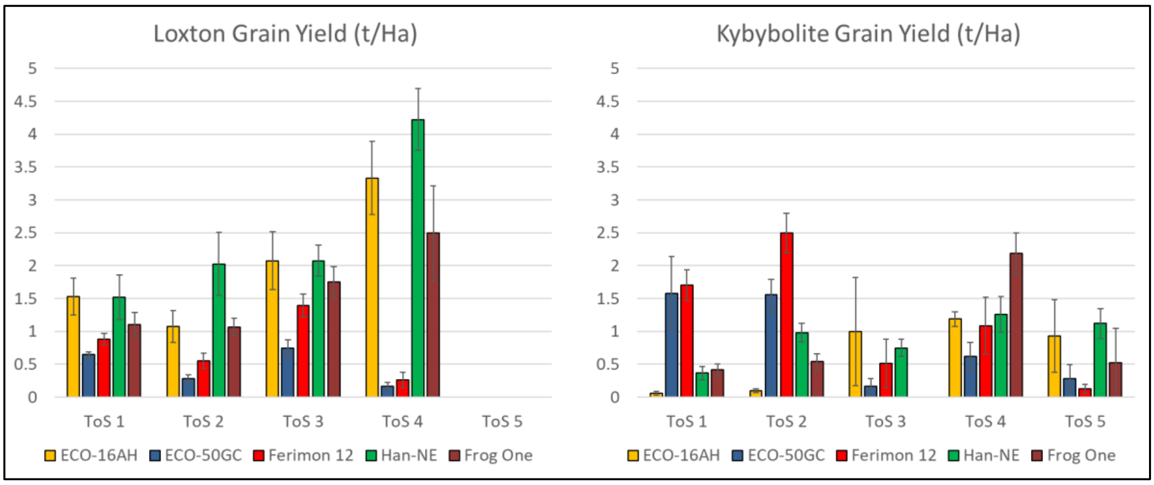

Figure 5 Average grain yield (error bars are SE)

At the Loxton site ECO-16AH and Han-NE were the top two yielding varieties in all ToS treatments, and ECO_50GC and Ferimon were the lowest yielding. Potential contributors to the poor performance of these early flowering varieties may include the small size of the plants when they flowered, limiting their ability to fill grain adequately, and also poor weed control due to sub-optimal plant density and the small and upright nature of the plants, which consequently failed to provide the same level of weed smothering as achieved by the more vigorous plants of the other varieties.

At Kybybolite there was less clarity between varieties, with ECO-50GC and Ferimon 12 yielding well in the early ToS treatments, but not in the later ToS treatments, relative to the later flowering varieties.

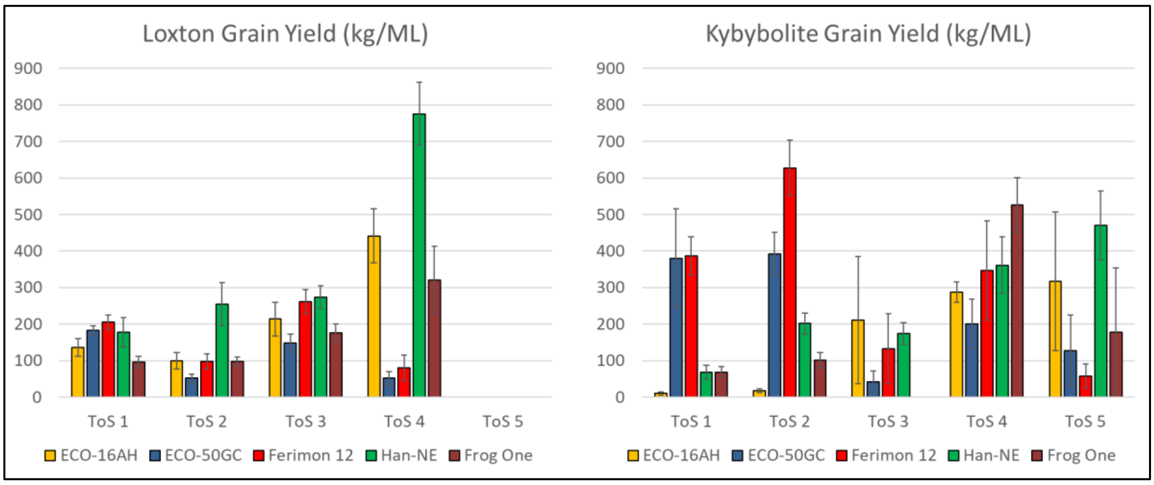

Figure 6 Average grain yield per volume of water applied (error bars are SE)

Water use efficiency, or yield per volume of water applied (t/ML) is displayed in Figure 6. Efficiency generally increased in later ToS treatments for ECO_16AH and Han_NE at both sites, due primarily to the decreased amount of water applied to these later treatments. It is clear that planting these varieties early is not an advantage, as the increased cumulative water application did not result in additional yield (Figure 5), and as a result water use efficiency was decreased.

Gross yield is only one aspect of production, especially when considering marketing grain for human consumption. The University of Adelaide conducted a number of tests to analyse the quality of the grain produced in the trials. The data presented here represents the initial set of data received from the University, further laboratory testing is continuing and will be reported in the final report at a later date.

Figure 7 displays relative grain weight (weight per 100 grains), and demonstrates a reduction in grain weight in the early flowering varieties (ECO-50GC and Ferimon 12) compared to the later flowering varieties at Loxton, with much less difference at Kybybolite. For some uses, such as oil or flour production, the smaller grain size may not cause a problem, but for hemp hearts or wholegrains size will likely be an important factor in crop value.

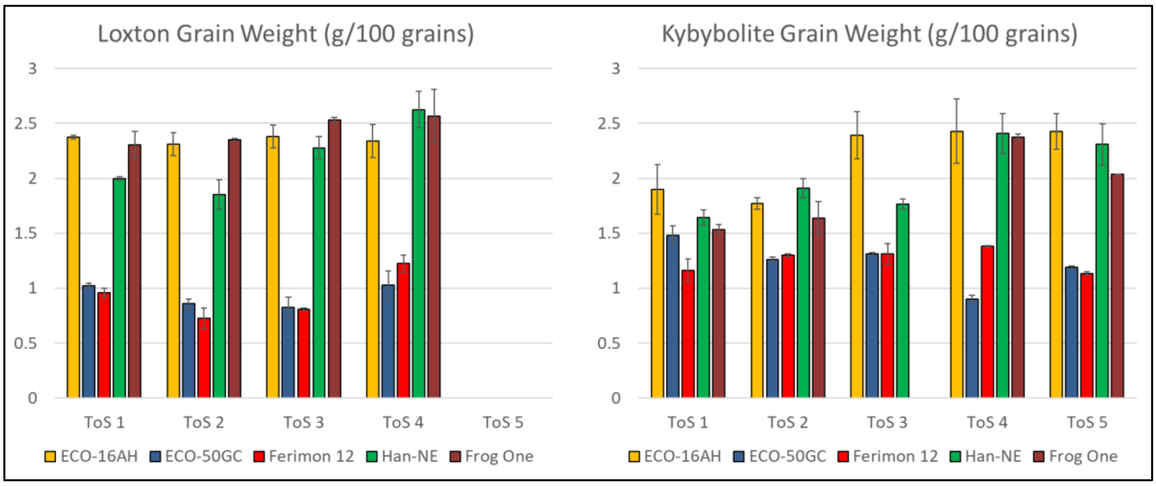

Figure 7 Average weight of 100 grains (error bars are SE)

Another key factor affecting eating quality of wholegrain, and yield of hemp hearts, is heart to hull ratio. Data in Figure 8 shows heart:hull ratio for one replicate of each variety/ToS/site combination, with a 1.0 ratio line (equal weight of heart and hull) included for easy comparison.

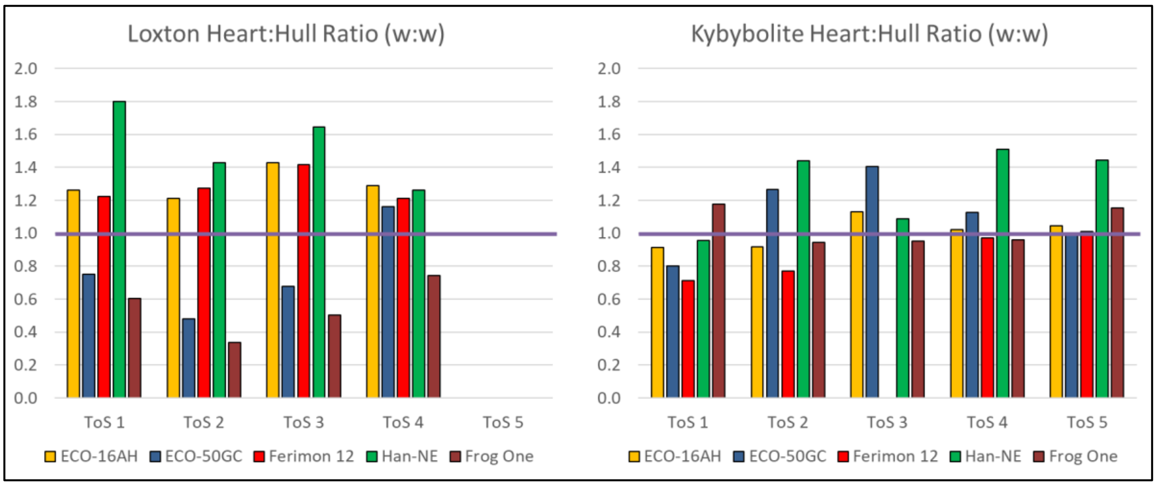

Figure 8 Representative ratio of heart to hull by weight, including 1:1 line for comparison

At Loxton, Frog One consistently produced grain with less heart than hull (ratio <1.0), which is not a desirable trait for eating or heart yield. ECO-50GC also produced very low heart:hull ratio in three of the four ToS treatments at Loxton, while Han-NE had the highest ratio across treatments. At Kybybolite no variety consistently produced grain with heart:hull ratio >1.0, but again Han-NE averaged the highest ratio across all treatments, followed by ECO-50GC. The inconsistency in performance of some varieties between the two trial sites is unexplained to date.

During harvest and grain threshing it became clear that there was a significant amount of grain in some treatments which was empty when cracked open. Detailed assessment of unfilled grain was carried out, and the results are displayed in Figure 9, presented as the percentage of grain which was properly filled. Note that the percentage axis begins at 50%, to enhance the differences between treatments.

All varieties showed some level of unfilled grain (< 100% filled grain), with some individual treatments recording as low as 60% filled grain (40% unfilled). It is difficult to identify clear trends, especially as the data comes from only one replicate of each treatment.

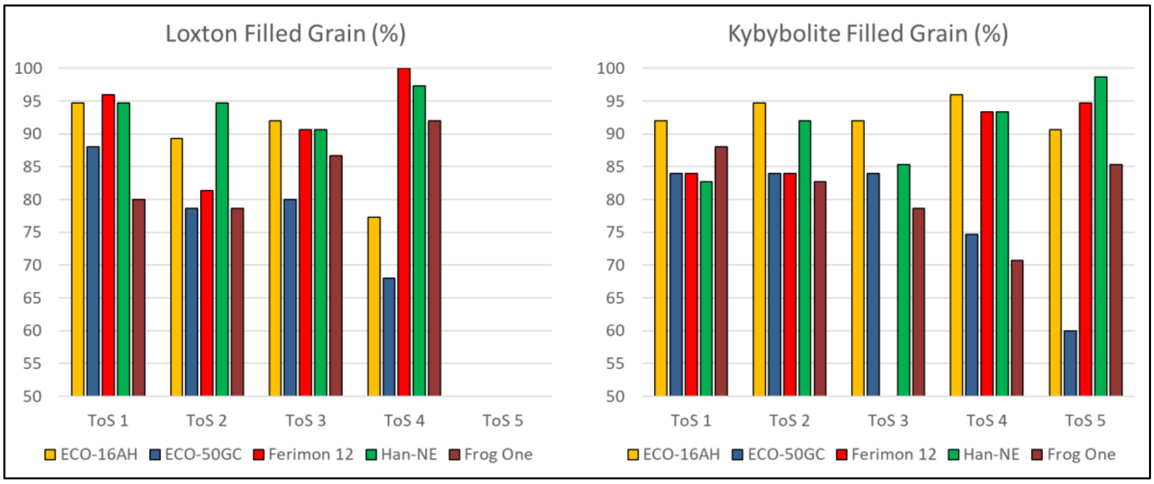

Figure 9 Representative percentage of fully filled grain

As noted above, further laboratory analysis of grain quality parameters is being undertaken by the University of Adelaide. In addition CSIRO are conducting fibre and bast yield and quality assessments on plant material sampled from the trial. When the results of these analyses is received a Final Report will be prepared containing this additional information.

Additional Agronomic Observations

As noted above, water salinity was a concern at the Kybybolite site. In early sown crops the winter rainfall stored in the soil, as well as regular rainfall events, diluted the effect of the saline irrigation water (2,000 ppm / 3600 EC units), resulting in little impact on the crop. Rainfall contributes fresh water to the soil, directly diluting irrigation water, and also assists in leaching salt from the rootzone..

However, in later plantings when the bulk of crop water use was sourced from irrigation water in the absence of rainfall, clear salt burn symptoms were evident in the young crop (Figure 10), and significant plant death was apparent. This resulted in low plant density in the later ToS treatments compared to earlier ToS (Figure 2). Interestingly, more mature plants (taller than around 20 cm) did not show the same impact from salt as younger plants, suggesting an ability for hemp to grow out of susceptibility to salt impacts.

Figure 10 Salt burn symptoms at Kybybolite

Hemp is also reported to be susceptible to waterlogging (Amaducci, Scordia et al. 2015), and observations at Kybybolite support this conclusion. An intense rainfall event of 23 mm, three weeks after sowing of the first ToS treatment at Kybybolite resulted in runoff accumulating in one of the trial plots due to the heavy soil. This caused waterlogging in this plot, and resulted in significant plant death. Free draining soil is highly recommended for hemp growing, to avoid this potential issue.

Another issue identified at the trial sites was weed control. There are no herbicides registered for use on hemp, and only a small number for which permits have been granted. Furthermore, there is almost no information on how these herbicides impact on hemp plants. At the trial sites the best weed control was achieved through smothering of weeds by the hemp canopy. This mechanism failed when plant density was low, and in the less leafy varieties ECO-50GC and Ferimon 12, which were more upright and allowed much more light to penetrate to the soil. This was particularly a problem at Loxton, where caltrop (*Tribulus terrestris* L.) became a major problem. Higher plant density would most likely help to address this (Amaducci, Scordia et al. 2015), as would good weed control prior to sowing, although for caltrop this is not effective due to the very hard coating on the seed, allowing seed to carry over in the soil for many years.

Conclusion

The first season of trials at Loxton and Kybybolite Research Centres have shown that industrial hemp can be successfully grown under South Australian conditions, when grown as an irrigated summer crop.

The trials compared five different industrial hemp varieties sown across five different sowing times, from late October to mid-January. Performance of the varieties varied between Loxton and Kybybolite sites, and between the different sowing times. More research is required to clearly identify best variety and timing combinations in the Riverland (Loxton) and Limestone Coast Kybybolite) regions.

Some of the key agronomic factors contributing to a successful industrial hemp crop include planting in free draining soil to avoid waterlogging, using good quality irrigation water (<1500 parts per million (PPM) / <2700 electrical conductivity units (EC)) to avoid salt burn which can lead to death of young seedlings, and achieving a high plant density (>50 plants/m2) to help smother weeds.

This report is preliminary only, and contains such data as was available for publication as at October 2018. A final report will be released once all of the grain quality data, and fibre/hurd yield and quality data, is received from project partners the University of Adelaide and CSIRO.

A second season of trials is underway at Loxton and Maaoupe (near Coonawarra), to replicate the trials under another set of seasonal conditions. In addition to moving the Kybybolite trial site to another location with better soil and water quality, some of the varieties have been removed from the trials based on their performance in the initial year of trials, and additional varieties have been included for evaluation.

The immediate focus of this research project remains the evaluation of varieties and times of sowing for optimal industrial hemp production in South Australia. However, future research questions could include evaluation of the impact of varying plant density or irrigation and fertiliser rates on yield and quality of industrial hemp grain, fibre and hurd.

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