Final Technical Report

Investment in WA-Focused Linseed Agronomy.

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Abstract

Western Australia's southern cropping regions have a need for further diversification in crop rotations for disease and weed management and for the development of more robust and sustainable farming systems. Current rotations revolve around cereal grains with break crops being heavily reliant on canola.

Linseed is not new to Western Australia or the Great Southern region as it was grown in the Boyup Brook region from the 1940's to the 1960's. Linseed (flax) *Linum usitatissimum* is a potential break crop that provides both a disease break and the opportunity for alternative weed management strategies. With an increasing consumer recognition of the nutritional value of flax seed and flax seed oil due to its high alpha-linolenic acid (ALA) content an omega-3 fatty acid there is potential for an increase in market demand.

The key objectives of this project were to determine if Linseed can be successfully grown under dryland farming conditions in southern WA, if any investment is required into machinery and infrastructure by growers to grow linseed, to develop basic agronomic guidelines and to assess the yield potential of three commercially available linseed varieties grown under dryland conditions in WA, Croxton, Glenelg and Bilton. All these outcomes were successfully achieved within the project.

Three small plot trials in 2019 and four producer demonstration sites in 2020 were undertaken in the Great Southern region of WA to determine if linseed could be successfully grown as a break crop under dry land growing conditions in Western Australia. In 2019 two commercially available linseed varieties were trialed assessing the response to time of sowing, seeding rates and nitrogen application rates. Harvest was by direct heading with the trial site average yields ranging from 0.56 to 0.99t/ha. In 2020 two commercially available linseed varieties were demonstrated Croxton and Bilton as part of the bulk up process of Linseed seed for future commercial production and to also integrate high level variety comparisons between the two varieties. Bilton yielded on average 0.95 MT/Ha and 85% of Canola and Croxton yielded on average 0.86 MT/Ha and 72% of Canola. Over the two seasons the trials and demonstrations were conducted, agronomic guidelines were developed and the crops were grown successfully in 2020 utilising producers existing cropping equipment.

The seasonal conditions may have contributed to Bilton out yielding Croxton. Bilton is a slightly shorter maturing variety and the below average rainfall received in 2020 is expected to have favoured shorter season varieties.

The project has successfully set in the place the ability for growers in the Great Southern region to scale up production of Linseed and demonstrated its ability to fit within the current rotations with the additional benefit of assisting in the long-term management of soil borne root pathogens.

While the agronomic building blocks for growers to scale up production in the Great Southern have been put in place, a remaining obstacle is the post farm gate marketability. For widespread adoption, there will need to be consistent year in year out demand, storage and handling options and Linseed oil processors (domestic and/or overseas). Positively however, grower adoption beyond the project has continued with over 60 Ha planted in southern WA in 2021 across 4 growers.

Executive Summary

Linseed is not new to Western Australia or the Great Southern region as it was grown in the Boyup Brook region from the 1940's to the 1960's. It was grown for fibre and milled at the Boyup Brook Flax Mill. Linseed (flax) Linum usitatissimum is a niche product and has the potential to offer an alternative revenue steam for producers outside of the traditional crop. Demand for Linseed has recently shifted to a health food. Linseed has several uses, it can be crushed for Linseed oil which is a rich source of linolic acid and Omega 3 fatty acid and the remaining linseed meal can then be used as livestock feed or it can also be eaten as a whole seed or ground.

Linseed also has agronomic benefits as a potential break crop that provides a disease break, the opportunity for alternative weed management strategies, provides an insect pest break and can be effective in reducing some soil borne root diseases and soil borne pathogens namely root lesion nematodes. Canadian research has demonstrated that cereal yields were higher when planted on linseed stubble compared to wheat stubble.

The aim of the project is to investigate agronomic packages which support the introduction and scale up of commercial cultivation of Linseed in the Great Southern region of Western Australia.

Consistent supply with volume is imperative to develop a market that has the ability to realise the full value of Linseed produced. Also, in order for growers to take up production it is important they have a full agronomic package available to grow the crop successfully. Finally, Linseed needs to generate an equivalent return per hectare of alternative rotational crops such as canola in order to expand into the rotation.

The key objectives of this project are:

A: To determine if Linseed can be successfully grown under dryland farming conditions in the Great Southern region of Western Australia with the potential to scale up to commercial cultivation.

B: To determine if any investment is required into machinery and infrastructure by growers to grow linseed.

C: To develop basic agronomic guidelines to grow linseed in WA.

D: To assess the yield potential of two commercially available linseed varieties grown under dryland conditions in WA, Croxton and Bilton.

The project was conducted over two years in 2019 and 2020. In 2019 the trials were conducted in small plots across three sites. In 2020 the trials were conducted as producer demonstration sites utilising grower machinery and large-scale plots.

In 2019 three sites were located across the Great Southern Region of Western Australia covering a variety of soil types, climates, paddock histories and growing conditions. The trials sites were in the shires of Darkan, Wagin and Kojonup. The trials involved growing two commercially available varieties Croxton and Glenelg over three times of sowing (TOS) 10 to 14 days apart at three seeding rates (SR): 35, 40 and 45 kg/ha and applying three top dressed nitrogen application rates (low, optimal and high) 40, 80 and 120 units N/ha.

Over the three trial sites, the seeding rates and nitrogen application rates trialed did not consistently result in significant differences in grain yield or oil quantity and quality. Time of sowing had the greatest impact, with the earliest time of sowing generally resulting in higher grain yields. Glenelg on average had a higher grain yield and oil quantity, with Croxton having the highest oil quality.

Trial Site	Average Site Yield t/ha
Darkan	0.562
Wagin	0.914
Kojonup	0.998

Table 1: Average Site Yields in 2019 (Below average rainfall)

The Darkan site plant counts were the highest, however this was not reflected in the yield. Darkan was the lowest yielding of the three sites. This may be due to the below average rainfall and lack of finishing rains experienced on the non-wetting forest gravel soils at this trial site. Kojonup and Wagin on average achieved nearly double the yield of the Darkan site despite lower plant counts and early plant disease.

In 2020 four demonstration/bulk up sites were established across the Great Southern Region covering a range of soil types, rainfall, rotations and growing conditions. The four sites were located in Katanning, Wagin, Darkan and Kojonup.

The methodology in the second year of the project was to bulk up the Linseed seed for future commercial production and to also integrate high level variety comparisons between the two varieties being utilized in the project Bilton and Croxton. Two sites, Wagin and Darkan, incorporated replicated plot treatments as a variety trial with the other 2 sites being predominantly bulk up sites.

The key outcome of any variety demonstration is the final yield result. Due to operational difficulties within the demonstration some yield data is not available however the key findings from the data available was:

- Bilton yielded on average 0.95 MT/Ha and 85% of Canola
- Croxton yielded on average 0.86 MT/Ha and 72% of Canola.
- Bilton out yielded Croxton on both sites.

The seasonal conditions may have contributed to Bilton out yielding Croxton. Bilton is a slightly shorter maturing variety and the below average rainfall received in 2020 is expected to have favoured shorter season varieties.

The project has successfully set in the place the ability for growers in the Great Southern region to scale up production of Linseed and demonstrated its ability to fit within the current rotations with the additional benefit of assisting in the long-term management of soil borne root pathogens.

However, for the scale up of the commercial cultivation of Linseed there is the requirement for beyond farm gate systems to be in place before producers will scale up production. An active market to determine a fair price, storage and handling facilities off farm to enable harvested grain to be stored before delivery to consumers, supply chains in place which enable efficient delivery of the grain anywhere around the world and long-term buyers/processors who will receive the grain year in year out. There is still a lot of process to be put in place before Linseed production will scale up to a considerable level.

Grower adoption beyond the project has continued with over 60 Ha planted in southern WA in 2021 across 4 growers. Confidence in the supply chain beyond the farm gate remains as the major obstacle stopping increased uptake and requires addressing before increased production can be expected.

Contents

Background

Linseed is not new to Western Australia or the Great Southern region as it was grown in the Boyup Brook region from the 1940's to the 1960's. It was grown for fiber and milled at the Boyup Brook flax mill. However, the mill ceased operation when Russia flooded the market with cheap product. Linseed has not been grown on a commercial scale in Western Australia since that time. Global production is estimated at 2.50 million tonnes annually, with Canada, China and the USA being the major producers.

Linseed (flax) Linum usitatissimum is a niche product and has the potential to offer an alternative revenue steam for producers outside of the traditional crop. Traditionally linseed was used as a commercial fibre crop but has recently shifted to a health food. Linseed has several uses, it can be crushed for Linseed oil which is a rich source of linolic acid and Omega 3 fatty acid and the remaining linseed meal can then be used as livestock feed. It can also be eaten as a whole seed or ground, raw or toasted and added to salads, cereals, smoothies or incorporated into baked goods.

Linseed also has agronomic benefits being a potential break crop that provides both a disease break, the opportunity for alternative weed management strategies and provides an insect pest break. It has been found that linseed grown after a cereal crop can be effective in reducing some soil borne root diseases including crown rot (*Fusarium pseudograminearum*), common root rot (*Bipolaris sorokiniana*), yellow leaf spot (*Pyrenophora tritici-repentis*) and spot form of net blotch *(Pyrenophora teres f maculate*), it is also resistant to two of the main species of root lesion nematodes *Pratylenchus thornei and P neglectus* (Hertel 2016).

Research conducted in Canada found that cereal yields were higher when planted on linseed stubble compared to wheat stubble. Canola and legume yields were also higher when grown on linseed stubble except in a drought year when yield was reduced. Increase in yields are associated with disease and insect pest breaks and weed control. (FCOC 5th Ed)

Linseed grown on canola stubbles has been found to perform poorly compared to other cereal and legume stubbles. This yield reduction is thought to be due to the negative impact canola has on soil arbuscular mycorrhizae and to the sensitivity of linseed to phytotoxic compounds release during canola stubble degradation. Canola also has high moisture and nitrogen requirements that can lead to soil depletion impacting on the subsequent crop. Linseed has a high soil arbuscular mycorrhiza fungi (AMF) dependency and significant yield losses can result if grown in low AMF situations. (FCOC 5th Ed)

Canadian research shows that linseed grown on cereal stubbles increased yield, with wheat and barley stubbles outperforming oat stubbles. Linseed grown on legume stubbles such as pea had similar yields to linseed grown on wheat stubbles. Linseed grown on linseed produced the lowest yields due to major plant pathogen build up. (FCOC 5th Ed)

There are numerous Linseed varieties available in Australia both of which are not under any type of PBR. Two varieties have been trialled and bulked up in this project:

- Croxton, is a blue flowering long season variety, with good wilt resistance but a taller variety that can be prone to lodging

- Bilton is a blue flowered variety, medium to late maturing with a good standing ability.

The re-emerging demand for Linseed along with the crop rotational benefits is expected to see an increase in production in future years. In order for this increase in production to transition smoothly and efficiently it requires the agronomic package to be developed to enable the crop to be grown within the modern production systems and to be specifically designed for the Great Southern climate and soils of WA.

Project objectives

The objective of the project is to support the introduction and scale up of commercial cultivation of Linseed in the Great Southern region of Western Australia and will support a larger initiative developed by Southern Dirt to develop a localised Linseed supply chain to take the crop from paddock to consumer on the back of renewed demand for Linseed's omega 3 oil composition and capturing additional value for local growers.

Consistent supply with volume is imperative to develop a market that has the ability to realise the full value of Linseed produced. In order for growers to take up production it is important they have a full agronomic package available to grow the crop successfully.

Additionally, Linseed needs to generate an equivalent return per hectare of alternative rotational crops such as canola in order to expand into the rotation.

The key objectives of this project are:

A: To determine if Linseed can be successfully grown under dryland farming conditions in the Great Southern region of Western Australia with the potential to scale up to commercial cultivation.

B: To determine if any investment is required into machinery and infrastructure by growers to grow linseed.

C: To develop basic agronomic guidelines to grow linseed in WA.

D: To assess the yield potential of two commercially available linseed varieties grown under dryland conditions in WA, Croxton and Bilney.

Methodology

The Linseed agronomy production project was conducted over two seasons 2019 and 2020. In 2019 the trials were conducted in small plots across three sites. In 2020 the trials were conducted as producer demonstration sites utilising grower machinery and large-scale plots.

2019 Methodology

Three sites were located across the Great Southern Region of Western Australia covering a variety of soil types, climates, paddock histories and growing conditions. Trials sites were in the shires of Darkan, Wagin and Kojonup.

Trial Site	Soil Type	*Average Annual Rainfall (mm)	*Rainfall 2019 (mm)	Paddock cropping History
Darkan	Forest Gravel (Non-wetting)	547	350	2017: Barley, 2018: Canola
Wagin	Loam	430	310	2017: Pasture, 2018: Barley
Kojonup	Loam/ sandy loam	524	387	2017: Pasture, 2018: Pasture

* Rainfall data from BOM.

Small Plots Trials:

- 1.5m x 10m.
- 162 plots/site with 3 replications at each time of sowing (TOS) in a randomised trial design. Trial design by SAGI.

Varieties:

Two commercially available varieties: Croxton and Glenelg.

Time of Sowing:

Three times of sowing (TOS) 10 to 14 days apart:

- The time of seeding was determined by seed availability, seasonal conditions (soil moisture), current seeding window for other crops and sowing time recommendations from eastern Australia.

Table 1: Times of Sowing

Time of Sowing	Darkan	Wagin	Kojonup
TOS1	30/5/2019	29/5/2019	29/5/2019
TOS2	12/6/2019	12/6/2019	13/6/2019
TOS3	25/6/2019	25/6/2019	26/6/2019

Table 2: Soil Moisture at TOS.

Time of Sowing	Darkan	Wagin	Kojonup
TOS1	Dry	Dry	Dry

TOS2	Slightly wet, moist	Slightly wet, moist	Slightly wet, moist
TOS3	Slightly wet, moist	Wet/ boggy conditions	Slightly wet, moist

Trials were seeded with a small Plot Air Seeder
- Direct Drilled
- Seeding depth: 0.5cm
- Tyne spacing: 24cm

Seeding Rates:

Three seeding rates (SR): 35, 40 and 45 kg/ha:

- Based on the linseed agronomic recommendations from Agriculture Victoria.

Fertiliser: 120kg/ha of Gusto Gold banded below the seed

Nitrogen Application Rates:

Three top dressed nitrogen application rates (low, optimal and high) 40, 80 and 120 units N/ha.

- Based on canola fertiliser recommendations.
- Nitrogen was as urea.
- Top dressed nitrogen applications of urea were applied on the 8/7/2019.

LowN	40 units N/ha
OptimalN	80 units N/ha
HighN	120 units N/ha

<u>Insecticide and Herbicide Applications</u>

All sites had a blanket insecticide application across the trial site prior to TOS 1 with Bifenthrin 200ml/ha, Alpha Forte 200ml/Ha and Chlorpyrifos 1L/Ha.

	TOS 1	**TOS 2**	**TOS 3**
Darkan	Trifluralin 2L/ha Sprayseed 2L/ha BS 1000 0.1%	Trifluralin 2L/ha Sprayseed 2.5L/ha BS 1000 0.1%	Trifluralin 2L/ha Roundup 3L/ha BS 1000 0.1%
Wagin	Trifluralin 2L/ha Sprayseed 2.5L/ha BS 1000 0.1%	Trifluralin 2L/ha Sprayseed 2.5L/ha BS 1000 0.1%	Trifluralin 2L/ha Roundup 3L/ha BS 1000 0.1%
Kojonup	Trifluralin 2L/ha Sprayseed 2.5L/ha BS 1000 0.1%	Trifluralin 2L/ha Sprayseed 2.5L/ha BS 1000 0.1%	Trifluralin 2L/ha Roundup 3L/ha BS 1000 0.1%

Table 2: Time of Sowing Herbicide Applications

Post emergent broad leaf weed control: Bromicide MA 1000ml/ha as required.

Post emergent grass control: Verdict 520 100ml/ha, Uptake 0.5%: as required.

Heliothis and Budworm Control: Alpha cypermethrin 300ml/ha, Chlorpyrifos 300ml/ha

2020 Methodology

In 2020 four demonstration/bulk up sites were established across the Great Southern Region of Western Australia covering a range of soil types, rainfall, rotations and growing conditions. The four sites were located in Katanning, Wagin, Darkan and Kojonup.

The method of the project was to bulk up the Linseed seed for future commercial production and to also integrate high level variety comparisons between the two varieties being utilized in the project Bilton and Croxton. Two sites, Wagin and Darkan, incorporated replicated plot treatments as a variety trial with the other 2 sites being predominantly bulk up sites.

Hall Trial Design - Katanning	**Treatments - 1 replicate**	
	1	Bilton
	2	Croxton
	3	Canola
Cummings Trial Design - Wagin	**Treatments - 4 replicates**	
	1	Croxton
	2	Bilton
	3	Bilton
	4	Croxton
	5	Canola
	6	Canola
	7	Bilton
	8	Croxton
	9	Croxton
	10	Bilton
	11	Bilton
	12	Croxton
	13	Canola
	14	Canola
Harrington Trial Design - Darkan	**Treatments - 2 replicates**	
	1	Bilton
	2	Croxton
	3	Canola
	4	Canola
	5	Bilton
	6	Croxton
Anderson Trial Design - Kojonup	**Treatments - 1 replicate**	
	1	Bulk up Croxton 12 Ha

Table 3: 2020 demonstration designs

Table 4 outlines the plot sizes for of the four demonstration sites and each of their agronomic packages.

Katanning:

Date	Operation	Product	Rate	Unit
	plot area	Bilton	8.5	Ha
		Croxton	1.5	Ha
		Mako Canola	35	Ha
20-Apr-20	Seeding	Bilton	45	kg/Ha
		Croxton	45	kg/Ha
		Mako Canola	4	kg/Ha
		Macro Pro Extra	100	kg/Ha
		Flexi N	40	L/Ha
27-Jun-20	Fert App 1	Urea	100	kg/Ha
10-Jul-20	Fert App 2	Flexi N	75	L/Ha
26-Mar-20		Roundup Ultra MAX	1	L/Ha
20-Apr-20		Trifluralin 480	2	L/Ha
22-Apr-20		Bifenthrin	0.08	L/Ha
		Chlorpyrofos	0.5	L/Ha
8-Jun-20		Clethodin	0.33	L/Ha
		Haloxyfop	0.1	L/Ha
		Clopyralid	125	g/Ha
10-Jul-20		MCPA	0.5	L/Ha

Wagin:

Date	Operation	Product	Rate	Unit
	plot area	Bilton	100 x 10	m
		Croxton	100 x 10	m
		Canola	100 x 10	m
16-May-20	Seeding	Bilton	50	kg/Ha
		Croxton	50	kg/Ha
		Canola	4	kg/Ha
		MAP blend	120	kg/Ha
		UAN	50	L/Ha
	Fert App 1	Urea	80	kg/Ha
19-Nov-20	Harvest			
17-May-20	PSPE	Bifenthrin 250	0.08	L/Ha
18-Jul-21		Verdict 520	0.1	L/Ha

Darkan:

Date	Operation	Product	Rate	Unit
	plot area	Bilton	100 x 12	m
		Croxton	100 x 12	m
		Canola	100 x 12	m
3-May-20	Seeding	Bilton	50	kg/Ha
		Croxton	50	kg/Ha
		Canola	4	kg/Ha
		NPK blend	150	kg/Ha
		Flexi N	50	L/Ha
	Fert App 1			kg/Ha
14-Dec-20	Harvest			
3-May-20		Paraquat	1	L/Ha
		Treflan	2	L/Ha
26-Jun-20		MCPA	0.5	L/Ha

Kojonup:

Date	Operation	Product	Rate	Unit
	plot area	Croxton	12	Ha
11-May-20	Seeding	Croxton	52	kg/Ha
		Agflow Cu ZN/MOP blend	110	kg/Ha
		Liquid Zn	0.2	L/Ha
		Lure (with seed)	1.5	L/Ha
28-Jun-20	Fert App 1	Urea/MOP	110	kg/Ha
15-Jan-21	Harvest			
		Glyphosate 450	1.5	L/Ha
11-May-20		Trifluralin 430	2	L/Ha
13-May-20		Bifenthrin 250	0.08	L/Ha
20-Jul-20		Factor	150	g/Ha
31-Jul-20		BromocideMA	1	L/Ha

Table 4: Plot size and agronomic packages for each demonstration site.

2021 Methodology

In 2021 Predicta B soil tests were taken on 3 of the 4 producer demonstration sites to test the impact of growing Linseed on soil borne pathogen root lesion nematode levels. The results were compared to the results from the soil tests taken prior to sowing the Linseed crop in 2020.

The following seasons crop yields on the Linseed and canola stubbles were measured to see if the impact of the Linseed crop on the root lesions nematodes was able to translate through to an impact on yield.

Location

NOTE: Where field trials have been conducted please include location details: Latitude and Longitude, or nearest town, using the table below (please add additional rows as required):

2019 Locations:

	Latitude (decimal degrees)	Longitude (decimal degrees)
Trial Site #1	-33.50291	116.70377
Nearest Town	Darkan	
Trial Site #2	-33.28106	117.28060
Nearest Town	Wagin	
Trail Site #3	-33.89466	117.03954
Nearest Town	Kojonup	

2020 Locations:

	Latitude (decimal degrees)	Longitude (decimal degrees)
Trial Site #1	-32.069251	115.757783
Nearest Town	Katanning	
Trial Site #2	-33.28106	117.28060
Nearest Town	Wagin	
Trial Site #3	-33.511739	116.688189
Nearest Town	Darkan	
Trial Site #4	-33.740925	116.975314
Nearest Town	Kojonup	

If the research results are applicable to a specific GRDC region/s (e.g. North/South/West) or Agro - Ecological Zone/s please indicate which in the table below:

Research	Benefiting GRDC Region (can select up to three regions)	Benefiting GRDC Agro-Ecological Zone (see link: http://www.grdc.com.au/About-Us/GRDC-Agroecological-Zones) for guidance about AE-Zone locations	
Experiment Title	Choose an item. Choose an item. Choose an item.	☐ Qld Central ☐ NSW NE/Qld SE ☐ NSW Vic Slopes ☐ Tas Grain ☐ SA Midnorth-Lower Yorke Eyre ☐ WA Northern ☐ WA Eastern ☐ WA Mallee	☐ NSW Central ☐ NSW NW/Qld SW ☐ Vic High Rainfall ☐ SA Vic Mallee ☐ SA Vic Bordertown-Wimmera ☐ WA Central ☐ WA Sandplain

Results

2019 small plot trial results

Harvest Results:

Harvest was completed on the 11/12/2019. All plots were harvested on the same day having all reached maturity at the same time regardless of the TOS. Plots were harvested by direct heading using a small plot harvester.

The main effects at the Darkan site were of variety and time of sowing with TOS1 being an important factor for producing the highest yields with the variety Glenelg generally out yielding Croxton. At the Kojonup site TOS1 was a factor in producing the highest yields but less so than at Darkan. At Kojonup the bottom 15 treatment combinations all involved Croxton. Unlike the other sites the Wagin site did not produce notable yield differences between the TOS or variety.

Darkan Harvest Results

Two of the plot treatments Glenelg TOS1; SR45; OptimalN and Glenelg TOS1; SR45; HighN had a mean yield significantly higher than the lowest yielding plots at the Darkan site. The two plots treatments with significantly higher yields appear to be anomalies in the data set with significant variability between the yields of the individual plots. The reason for the higher mean yields in these two plots alone was not able to be determined.

The average yield for the Darkan site was 0.562t/ha.

The seeding rates trialed did not produce significant yield differences at the Darkan site. Nitrogen rates were rated as significant however showed no consistent correlation with the other treatment variables. Variety and TOS produced the main effects with TOS1 on average producing the highest yields, and Glenelg on average out yielding Croxton.

Variety: TOS Average Yield, Darkan: t/ha			
	TOS1: 30/5/2019	TOS2: 12/6/2019	TOS3: 25/6/2019
Croxton	0.603	0.534	0.439
Glenelg	0.7	0.613	0.483

Table 5: Darkan average yield by TOS and Variety

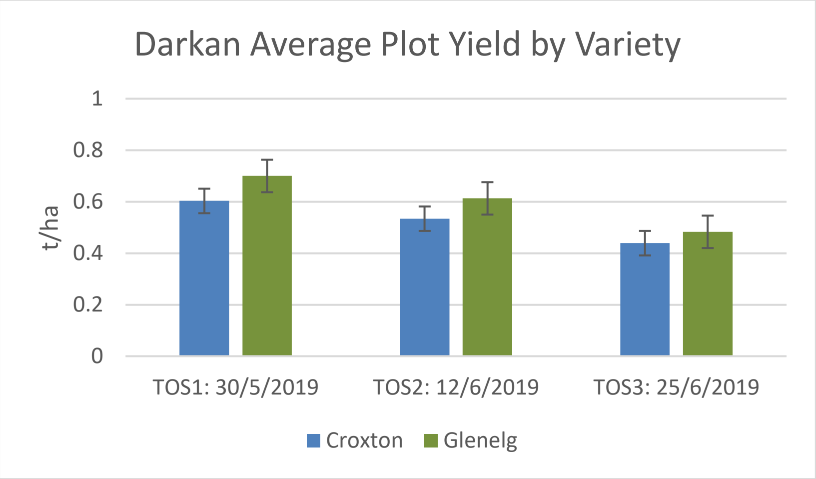

Chart 1: Darkan Average Yields of Glenelg and Croxton for all TOS.

Glenelg consistently yielded higher at the Darkan site. On average TOS1 produced the highest yields followed by TOS2 then TOS3.

Wagin Harvest Results

There were no significant differences between the plot mean yields at the Wagin site.

The average yield for the Wagin site was 0.914t/ha.

TOS3 was not harvested as it failed to germinate. TOS3 at Wagin on the 25/6/2019 occurred after a rainfall event of over 30mm two days prior to seeding. The site became boggy which significantly impacted the ability to control seeding depth. Seed was sown too deep and failed to emerge.

Image 1: Wagin 20/8/2019, from left TOS3- 3 rows, TOS1- 3 rows, TOS2- 3 rows (B. Copestake)

The seeding rates trialed did not produce a significant yield difference at the Wagin site. There was a response to nitrogen, but this was not consistent between the TOS. TOS1 mean yields were highest in the High N followed by Low N then Optimal N. TOS2 mean yields were highest in the High N followed by Optimal and then Low N.

Variety: TOS Average Yield, Wagin: t/ha			
	TOS1: 30/5/2019	**TOS2: 12/6/2019**	**TOS3: 25/6/2019**
Croxton	0.903	0.883	0
Glenelg	0.957	0.914	0

Table 6: Wagin average yield by TOS and Variety

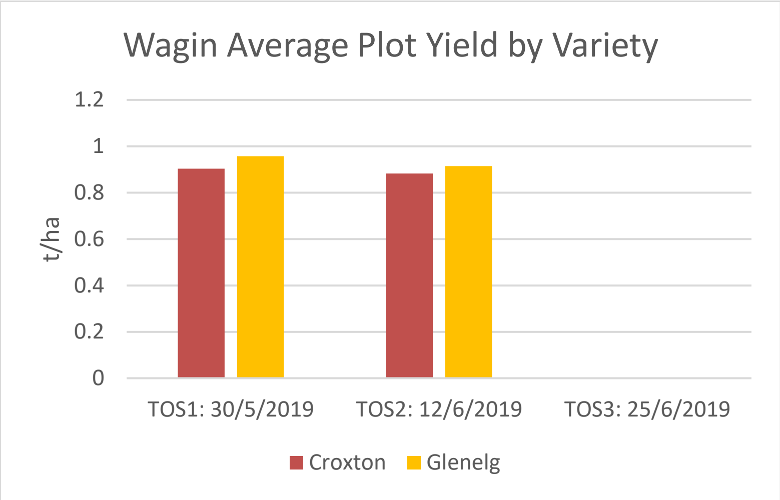

Chart 2: Wagin Average Yields of Glenelg and Croxton for all TOS.

Glenelg on average was slightly higher yielding than Croxton at the Wagin site, with TOS1 yielding slightly higher than TOS2 for both varieties. Overall, Croxton showed more variability in yield than Glenelg.

Kojonup Harvest Results

There were no significant differences between the plot mean yields at the Kojonup site.

The average yield for the Kojonup site was 0.998t/ha.

The seeding rates and top-dressed nitrogen application rates trialed did not produce a significant yield difference at the Kojonup site. Variety and TOS produced the main effects with Croxton mean yields being consistently higher for each TOS.

Variety: TOS Average Yield, Kojonup: t/ha			
	TOS1: 29/5/2019	TOS2: 13/6/2019	TOS3: 26/6/2019
Croxton	0.924	0.947	0.86
Glenelg	1.227	1.034	0.996

Table 7: Kojonup average yeild by TOS and Variety

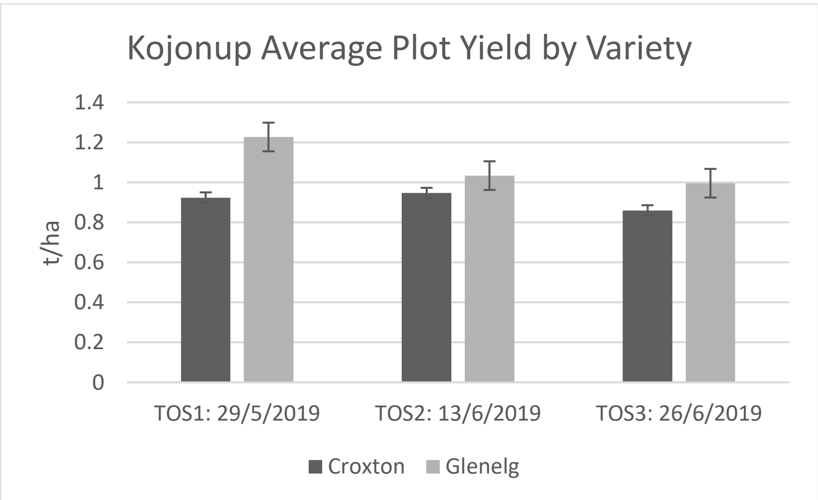

Chart 3: Kojonup Average Yields of Glenelg and Croxton for all TOS.

Glenelg on average was significantly higher yielding than Croxton at the Kojonup site for each TOS. Glenelg yields on average decreased with each TOS. Croxton yields were less variable between the 3 times of sowing, however the 15 lowest ranked yields involved the variety Croxton.

Oil Quality and Quantity Analysis Results

Grain samples of Croxton and Glenelg SR45 from TOS 1: low, optimal and high N from each site were collected for oil analysis performed by Symbio Laboratories. (See Appendix C for results).

Oil quantity was lower than expected ranging from 29.6 to 40.6%. Glenelg consistently had a higher oil content than Croxton.

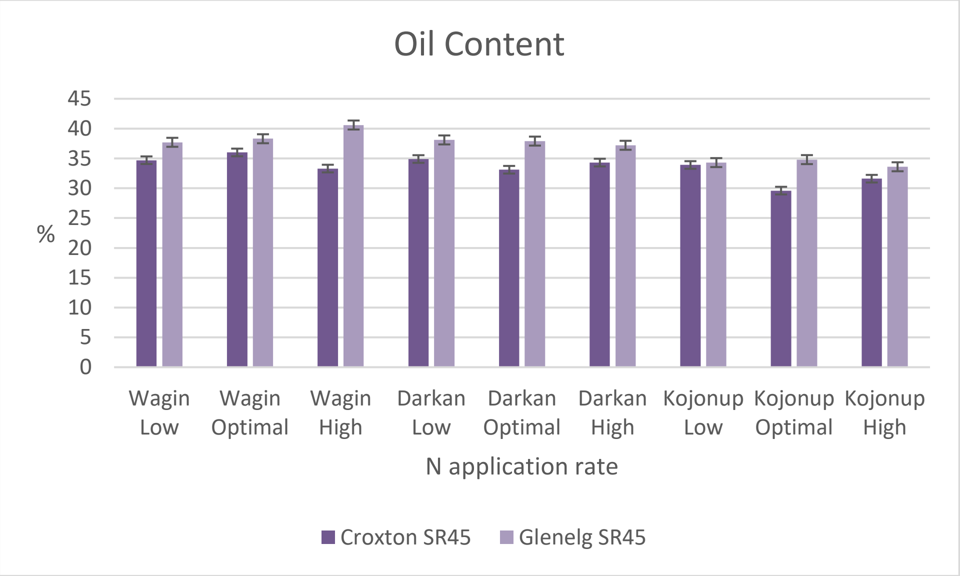

Chart 4: Oil Content

There were no consistent correlations between N rate and oil quality and quantity across the sites.

Croxton had a higher alpha-linolenic acid content ranging from 54.1- 58.3% than Glenelg 52.2- 55.4% with the exception being the high N application rate at the Wagin site.

2019 Results Summary:

Over the three trial sites, the seeding rates and nitrogen application rates trialed did not consistently result in significant differences in grain yield or oil quantity and quality. Time of sowing had the greatest impact, with the earliest time of sowing generally resulting in higher grain yields. Glenelg on average had a higher grain yield and oil quantity, with Croxton having the highest oil quality.

Trial Site	Average Site Yield t/ha
Darkan	0.562
Wagin	0.914
Kojonup	0.998

Table 8: Average Site Yields in 2019 (Below average rainfall)

The Darkan site plant counts were the highest, however this was not reflected in the yield. Darkan was the lowest yielding of the three sites. This may be due to the below average rainfall and lack of finishing rains experienced on the non-wetting forest gravel soils at this trial site. Kojonup and Wagin on average achieved nearly double the yield of the Darkan site despite lower plant counts and early plant disease.

2020 producer sized plots results

Wagin Results:

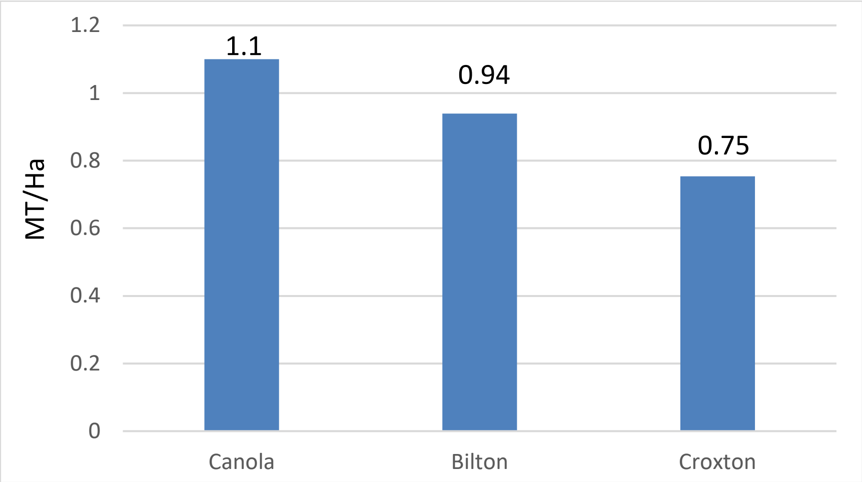

Chart 5: Wagin yield results

The harvest technique did not allow the individual plots to be weighted and therefore individual plot yields measured. The total yield of each of the Linseed varieties across all plots was measured and is shown in chart 5. The canola yield was not recorded Bilton yielded higher than Croxton it is expected that both -yielded less than Canola.

Darkan Results:

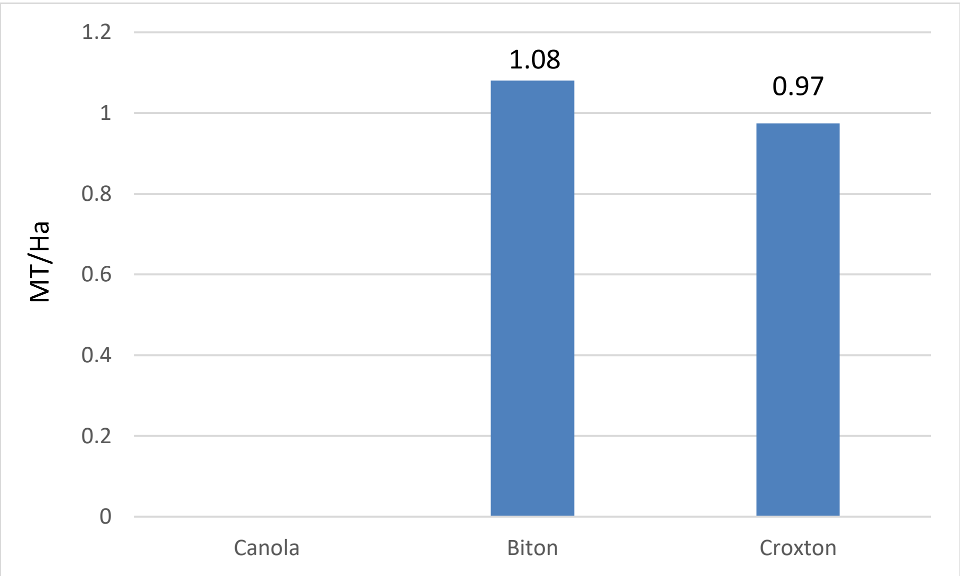

Chart 6: Darkan yield results

Despite Croxton having a higher second NDVI reading than Bilton, this did not translate into a higher yield. Bilton out performed Croxton at the Darkan site. The Canola yield results were not available from this demonstration.

Kojonup Results:

Description	Result
Variety	Bilton
NDVI (3 July 2020)	0.37
Plant count (3 July 2020)	300
Yield (MT/Ha)	0.83

Table 9: Summary of Kojonup bulk up results

As the Kojonup site was the primary bulk up site with only 1 variety grown the only results available are those tabled in table 1. However they do assist in giving a wider database of Linseed performance throughout the Great Southern of WA

2021 Results

In 2021 the canola and Linseed stubbles were tested for soil borne pathogens (PredictaB) and the following crops yields measured to determine if there was a benefit to the following crop from the potential drop in disease pressure.

Over the three producer demonstration sites there was a considerable drop in nematode pressure and overall soil borne pathogen pressure. P. neglectus and P. quasitereoides disease pressure in particular was reduced from medium to medium to low disease risk down to low to zero disease risk.

Site	Pratylenchus penetrans	Pratylenchus thornei	Pratylenchus neglectus	Pratylenchus quasitereoides
Katanning	None	None	None	Medium
Darkan	None	None	None	Low
Kojonup	None	None	Medium	Low - medium

Table 1: Predicta B results prior to planting Linseed.

Site	Pratylenchus penetrans	Pratylenchus thornei	Pratylenchus neglectus (nematodes)	Pratylenchus quasitereoides (nematodes)
Katanning	None	None	None	Low
Darkan	None	Low	None	Low
Kojonup	None	None	None	Low

Table 2: Predicta B results June 2021, post harvest of Linseed, with following crop planted.

2021 Crop summary and Harvest dates

Location	Crop type	Harvest date	Yield recording method
Darkan	Barley	13 December 2021	Yield Map
Katanning	Lupins	6 December 2021	Weight trailer
Kojonup	Lupins	31 December 2021	Yield map

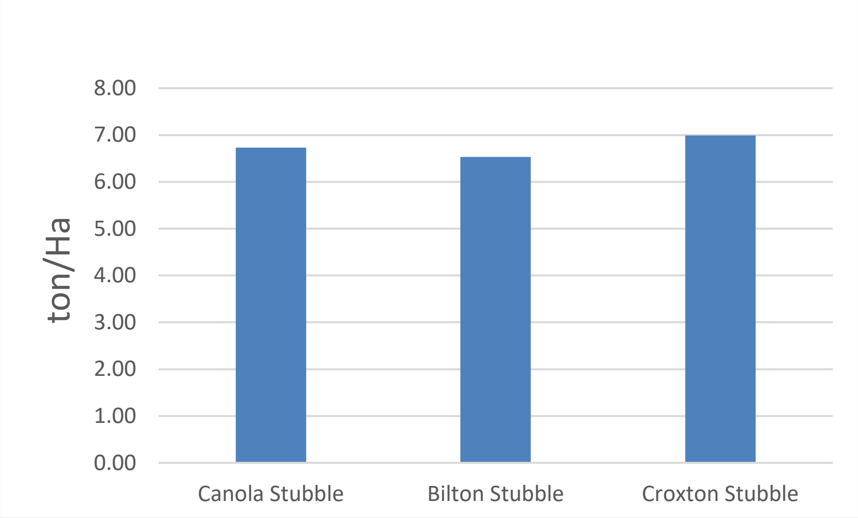

Chart 7: 2021 Barley yields grown on canola and Linseed stubbles at Darkan.

Katanning yields

1.55 ton/Ha Lupins on Linseed stubble

1.23 ton/Ha Lupins on Canola stubble

Kojonup yield

2.90 ton/Ha Lupins on linseed bulk up site

Discussion of Results

2019 small plot trial results

The growing season of 2019 experienced below average rainfall across all trial sites, with TOS1 at all sites being dry seeded. TOS2 and TOS3 were seeded into moist soil.

Patchy areas of plant disease and deaths occurred in some plots at both the Wagin and Kojonup sites during the early growth stages. It occurred in both the Glenelg and Croxton plots with neither variety being observed to be more susceptible. The symptoms were of a Damping Off disease. Fungicides were not applied at any stage throughout the trial, as available fungicides were not registered for use on linseed. The use of fungicides in furrow or as a seed dressing may be of benefit to control early fungal disease.

Plant counts from all sites were not reflective of the final yield. Darkan with the highest plant counts had the lowest grain yields. However, it is worth noting the plant counts at Darkan were well above the recommended number for Linseed by Agriculture Victoria. Darkan plant numbers ranged between 485 to 675 plants/m2 compared to the recommended 300 plants/m2. It is likely the very high numbers had a negative impact of yield. Wagin plant counts ranged between 213 – 348 and Kojonup ranged between 260 to 432.

In general, Croxton plots had higher plant counts compared to the equivalent Glenelg plots. A germination test of the seed was not done prior to seeding. Glenelg overall out yielded Croxton. Sites and plots with higher plant densities may have suffered a yield penalty due to the lack of soil moisture with a below average rainfall and dry finish.

The seeding rates trialed were the recommended seeding rates from Agriculture Victoria and may not best suited for the Great Southern Region of WA with a lower rainfall. Results from the trial showed no significant differences in yield between the three seeding rates trialed. To establish a recommended seeding rate further seeding rate trials over successive seasons needs to be undertaken.

Results of the time of sowing (TOS) from these trials indicate that an earlier time of sowing has yield benefits with the 2 varieties trialed. Further trials are required to determine if these results were due to a lower than average rainfall year with limited finishing rains or if these linseed varieties require a longer growing season to maximise yield potential.

Utilising the existing canola seeding window (April) to seed linseed would provide the benefits of earlier seeding along with seeding machinery already calibrated for small seed and a shallow seeding depth.

The top-dressing rates of nitrogen trialed did not result in a consistent difference in grain yield or oil quantity and quality. Further work is required to determine optimal N requirements for linseed grain yield and oil quantity and quality.

2020 Producer demonstration sites results

The key outcome of any variety demonstration is the final yield result. Due to operational difficulties within the demonstration some yield data is not available however the key findings from the data available was

- Bilton yield 85% of Canola
- Croxton yielded 72% of Canola.
- Bilton out yielded Croxton on both sites.

The seasonal conditions may have contributed to Bilton out yielding Croxton. Bilton is a slightly shorter maturing variety and the below average rainfall received in 2020 is expected to have favoured shorter season varieties.

Plant counts across all the demonstration sites were well within the required plant densities ensuring the full yield potential could be achieved and demonstrates that Linseed can be seeded and germinated with existing modern seeding equipment. There were no reports of seeding difficulties from any of the four demonstrations.

One of the key outcomes of this project is to continue to develop the agronomic package of Linseed for future commercial production. There are five main components to any agronomic package, handling (seeding and harvest), weed management and fertiliser requirements, disease control and pest management. Importantly from the demonstrations all the components were able to be managed within the current available agronomic systems. Linseed has good grass control options being a Broadleaf crop however has limited broadleaf weed control options like other broadleaf crops. MCPA and BromocideMA were both used successfully within the demonstrations for weed control. For Linseed to continue to expand its footprint as an alternative option in the existing rotations further work will be required on broadleaf weed management options.

It is difficult to draw any conclusions from the fertiliser applications applied over the 4 demonstrations in relation to developing best practice fertilser requirements for growing Linseed as there is no direct correlation between application rates and yield. Applications were all in line with canola best practice which appears to be excessive for the yields produced. However, this is quite likely due to the below average rainfall received in the spring which impacted yield potential.

Disease pressure and management options were realistically not able to be tested due to the limited Linseed crops that are grown in the area and the very small history to develop disease pressure. However, given Linseed will always only be a niche in any rotation it can be expected that disease pressure will not build and therefore impact crop performance. The dry spring resulted in a low pest pressure throughout the state. The Darkan demonstration was the only site to come under any pest invasion. Umiliotis native bud worm built up in numbers in early November, was successfully sprayed and had no impact on yield.

Additionally, both seeding and harvest didn't present any handling issues showing Linseed is a crop that will fit into a rotation in the Great Southern.

Cost benefit analysis:

In order for Linseed to expand on its current niche production area it is important the profitability of growing it is comparable to other break crops such as canola. Production costs of growing Linseed will be very similar to a TT variety of canola given the similarities of the agronomy packages.

The cost benefit analysis result is determined by the final sale price and yield. From the demonstration results we know that Linseed yields 85% of canola. Therefore, for Linseed to generate the same return for growers Linseed will need to trade at 117% of Canola. At the time of completing the cost benefit analysis Canola was trading at $755/MT. Linseed will need to be trading at $883/MT to offer a similar return to Canola. It is worth noting that canola is trading in its 90 percentile.

Linseed production is very niche in WA and therefore pricing is not transparent and is difficult to determine. Increasing production to produce a consistent supply would work to secure firm pricing as wholesalers would have the ability to build market supply chains.

Rotational benefits have not been considered in the cost benefit analysis and they are expected to be very similar to that of canola. The key rotational benefit of growing Linseed is its Nematode root disease control. Linseed is resistant to Nematodes and bringing the crop into rotation has the ability to drive down the parasitic numbers. Further work is required in this area to determine the longer term benefits of growing Linseed to manage the issue which currently has limited management strategies.

2021 yield results from Linseed and Canola stubbles

The results from the crop yields in the season following the linseed or canola crops were mixed. The PredictaB results certainly demonstrated a reduction in soil borne disease pressure however this wasn't always able to translate into final yield. The Katanning site did demonstrate an advantage in growing lupins after linseed compared to canola however due the very wet season a large portion of the canola area was damaged by water logging which impacted the validity of the findings. The Darkan site gave mixed results with one Linseed variety stubble producing a higher barley yield than canola stubble and the other variety lower.

Overall 2021 was an exceptional season with good rainfalls received across the entire season. In good seasons it is difficult for soil borne pathogen trials to show differences in results as roots that may be impacted by disease are still able to access enough moisture to grow a healthy crop. It is in poorer seasons that the benefits of reducing soil disease can be shown in crop yields as better developed root systems are able to access more moisture.

Conclusion

The objective of this project was to support the introduction and scale up of commercial cultivation of Linseed in the Great Southern region of Western Australia by specifically determining if Linseed can be successfully grown under dryland farming conditions in the Great Southern, if any investment is required into machinery and/or infrastructure, to develop basic agronomic guidelines to grow linseed in WA and to assess the yield potential of two commercially available linseed varieties, Croxton and Bilton.

The four main objectives of the project were successfully achieved. Current farming equipment can be utilized to grow Linseed and there is no requirement for any investment into machinery or infrastructure. The four growers who conducted the demonstrations on their properties were able to use their existing equipment.

A basic agronomic package was collated throughout the project which enabled the participating producers the ability to grow a weed free, productive crop. There is however a lot of scope for further work to refine the agronomic package. Fertiliser response curves, sowing windows, seeding rates, variety selection and most importantly expanded broadleaf management options as the herbicides used within the project of MCPA and BromicideMA will limit the uptake of Linseed due to resistance concerns.

The yield potential of the two commercially available linseed varieties, Croxton (0.75 – 0.97 MT/Ha) and Bilton (0.83 – 1.08 MT/Ha), was demonstrated within the project. Between the two varieties they on average yielded 78.5% of the canola crop alongside.

The project has successfully set in the place the ability for growers in the Great Southern region to scale up production of Linseed and demonstrated its ability to fit within the current rotations with the additional benefit of assisting in the long-term management of soil borne root pathogens.

However, for the scale up of the commercial cultivation of Linseed there is the requirement for beyond farm gate systems to be in place before producers will scale up production. An active market to determine a fair price, storage and handling facilities off farm to enable harvested grain to be stored before delivery to consumers, supply chains in place which enable efficient delivery of the grain anywhere around the world and long-term buyers/processors who will receive the grain year in year out. There is still a lot of processed to be put in place before Linseed production will scale up to a considerable level.

Grower adoption beyond the project has continued with over 60 Ha planted in southern WA in 2021 across 4 growers. Confidence in the supple chain beyond the farm gate remains the primary reason for the lower than expected uptake and requires addressing before improved scale up of production can be expected.

Implications

Linseed has been demonstrated through the project to fit as a further option in the cropping rotation to increase crop diversity and lengthen crop rotations in the Great Southern of WA. Linseed has the potential to be a profitable break crop with the additional benefit of providing soil borne pathogen management, fits seamlessly into existing machinery resources and within the readily available cropping inputs (fertilisers/chemicals) to grow a weed free productive crop.

The project has demonstrated the fit and potential for Linseed within the cropping rotation in the Great Southern however there are two key implications that need to be addressed before the large scale up of Linseed can reasonably be expected:

1) Supply chain beyond the farm gate

While it has been demonstrated that Linseed can be successfully grown, what will happen beyond the farm gate should production reach a reasonable scale of 10,000 MT or even 50,000 MT? Is there demand for this amount of linseed, enough competition within the market to set a fair price and the supply chain infrastructure to receive the grain once produced?

2) Improved Agronomic Production Packages

The project was successful in generating basic agronomic guidelines for the production of Linseed there is a lot of further work required to enable growers to optimize the production of Linseed through developing an optimal agronomic package. Fertiliser rates were modelled around canola and response curves need to be developed for Linseed, more robust broadleaf control strategies are required and variety selection trials are needed to determine the most suited variety for Western Australia. The varieties chosen for the project were over 40 years old and there are more modern varieties available.

In summary the platform for the scale up of Linseed has been set through this project however there is still further development required before a considerable production of Linseed can be expected out of the Great Southern region of WA.

Recommendations

The finding from this project are that linseed can successfully be grown in the Great Southern Region of WA under dryland farming conditions. There are two key recommendation platforms that have come out of the project which are:

1) To further develop the agronomic guidelines for growing Linseed in WA, successive years of growing experience and trials are required.

Recommended areas for further trials:

- Time of sowing
- Seeding rates
- Variety trials
- Yield response to previous and successive crops in rotation
- In furrow and seed dressing applications of fungicides to control early damping off disease. Currently no APVMA registered products for use on linseed.
- Weed control options, specifically broadleaf control strategies
- Nutrient response curves and in particular Nitrogen requirements
- Harvesting techniques: direct heading vs swathing vs desiccation
- Expansion of growing region
- Farmer scale trials

There is a need for the breeding and development of high yielding disease resistant varieties with good oil quantity and quality that are suitable for dryland farming in WA.

2) Investigation into the supply chain beyond the farm gate. It is recommended that a project is developed and funded to investigate the potential of large scale Linseed production to be handled efficiently beyond the farm gate within the existing infrastructure and supply chains or if there will be a need for further infrastructure to be developed in the event Linseed production is increased.

As part of this project there is a need to understand where demand for Linseed is both domestically and offshore plus number of potential participants in the market, processing capacity and the size of the end market or consumer demand to ensure if the linseed grain is produced that there is demand for it and at profitable prices.

Appendix A.
Appendix Title

Glossary and Acronyms

Below is a sample Abbreviations and Acronyms list. Be sure to include on this page all abbreviations and acronyms that appear in the report

DAFWA	Department of Agriculture and Food, Western Australia
DAP	di ammonium phosphate
DArT	Diversity Arrays Technology
DAT	days after treatment
Db	bulk density
DAFWA	Department of Agriculture and Food, Western Australia

References

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Linseed a Growers Guide. Premium Crops, Hampshire, UK

Purse J (1990) A Flax Mill by the River, Janet Purse, Boyup Brook

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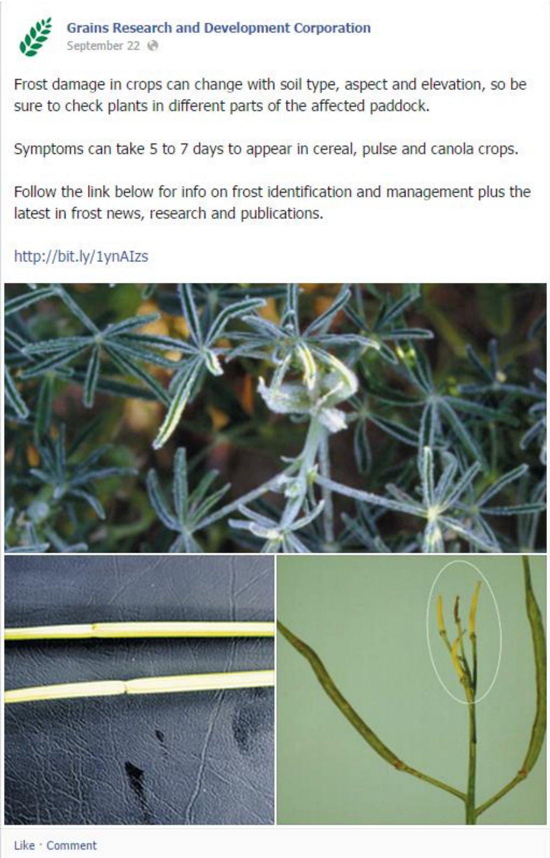

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