Final Technical Results Report

2023

Barley agronomic strategies for the Geraldton Port Zone

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REPORT SENSITIVITY

Does the report have any of the following sensitivities?

Intended for journal publication	YES ☐ NO ☒
Results are incomplete	YES ☐ NO ☒
Commercial/IP concerns	YES ☐ NO ☒
Embargo date	YES ☐ NO ☒ If Yes, Date: <Choose date>

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ABSTRACT

The barley agronomy project sought to provide up to date information for growers in the Geraldton port zone to make informed decisions around barley variety choice, sowing time and in season management to maximise barley productivity and profitability.

Barley varieties were grown in small plot trials over three years in soils typical to the WA northern wheat belt. They were subjected to nitrogen strategies and tested for yield, grain quality and profitability against a well-adapted wheat.

Barley showed it can be grown successfully in the Geraldton port zone and it can match the yield of wheat and record a yield advantage.

However, barley could not compete with wheat financially as the first choice cereal in a crop rotation. The yield benefit was not large enough to overcome the price premium for wheat in the duration of this project.

In general, applying all nitrogen up front, prior to seeding, was a robust nitrogen strategy for the yellow sands at Binnu and the loam soil of Northampton. An active nitrogen strategy was more likely to be beneficial at Eradu, Tenindewa, Canna and West Casuarinas

Barley's ability to flower before August may make it a low risk and profitable option as a third cereal before a break crop, in a mixed farming enterprise where the extra stubble has value for animals or as an option on the acid soils.

EXECUTIVE SUMMARY

This barley agronomy project sought to provide up to date information for growers in the Geraldton port zone to make informed decisions around barley variety choice, sowing time and in season management to maximise barley productivity and profitability.

Small plot trials were established across the Geraldton port zone covering the main soil types typical to the region with trials conducted over three years. Trials contained 6 varieties of barley providing a range of maturities, herbicide tolerance, market end use and acid tolerance (Planet, Spartacus, Rosalind, Buff, Bass and Scope) at two sowing times. In year two and three, Scepter wheat was introduced for comparative yield and gross margins. Nitrogen strategies were site specific and tested whether nitrogen was best applied all prior to seeding or split with an early post emergent application and if a higher rate was beneficial in above average seasons. Irrigation using pressure compensated drip tubes was used to establish the early sowing option if necessary.

The three seasons sampled in this project varied greatly in seasonal rainfall, the timing of rainfall and maximum temperatures during grainfill, however the more extreme finishes with hot dry winds and high springs temperatures were not encountered.

The 2020 growing season experienced decile 2-3 rainfall yet most sites experienced "season saving" rainfall in August. This was accompanied by as many as 39 days above 30°C during the grain fill period.

Substantial autumn rainfall provided an ideal start to the 2021 growing season to test early sowing opportunities and consistent cold fronts through July helped to maintain a high yield potential at each site. The grain fill period experienced steadily increasing maximum temperature from mid-August.

The 2022 growing season was an average season judged by total rainfall, yet consistent cold fronts through July and August provided the opportunity for crops to compensate for low rainfall through May and June. August rainfall was accompanied by mild temperatures and temperatures greater than 30°C were not recorded until the end of September.

Barley varieties with consistent high relative yield in each of the three years were identified for each of the six locations. Planet did well when sown early at Tenindewa and West Casuarinas, whilst Rosalind was better suited to the later sowing at these sites. Bass and Planet were suited to early sowing at Northampton and Eradu. A later sowing at Northampton showed no specific advantage for any barley and there were many options available. Buff was the best performing barley on the acid sands locations such as at Binnu and Canna over the 3 years of the trial and was also suited to the later sowing at Eradu.

Malt grade barley was successfully produced in the trials. MALT grade was more likely to be achieved at Binnu, Northampton and Tenindewa yet malt grain cannot currently be delivered to CBH facilities in the Geraldton port zone.

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Barley yield was comparable to wheat at each site in 2021 and 2022, and was capable of recording a significant yield advantage, yet this project demonstrated that barley cannot compete with wheat financially as the first choice cereal in a crop rotation. The yield benefit was not large enough to overcome the price premium for wheat over the duration of this project. Barley sown early could be more profitable, such as Binnu and Northampton in 2021 and Tenindewa in 2022, yet this was on the back of a 1.1 to 2 t/ha yield advantage and wheat failing to reach a premium grade.

Splitting nitrogen offered few yield advantages on the yellow sands at Binnu or the loam soils of Northampton, Tenindewa and Canna. Significant yield gains were more likely to be found in Eradu and West Casuarinas. Grain protein was more responsive to splitting nitrogen with increased protein most likely at Eradu, Canna and West Casuarinas. In 2022 splitting nitrogen increased protein in sowing time two at five locations with the exception of Binnu which was grown on a lupin stubble.

Increasing the nitrogen rate raised yield at Eradu and Canna. Protein was more responsive than yield with increased protein measured all locations and at both sowing times.

In general, applying all nitrogen up front, prior to seeding, was a robust nitrogen strategy for the yellow sands at Binnu and the loam soils of Northampton and Tenindewa in 2020, 2021 and 2022. An active nitrogen management was more likely to be beneficial at Eradu, Canna and West Casuarinas.

Barley varieties were found to respond in a similar manner to nitrogen application, therefore crop nitrogen strategies need to just consider crop growth stage, paddock history and expected growing season, not the variety. This is in line with similar findings in the GRDC YARD STICK trials.

Barley sown early and flowering before August is more likely to avoid the high temperatures during grainfill and this may make it a low risk and profitable option in specific agronomic circumstances, such as a third cereal before a break crop on the yellow sands of Binnu and Eradu or where the extra stubble has value for animals. Imidazoline tolerance may also provide a specific fit for a grower.

BACKGROUND

Barley has become a more profitable crop than wheat in many parts of the Western Region, and many growers are expanding their areas of barley, including into regions that have not been identified as traditional barley growing areas. Some growers in the Geraldton port zone recently have returned to growing barley after a hiatus of some ten years or more, with others seeking barley as an addition to their rotation. Growers in the Geraldton port zone have identified (through RCSN forums) the lack of barley management and agronomic packages for the northern agricultural region. Many growers are unsure of how to manage a barley crop compared to wheat and how it has a fit within their farming system.

Barley varieties vary widely in their phenology and agronomic characteristics, and barley has different management requirements to wheat, particularly around disease management, nutrition, grain quality and ideal sowing times. As barley is becoming more widely grown, it is essential to be able to maximise yield and profitability of this cereal. Growers in the northern wheatbelt of WA need to be better informed on how planting times influence yield and grain quality, particularly with early sowing opportunities or late sowing on ameliorated soils. Nitrogen management with different rotations or soil types (including ameliorated) needs better understanding, along with other agronomic management practices such as those that influence weed competitiveness or disease susceptibility.

PROJECT OBJECTIVES

This project sought to maximise the profitability of barley in the northern Geraldton Port Zone by providing information to growers to allow them to make informed decisions around barley variety choice, sowing time, in season management and management of their rotations in order to maximise barley productivity and improve the overall profitability of their farming business.

The project sort to answer specific questions of -

Do barley's have specific adaptation which can be exploited.

Can varieties attain malt quality in the Geraldton Port zone.

Do variety maturity and planting times influence yield and grain quality, particularly with early sowing opportunities.

Does barley out yield wheat, sown early, or sown late.

Was barley profitable compared to wheat.

Can early sowing of short season varieties provide a maturity window and low risk option to avoid late season hot/dry finishes and produce a profitable yield.

To gather data on barley performance when late sowing on ameliorated soils. Can barley provide a more profitable option than wheat for late sowing on ameliorated soils?

Gain a better understanding of nitrogen management with different rotations or soil types (including soil amelioration) for barley yield with feed quality and for malt production.

Did barleys differ in their response to nitrogen.

Can early sowing and fertilising for high yield feed deliveries be more profitable than wheat.

Did project sample an adequate range of seasons.

METHODOLOGY

Small plot trials were established across the Geraldton port zone covering the main soil types typical to the region with trials conducted over three years. Each site comprised 6 varieties of barley providing a range of maturities, herbicide tolerance, market end use and acid tolerance (Planet, Spartacus, Rosalind, Buff, Bass and Scope) at two sowing times. In year two and three a wheat variety (Scepter wheat) was introduced for comparative yield and gross margins. Variety information is shown in Table 1.

Table 1. Varietal description for maturity, market end use, herbicide tolerance and acid tolerance

Variety	maturity	Market end use	Herbicide tolerance	Acid tolerance
Planet	Early sowing	malt	none	no
Spartacus CL	Early maturing	malt	Imidazolinone (Imi)	no
Rosalind	Mid (May sowing)	feed	none	no
Buff	Early maturing	feed	none	yes
Bass	Mid	malt	none	no
Scope CL	Mid	malt	Imidazolinone (Imi)	no
Scepter	Mid	AH quality wheat	none	no

Each site received basal P K and S whilst manipulating nitrogen by varying rate and timing. Basal nutrition, and N inputs were specific for each location and were determined by soil testing and interpretation by qualified local consultants. Nutrition at seeding was derived from a mix of Gusto Gold (banding), Urea and Sulphate of Ammonia (both spread pre-seeding). Post-emergent nitrogen treatments were applied when the majority of varieties were at the specified growth stage (determined by plant dissection).

Nitrogen rates were site specific and assumed a typical season. Two rates of nitrogen were applied. A standard rate was expected to give an average yield and was applied either all at seeding (100% topdressed before seeding, Treatment one) or split with 50% before seeding and 50% early post emergent (Treatment two). A high rate, to capitalise on above average seasons, was also tested and applied in a split application with 50% before seeding and 50% early post emergent (Treatment three).

Changes were made to the methodology in years 2 and 3 of the project. A wheat variety was included in year 2 and 3 to compare profitability and in year 3 the followup post emergent nitrogen application was brought forward from growth stage 31 to growth stage 14 to align more closely with local farmer practise on the advice of the consulting agronomists.

An example of nutrition treatments across the six locations is shown in Table 2.

Table 2. Nutrition treatments in 2021

Location	Soil type	N1	N2	N3	P & K & S		
		All N upfront	Split N 50% sowing GS31	High N 50% sowing GS31	Units P	Units K	Units S
Binnu	Deep yellow sand	50.0	50.0	74.8	10.1	20.4	10.2
Northampton	Red loam	47.3	47.3	70.3	15.1	11.8	12.0
Eradu	Deep yellow sand	65.4	65.4	100.8	12.5	34.8	12.0
Mullewa	Soft red loam	55.0	55.0	79.8	12.2	9.6	12.0
Canna	Wadjil light loam	35.7	35.7	50.4	9.2	7.2	6.7
West Casuarinas	White sand over gravel	70.5	70.5	100.4	14.4	28.3	19.4

A general soil description for each of the six locations in shown in Table 3. Whilst sites were moved each year to align with farmer rotations, the sites at each of the six locations were maintained on the same soil type and within a few kilometres of each other over the three years of the project.

Table 3. Soil Description for each location

Location	Soil type	Avg GSR[1]	pH at depth	Exch Al	Soil [2] compaction	WHC[21]
Binnu	Deep yellow sand	265	4.0-4.1	17-35	20-70	90
Northampton	Red loam	325	4.8-5.9	<1.8-6	18-36	160
Eradu	Deep yellow sand	292	4.8-6.0	<1.8-9	28-50	120
Tenindewa	Soft red loam	202	5.4-6.2	<1.8	18-22	180
Canna	Wadjil light loam	246	4.1-4.4	25-36	16-22	110
West Casuarinas	White sand / gravel	322	5.3-6.9	<1.8	30-70	70

1 GSR = Growing Season Rainfall
3 Soil compaction = depth at which >60% of measurements recorded ≥3.5 mPa
2 WHC = Water holding capacity in mm/meter of soil, estimated

Plots were seeded using a small plot cone seeder with knife points and press wheels. Each trial contained three replications with time of sowings located in adjacent blocks. The first time of sowing simulated an early sowing opportunity used by growers (mid to late April). This sowing time was facilitated by irrigation using pressure compensated drip tubes if soil moisture was low. Moisture was applied equivalent to 16.4mm over the entire plot area, but delivered into each seed furrow, which is close to 20mm equivalent rainfall. The second sowing time followed about a month later towards the end of May. An example of the irrigation is shown below.

Figure 1. An example of irrigation using pressure compensated drip tube for time of sowing one in 2020, 2021 and 2022.

Each site received a soil test, predicta B test and soil compaction measurement. Crop growth was evaluated by rating visual establishment, crop biomass (visual and NDVI) and crop phenology. Disease was managed using prophylactic fungicide and weeds and insects were controlled with commercial pesticides at label rates. Plots were harvested for yield at maturity along with visual ratings for lodging and head loss if needed. Grain quality measured protein, hectolitre weight, screenings, retention and colour. Screenings for barley represented the percent passing through a 2.2mm slotted sieve and grain retention represented the percent of grain remaining above a 2.5mm sieve.

The experimental design for each site consisted of a split-plot design for each time of sowing (TOS), with Variety nested within Nitrogen along each column. Two-directional blocking was used to account for spatial variability. An example of this is shown for the Mullewa (Tenindewa) site in Figure two. Each site followed a similar layout with different randomisation.

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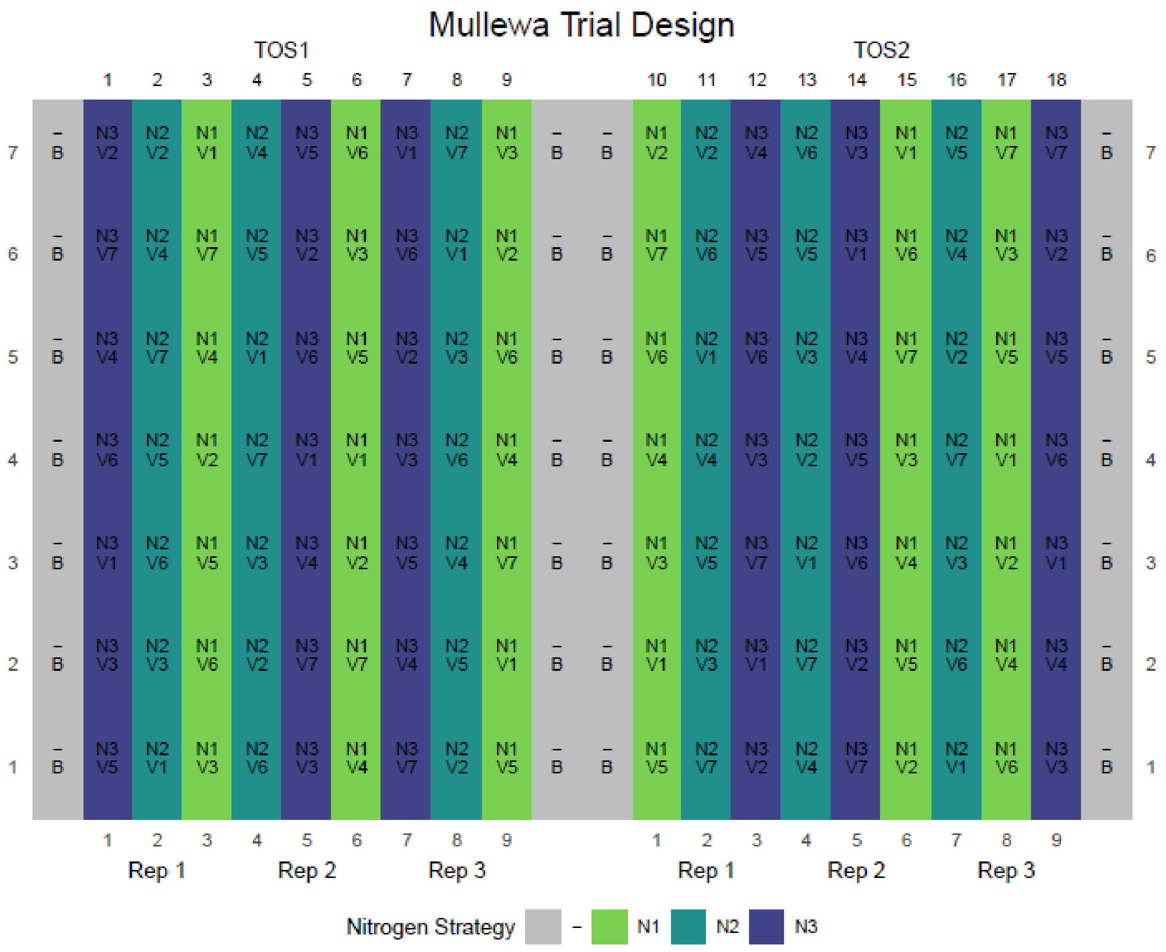


Figure 2. Split-plot trial design with at Mullewa (Tenindewa).

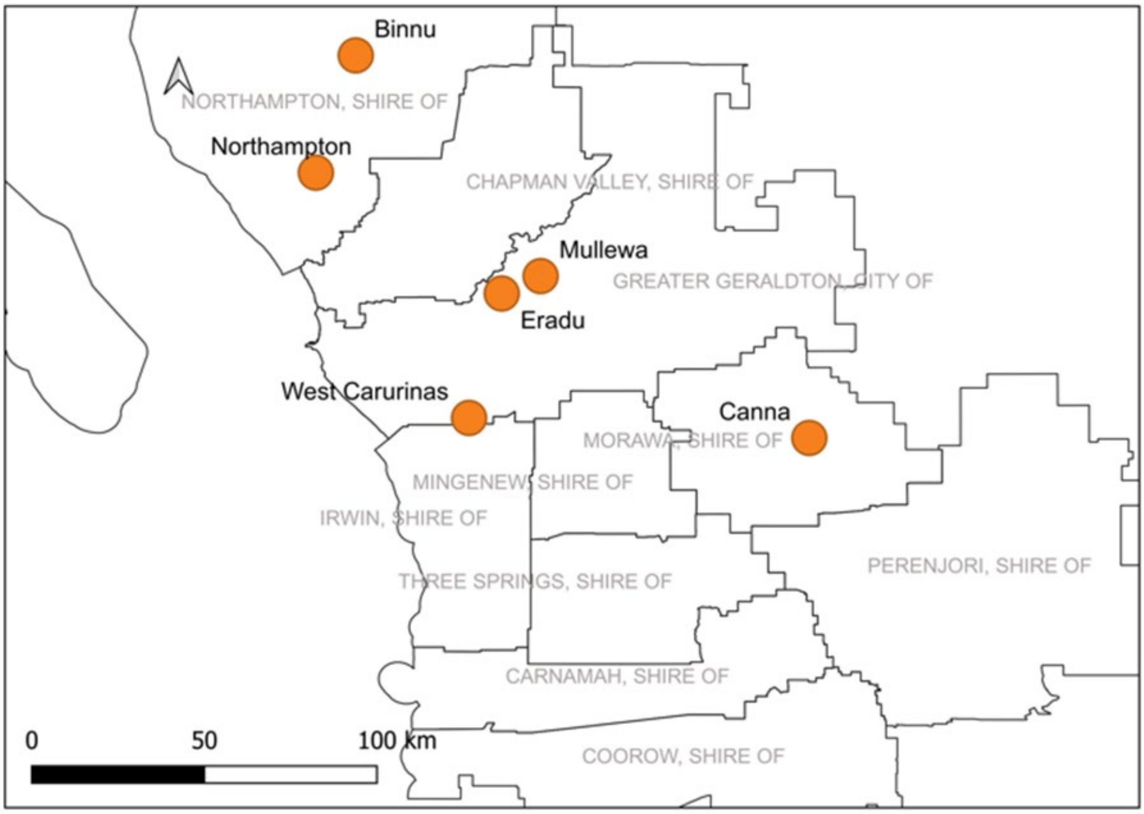
Trials were analysed by SAGI West. Data was firstly adjusted for spatial variability and then a model fitted to the data to account for main effects of variety and nitrogen and their interactions.

Economic analysis was conducted by Agrarian Management. Income and gross margin were calculated for each barley variety based on whether it is classified as a feed or malt type and on the assumption a malt variety can be delivered as malt if grain quality was appropriate. A standardised farm gate price (FIS less R&A less Levies/Royalties less averaged freight to port) for mid-November was used in each crop. Gross margin for each variety used the mean price of the three nitrogen treatments. Gross margin for each nitrogen treatment only included the barley varieties.

LOCATION

Where field trials have been conducted, provide the following location details in the table below: latitude and longitude, or nearest town.

Site #	Latitude (decimal degrees)	Longitude (decimal degrees)	Nearest town
Trial Site #1	27.90689 S	114.727 E	Northampton (Binnu)
Trial Site #2	28.26002 S	114.60703 E	Northampton (Alma)
Trial Site #3	28.57149 S	115.2832 E	Mullewa (Eradu)
Trial Site #4	28.57149 S	115. 2832 E	Mullewa (Tenindewa)
Trial Site #5	29.05887 S	116.09148 E	Morawa (Canna)
Trial Site #6	28.99856 S	115.06784 E	Walkaway (West Casuarinas)



If the research results are applicable to a specific GRDC region/s (e.g. North/South/West) or GRDC agro-ecological zone/s, indicate which in the table below:

Research	Benefiting GRDC region (select up to three)	Benefitting GRDC agro-ecological zone	
<Experiment title>	Western Region 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

The three seasons sampled in this project were characterised by differences in rainfall and temperature regimes. The rainfall deciles for the Geraldton port zone are shown in Appendix A for each year and are accompanied by the daily rainfall for Binnu and Tenindewa. Maximum temperature during the predicted grain filling period (1st Aug to 31st October) are shown for Binnu and Tenindewa in Appendix B. The data for each location can be found in the Annual Report of each year.

The 2020 growing season experienced decile 2-3 rainfall and all sites recorded below average seasonal rainfall yet trial sites experienced "season saving" rainfall in August, with the exception of Canna. This was accompanied by many hot days through the grain filling period at each site with a maximum temperature above 30°C measured on 39 days at Binnu and 35 days at Tenindewa.

Substantial autumn rainfall provided an ideal start to the 2021 growing season to test early sowing opportunities and consistent cold fronts through July helped to maintain a high yield potential at each site. The grain fill period at each site was represented by steadily increasing maximum temperature with greater than 30°C recorded from mid-August. Binnu recorded 35 days with a maximum temperature above 30°C with 22 days above 30°C at Tenindewa.

The 2022 growing season was an average season judged by total rainfall yet consistent cold fronts through July and August provided the opportunity for crops to compensate for low rainfall through May and June. August rainfall was accompanied by mild temperatures and temperatures greater than 30°C were not recorded until the end of September. Binnu recorded 11 days above 30°C and Tenindewa recorded 18 days above 30°C.

Barley yield and Gross Margin versus wheat

Barley varieties with consistent high relative yield in each of the three years were identified for each of the six locations and are shown in Table 4 along with their aggregate relative yield ranking (0-1).

Planet did well when sown early at Tenindewa and West Casuarinas, whilst Rosalind was better suited to the later sowing at these sites. Bass and Planet were suited to early sowing at Northampton and Eradu. A later sowing at Northampton showed no specific advantage for any barley and there were many options available. Buff was the best performing barley on the acid sands locations such as at Binnu and Canna over the 3 years of the trial and was also suited to the later sowing at Eradu.

Table 4. The best performing barleys for each location (averaged across N treatments)

Site	TOS1	TOS2
Binnu	Buff (1.0)	Buff (1.0)
Northampton	Bass (0.93), Planet (0.97)	Bass (0.91), Buff (0.94), Planet (0.95), Rosalind (0.97), Spartacus (0.97)
Eradu	Bass (0.93), Buff (0.92), Planet (0.95)	Buff (1.0)
Tenindewa	Planet (0.96)	Rosalind (0.98)
Canna	Bass (0.93), Buff (0.91)	Buff (1.0)
West Casuarina	Planet (0.96)	Planet (0.94), Rosalind (0.94), Scope (0.95)

Gre en = early, = mid, ora ge = late

Grain quality was also an important consideration for barley choice in this project and whether any variety could reliability achieve MALT grade, or whether maximising profitability in barley is more easily achieved by pursuing high yield within the FEED grade.

Each variety with MALT accreditation was graded for the number of times it was able to achieve MALT at each location and the results can be seen in Table 5. Bass and Spartacus were able to reliably achieve Malt and it was more likely with early sowing. MALT grade was more likely to be achieved at Binnu, Northampton and Tenindewa.

Table 5. The number of times MALT was achieved (averaged across N treatments)

Site		Binnu	Northampton	Eradu	Tenindewa	Canna	West Cas
Bass	TOS1	3 x	2 x	1 x	3 x	1 x	2 x
	TOS2	3 x	2 x	0	1 x	0 x	1 x
Planet	TOS1	2 x	2 x	1 x	0	0	1 x
	TOS2	2 x	0	0	1 x	0	1 x
Scope	TOS1	0	0	0	0	0	0
	TOS2	0	0	0	0	0	0
Spartacus	TOS1	3 x	2 x	1 x	2 x	1 x	1 x
	TOS2	3 x	2 x	0	1 x	0	1 x

The question of whether barley can compete with wheat rests with the respective yields and gross margins. These are shown in Figures 3 and 4. Wheat was only included in 2021 and 2022 so no comparative data is available for 2020. Each graph shows only the yield of the barley varieties that recorded consistently high yield in each of the 3 years at a location (Table 4) and their gross margin. This is compared to the yield and gross margin for Scepter wheat with the difference shown as dollars followed by the quality grade of Scepter wheat.

Figure 3. Grain yield and profitability of barley versus wheat for 2021

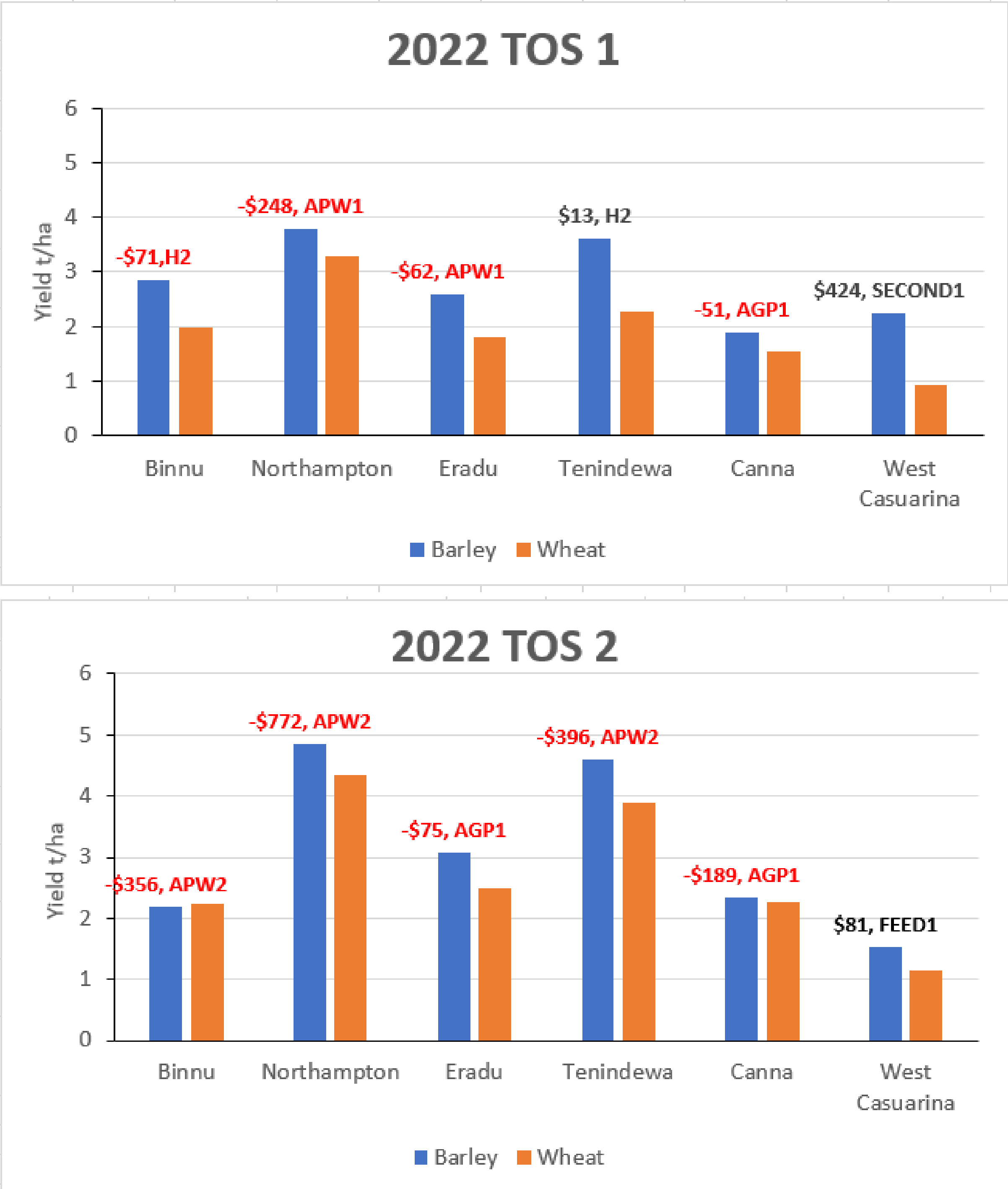


Figure 4. Grain yield and profitability of barley versus wheat for 2022

In 2021 barley was able to match the yield of Scepter wheat at all sites. Very high barley yields at Northampton meant barley was considerably more profitable than wheat, especially with the early sowing. This is mitigated in part however by Scepter wheat receiving an AGP1 grade classification.

Early sowing at Binnu and West Casuarinas also showed a clear yield benefit for barley but the profitability of barley over wheat was less clear. The yield benefit of 1.1 t/ha for barley at

Binnu resulted in a gross margin gain of just $47/ha and the yield benefit of 1.3 t/ha for barley at West Casuarinas resulted in a net loss to barley of $65/ha as Scepter achieved a better quality grade of H2. Barley recorded a lower gross margin than wheat at Eradu, Tenindewa, Canna and Binnu TOS2.

In 2022 barley was again able to match or exceed the yield of Scepter wheat at all sites. Barley was more likely to record a higher yield at Northampton, Eradu and Tenindewa and an early sowing at Binnu. However, Scepter wheat recorded better quality in 2022 and achieved higher end use grades of H2, APW1 from an early sowing and APW2 at the later sowing. The better quality grades for wheat meant gross margin of barley was lower than wheat at most sites; ranging $51-248/ha at an early sowing and $75-772/ha at the later sowing. There were some exceptions to this with gross margin of barley comparable to wheat when sown early at Tenindewa, principally due to a yield advantage of 1.3t/ha, and very poor quality for wheat at West Casuarinas due to animal damage in the wheat plots.

Effect of N nutrition on barley performance; yield and gross margin

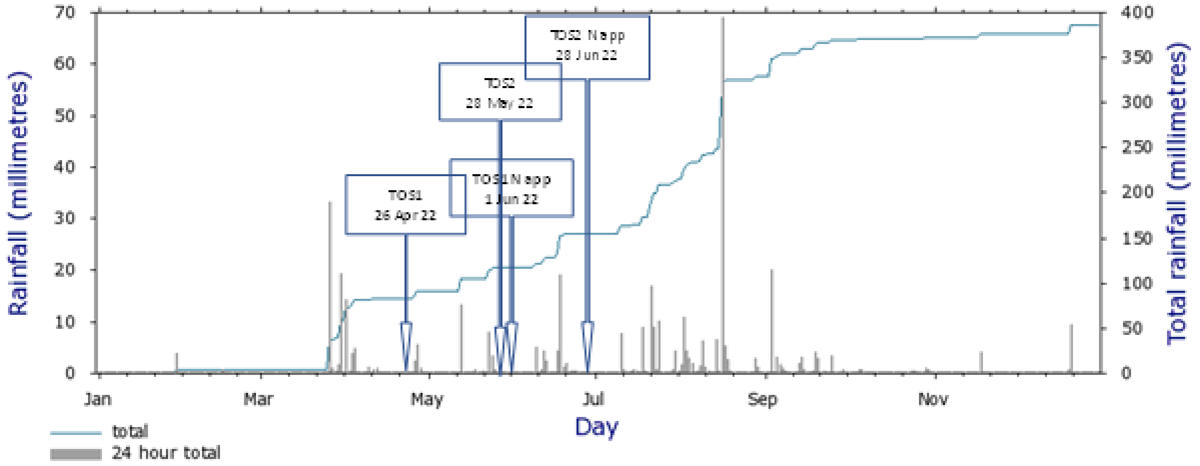
Three nitrogen strategies were tested. N inputs were specific for each location and in each year. The base rate of nitrogen assumed a typical season and was all applied prior to seeding. The second treatment split the application of this rate of nitrogen with 50% applied prior to seeding and 50% early post emergent (Treatment two). To capitalise of an above average season, a higher rate was also tested and applied in a split application with 50% before seeding and 50% early post emergent (Treatment three). An example of the rates used is shown for 2021 in Methodology in Table 2021.

One of the questions posed in this project was "did individual barley varieties differ in their response to nitrogen". The interaction term of variety x nitrogen treatment in the statistical analysis was not significant for grain yield or grain protein for all locations in 2020 and 2021.

In 2022 the timing for post emergent application was brought forward to growth stage 14 (~ GS21) which is more in line with current farmer practise and the relation between variety and nitrogen was less clear with Eradu and West Casuarinas recording significant interactions between variety and nitrogen treatment. This coincided with very low protein for all varieties at each site and is thought to most likely reflect leaching of nitrogen on these light textured low clay content soils after heavy rainfalls rather than differences between varieties. The timing of nitrogen treatments and daily rainfall for Eradu and West Casuarinas is shown in Figure 5.

The overall results over three years suggests that varieties responded in a similar manner to the way nitrogen was applied and the crop nitrogen regime needs to just consider timing and growth stage of the crop, paddock history and expected growing season, not the variety.

(a) Eradu rainfall 2022



(b) West Casuarinas rainfall 2022

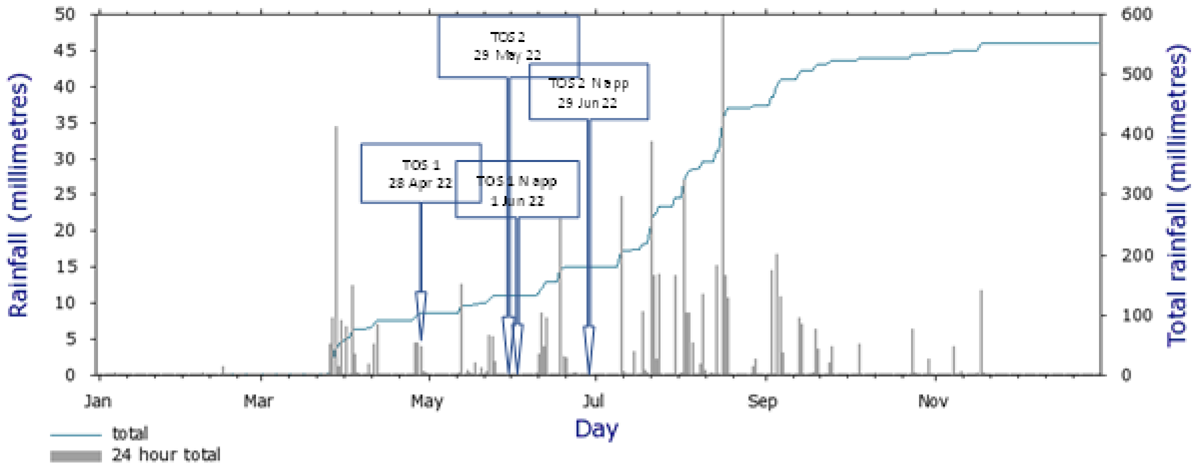


Figure 5. Rainfall events in relation to post emergent nitrogen application for (a) Eradu and (b) West Casuarinas

The response of barley to the nitrogen strategies can be treated as main treatments effects and is summarised in Table 6 for each location and each year.

Splitting nitrogen offered few yield advantages on the yellow sands at Binnu or the loam soils of Northampton, Tenindewa and Canna. Significant yield gains were more likely to be found in Eradu and West Casuarinas. Grain protein was more responsive to splitting nitrogen with increased protein most likely at Eradu, Canna and West Casuarinas. In 2022 splitting nitrogen increased protein in sowing time two at five locations with the exception of Binnu which was grown on a lupin stubble.

Increasing the nitrogen rate raised yield at Eradu and Canna. Protein was more responsive than yield with increased protein measured all locations and at both sowing times.

In a general sense nitrogen management was more likely to be beneficial at Eradu, Canna and West Casuarinas. Improvements were recorded for Binnu, Northampton and Tenindewa but they occurred less often and were more often reflected as higher protein.

In terms of gross margins, Binnu was responsive to nitrogen in 2020, and in 2021 it was very responsive to nitrogen from an early sowing yet all nitrogen up front was most profitable at the late sowing (Table 7). This is an example where the timing of nitrogen had an impact on profit. In 2022 the lowest nitrogen rate was the most profitable which is not surprising considering it was grown on a lupin stubble. Northampton had a very low response to nitrogen in each year due to the legume pasture used in the rotation. Eradu in 2020 was badly affected by strong winds soon after emergence and plant density was low. This inhibited response to nitrogen whilst 2021 was on a canola stubble and the high rate of nitrogen increased gross margin from an early sowing but the later sowing, with a dry finish (with rainfall easing from the last week of July), was not able to take advantage of split nitrogen. In 2022 the season was more ideal with a cool grain fill period and available moisture, and the high rate of nitrogen was the most profitable. In Tenindewa the hot finish meant the response to nitrogen late was limited apart from 2022. The early application of nitrogen gave the highest profitability with early sowing, due in part to the plants ability to tiller and increase yield potential. Canna was very responsive to nitrogen in 2022 due to the higher rainfall and application of post emergent nitrogen at 4 leaf. In 2020 and 2021 the follow-up split application of nitrogen benefited the early sowing, and all up front was most profitable from a later sowing. West Casuarina did not generally respond to a split application of nitrogen in 2020 and 2021, due in part to nitrogen applied on a leaching soil based on growth stage and the crop could not take advantage of the extra nitrogen. An earlier application at the 4th leaf in 2022, and a higher rate, was beneficial and recorded the highest gross margin of the three nitrogen strategies.

Seasonal conditions play a major role in the response to nitrogen and the nitrogen rates and timing tested in this project were not reactive to the season. This meant the returns were problematic as treatments could not necessarily take advantage of unpredictable rains or manage leaching soils correctly. However, general themes have emerged for nitrogen management of barley crops. The split application of nitrogen can have merit on the leaching sands such as Eradu and West Casuarinas and can increase yield. Splitting nitrogen and increasing rates can also increase yield and protein on other soil types. However, for a more consistent response to nitrogen a more prudent strategy may be a flexible approach; to apply a greater percentage of nitrogen at sowing, unless on a leaching soil type, followed up by rates dictated by the seasonal conditions such as a soft finish at Tenindewa and Canna, and leaching rains events at Eradu and West Casuarinas.

Table 6. Effect of nitrogen strategy on barley (a) yield and (b) protein

(a) yield

Year	Nitrogen strategy	Binnu		Northampton		Eradu		Tenindewa		Canna		West Casuarinas	
		TOS1	TOS2	TOS1	TOS2	TOS1	TOS2	TOS1	TOS2	TOS1	TOS2	TOS1	TOS2
2020	N1						-						
	N2					1	-						
	N3	1					-						
2021	N1												
	N2												
	N3				1								
2022	N1												
	N2					1	1						1
	N3					1	1			1	1		

(b) protein

Year	Nitrogen strategy	Binnu		Northampton		Eradu		Tenindewa		Canna		West Casuarinas	
		TOS1	TOS2	TOS1	TOS2	TOS1	TOS2	TOS1	TOS2	TOS1	TOS2	TOS1	TOS2
2020	N1						-						
	N2			1			-			1		1	1
	N3	1	1		1	1	-	1		1	1	1	1
2021	N1												
	N2		1			1	1	0	1	1	0	0	0
	N3			1		1	1	1	1	1	0	0	1
2022	N1												
	N2				1		1		1		1		1
	N3		1	1	1	1	1			1	1	1	1

[green] N2 is significantly higher than N1, [orange] N3 is significantly higher than N1 or N2 (N rates for average season)

Table 7. Effect of nitrogen strategy on gross margin of barley

Year	Nitrogen strategy	Binnu		Northampton		Eradu		Tenindewa		Canna		West Casuarinas	
		TOS1	TOS2	TOS1	TOS2	TOS1	TOS2	TOS1	TOS2	TOS1	TOS2	TOS1	TOS2
2020	N1				1		-				1	1	
	N2			1		1	-		1	1			
	N3	1	1				-	1					1
2021	N1		1				1	1	1		1	1	1
	N2			1	1				1	1	1	1	
	N3	1			1	1				1			
2022	N1	1	1	1	1			1					
	N2						1		1				1
	N3					1	1		1	1	1	1	

Yield of N3 is significantly greater than N1 but GM for N2 and N3 are the same.

DISCUSSION OF RESULTS

A survey of growers in the Geraldton Port Zone indicated that the uptake of barley was limited by its inability to compete financially with wheat as the main cereal in the rotation. This project sought to identify limitations in the productivity of barley and to identify whether changes can be made to the agronomy of barley crops to reduce risk and make barley more profitable. The Barley Agronomy Project was conducted over three seasons with growing conditions and the drivers for crop yield varying in each year. Year one was characterised by a decile 2-3 low rainfall season with steadily increasing hot days from mid-August, yet timely August rainfall provided for an average season at each location. Substantial autumn rainfall provided an ideal start to the 2021 growing season to test early sowing opportunities and consistent cold fronts through July helped to maintain high yield potential at each location. The 2022 growing season was an average season judged by total rainfall yet consistent cold fronts through July and August provided the opportunity for crops to compensate for low rainfall through May and June and a cool grain filling period through spring allowed crops to achieve high yields.

Locations were chosen to represent the range of soils, rainfall patterns and season lengths in the Geraldton Port Zone and the trials were repeated over three years to capture a range of rainfall/temperature scenarios. Interpretation of the results and conclusions from this project need to bear in mind that yield potential was quite reasonable in each year, although not at all locations, and no season captured the hot/dry finish to the season that can occur in this port zone.

Trials were sown at the end of April to simulate an early sowing opportunity and irrigation was used, if necessary, with water equivalent to a 20mm rainfall event applied in the furrow. On only one occasion was a followup irrigation needed due to a dry start; Canna in 2020.

The locations represented six soil types. Binnu was a deep yellow sand that was quite acidic at depth. Northampton was a red loam with a history of legume pasture, neutral pH and a large water holding capacity. Eradu was an ameliorated deep yellow sand with a history of liming yet with some acidity still at depth. Tenindewa offset the Eradu site with a soft red loam and a better water holding capacity. Canna represented an acidic soil with Aluminium and low rainfall. West Casuarinas had a non-wetting sandy soil susceptible to leaching yet with a soft finish due to August/September rains. Each of these locations suffered sub soil constraints to some degree such as compaction and/or acidity and Aluminium and this influenced the amount of water accessible to the crop.

Yield performance and malt quality of barley

Barley varieties with high relative yield in each of the three years were identified for each of the six locations. These varieties recorded the highest yield or close to the highest yield in each of the three years.

The acid tolerant variety Buff was the best performing barley on the acid sands at Binnu and Canna over the 3 years of the trial and was also suited to the later sowing at Eradu.

The longer season varieties Bass and Planet were suited to early sowing at Northampton and Eradu where their later maturity allowed them to make full use of the growing season. The short season and acid tolerant Buff also showed it was well adapted at Northampton and was able to take advantage of the longer growing season with yield equivalent to Bass and Planet. A later sowing at Northampton showed no specific advantage for any barley. The favourable finishes in each year meant there were many options available.

Planet did well when sown early at Tenindewa and West Casuarinas, whilst the early maturing Rosalind was better suited to the later sowing at these sites. Planet proved to be a flexible variety at West Casuarinas and was a viable option for later sowing.

Grain quality and end use is an important consideration for barley choice. Historically the pricing for barley has only considered it as a feed grain in the Geraldton port zone yet the malt varieties Bass and Spartacus were able to achieve malt grade consistently. This was more likely at Binnu, Northampton and Tenindewa and with early sowing. It was surprising that malt was not achieved at West Casuarinas with a more mild spring than Binnu or Northampton. This most likely reflects the structured way nitrogen strategies were applied in this project rather than the location itself with nitrogen application based on crop growth stage rather than managing leaching. The results in this project show that malt grade barley can be grown successfully in the Geraldton port zone, yet it cannot currently be delivered to CBH facilities and substantial and consistent tonnages will need to be produced before a malt grade segregation at Geraldton could be considered.

The question of whether barley can compete with wheat as the main cereal in rotations rests with the respective yields and gross margins. Only barley varieties with consistent high relative yield at a location were considered in this part of the analysis and it only considers the years 2021 and 2022 when Scepter wheat was included in the trials.

The highest yielding barleys were competitive with Scepter wheat and were able to match the wheat yield at all locations and in many cases were able to achieve higher yields. In 2021 and 2022 barley yielded more than wheat at all locations when sown early.

Barley sown late in 2021 was more exposed to the higher spring temperatures during grainfill and this impacted its yield relative to wheat yet barley yield was still comparable to wheat at all locations. Barley was also able to maintain a yield advantage sown late at locations with a mild spring; of 5.25 t/ha versus 3.77 t/ha at Northampton and 2.14 t/ha versus 1.35 t/ha at West casuarinas.

Barley sown late was also comparable to wheat at all locations in 2022 and the mild spring temperatures through August and most of September coupled with consistent August rainfall events produced higher yields at Northampton, Eradu and Tenindewa. The yield for West Casuarinas has not been considered as the wheat plots suffered animal damage.

Gross margin of barley versus wheat

Whilst barley can match or exceed the yield of wheat the gross margins in 2021 and 2022 clearly show that the financial returns for barley are much lower than for wheat.

In 2021 the loss ranged $49/ha to $528/ha at Eradu, Tenindewa and Canna. The greatest losses occurred when wheat was accepted into a premium grade of H2. Barley was more successful at Binnu and Northampton with yield advantages of more than 1t/ha producing gross margins of $47/ha to $233/ha and offsetting the higher price of AGP1 wheat.

Barley gross margins were also lower in 2022 at Binnu, Northampton, Eradu and Canna where the smaller yield advantage could not overcome the higher price for wheat and premium grades of H2, APW1, APW2. There was one exception, at Tenindewa, where a yield advantage of 1.33 t/ha meant that barley broke even with wheat delivered into H2. However, a yield advantage of 0.73 t/ha at the later sowing resulted in a $396/ha loss compared to wheat.

This project has shown that barley cannot compete with wheat as a first choice cereal in the rotation. Whilst barley can yield similarly to wheat the yield benefit is not large enough to overcome the price premium for wheat. This is shown in Figure 6 where the farmgate prices for wheat and barley are shown. The barley price has been consistently lower than wheat for the duration of the project.

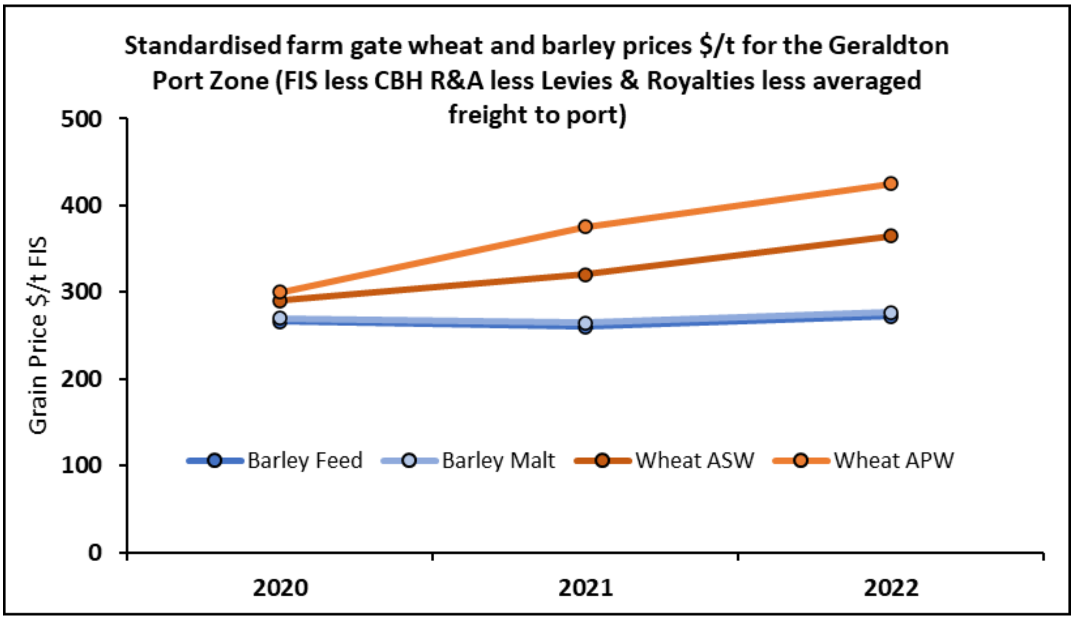


Figure 6. Farmgate grain prices for wheat and barley for 2020, 2021 and 2022

Barley may however have a fit in other parts of the rotation. Barley's ability to flower before August when sown early helps it to avoid the high temperatures during grainfill and may make it a low risk and profitable option as a third cereal before a break crop on the yellow sands of Binnu and Eradu or in a mixed farming enterprise where the extra stubble has value for animals. Imidazolinone tolerant and acid tolerant barley may have specific uses. Barley use in these scenarios is predominantly an agronomic decision.

Effect of Nitrogen strategy on barley performance, yield and gross margin

Nitrogen inputs were specific to each location and in each year. The basal rate for each trial assumed a typical season and was all applied prior to seeding. The second treatment split the application with 50% applied prior to seeding and 50% early post emergent. The third treatment increased the nitrogen rate to capitalise of an above average season, split 50% before seeding and 50% early post emergent.

The question of do cereal varieties respond differently to nitrogen has been tested in previous GRDC projects (Yardstick Trials) and it was found that they do not. That was also the case in this project. The overall results over three years suggests that varieties responded in a similar manner to the way nitrogen was applied and the crop nitrogen regime needs to just consider timing and growth stage of the crop, paddock history and expected growing season, not the variety.

In general, applying all nitrogen up front, prior to seeding, was a robust nitrogen strategy for the yellow sands at Binnu and the loam soils of Northampton and Tenindewa.

An active nitrogen management was more likely to be beneficial at Eradu, Canna and West Casuarinas yet the the financial return was not seen in every year. Improvements at Binnu, Northampton and Tenindewa were less likely and more often to be reflected as higher protein.

Seasonal conditions play a major role in the response to nitrogen and the nitrogen rates and timing tested in this project were not reactive to the season. This meant the returns were problematic as treatments could not necessarily take advantage of unpredictable rains or manage leaching soils correctly. However, general themes have emerged for nitrogen management of barley crops. The split application of nitrogen can have merit on the leaching sands such as Eradu and West Casuarinas and can increase yield. Splitting nitrogen and increasing rates can increase yield and protein and profit on other soil types although the returns are very seasonal dependent. For a more consistent response to nitrogen a more prudent strategy may be a flexible approach; to apply a greater percentage of nitrogen at sowing (to increase tiller number), unless on a leaching soil type, followed up by rates dictated by the seasonal conditions such as a soft finish at Tenindewa and Canna, and leaching rains events at Eradu and West Casuarinas.

CONCLUSION

The project "Barley Agronomic Strategies for the Geraldton Port Zone KAL2003-002SAX \ 9178054" demonstrated that barley can be successfully grown in the Geraldton port zone and it can compete successfully with wheat. Varieties that performed well over years were identified at each location and these varieties matched the yield of wheat and in many instances recorded a significant yield advantage. This is most likely when barley is sown early.

Malt grade barley can be grown successfully in the Geraldton port zone, yet it cannot currently be delivered to CBH facilities.

Barley cannot compete with wheat financially as the first choice cereal in a crop rotation. The yield benefit was not large enough to overcome the price premium for wheat in the duration of this project.

Under the growing conditions and treatments experienced in this project it is clear that varieties respond in a similar manner to the way nitrogen is applied, therefore crop nitrogen strategies need to just consider crop growth stage, paddock history and expected growing season, not the variety.

In general, applying all nitrogen up front, prior to seeding, was a robust nitrogen strategy for the yellow sands at Binnu and the loam soils of Northampton, Tenindewa and Canna. An active nitrogen management was more likely to be beneficial at Eradu, Canna and West Casuarinas.

This project sampled three growing seasons. Whilst two seasons experienced many hot days above 30°C during grain fill no season experienced a very hot / dry finish that can occur in the Geraldton Port Zone.

IMPLICATIONS

Barley may still have a fit in other parts of the crop rotation. Barley's ability to flower before August when sown early helps it to avoid the high temperatures during grainfill and may make it a low risk and profitable option as a third cereal before a break crop on the yellow sands of Binnu and Eradu or in a mixed farming enterprise where the extra stubble has value for animals. Imidazoline tolerant or acid tolerant barleys may also have a specific fit for a grower. Barley use in these scenarios is predominantly an agronomic decision not a financial one.

RECOMMENDATIONS

The release of higher yielding barley varieties from breeding companies may change the financial balance against wheat. It would be useful to include a well-adapted wheat as a check or at least as a buffer in barley variety trials in the Geraldton Port Zone if it doesn't affect the integrity of the barley trial.

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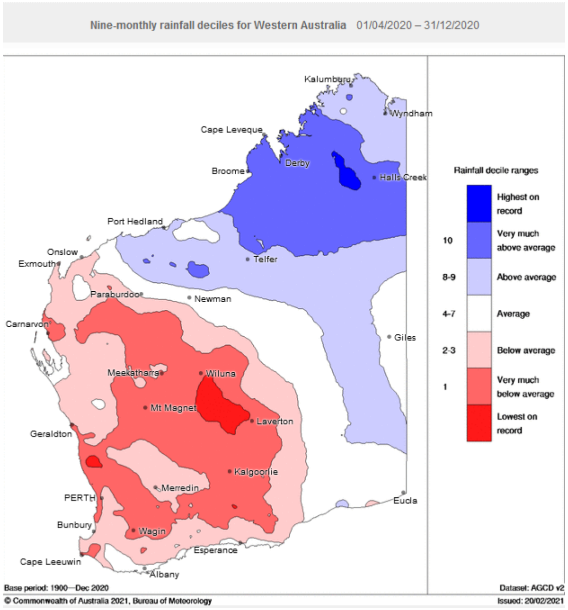
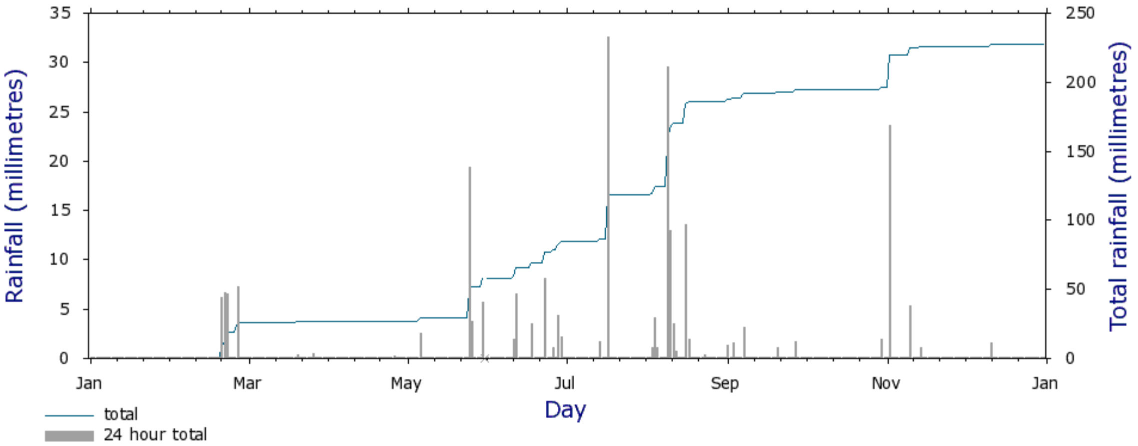
APPENDIX A: Rainfall deciles and seasonal rainfall

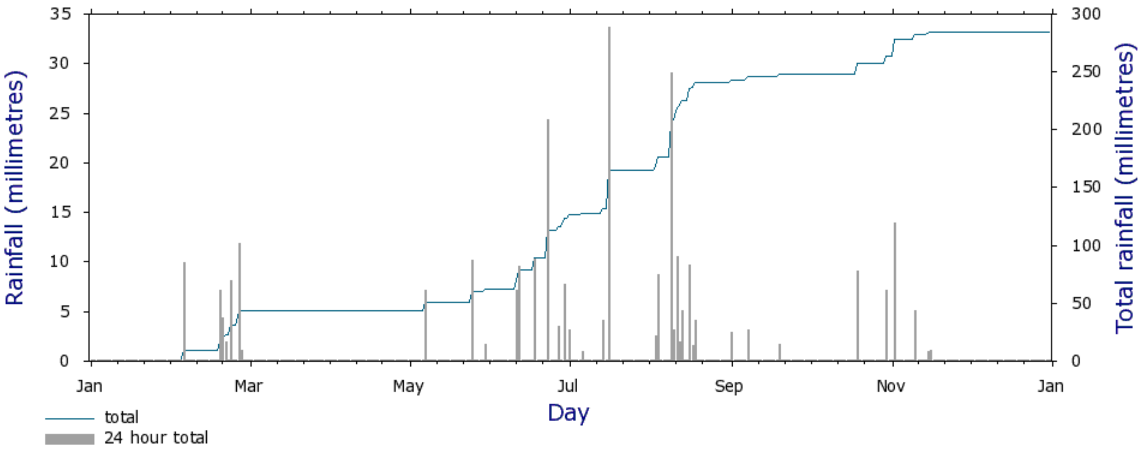
Rainfall Deciles for growing season 2020 with Binnu and Tenindewa locations as examples



Binnu rainfall



Tenindewa rainfall



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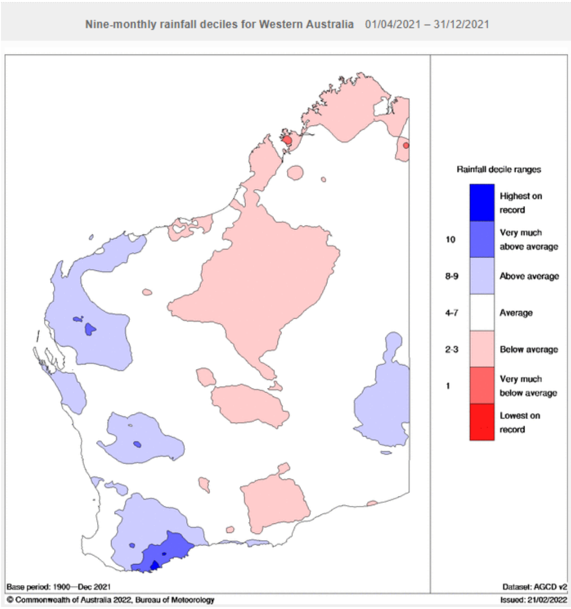
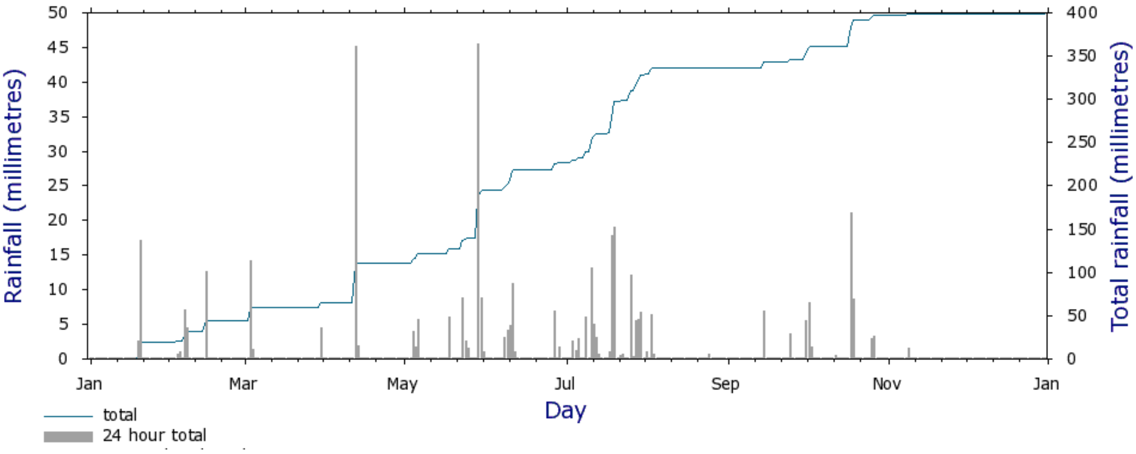
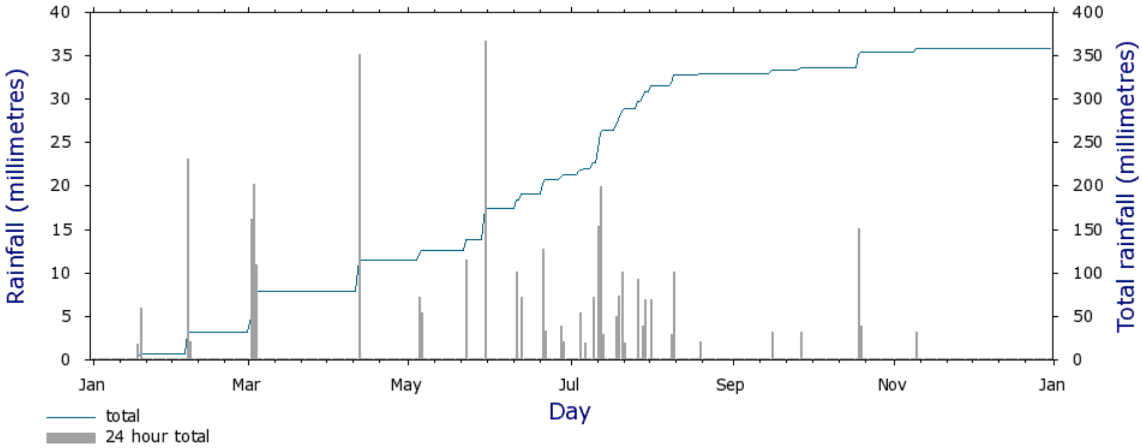
Rainfall Deciles for growing season 2021 with Binnu and Tenindewa as examples



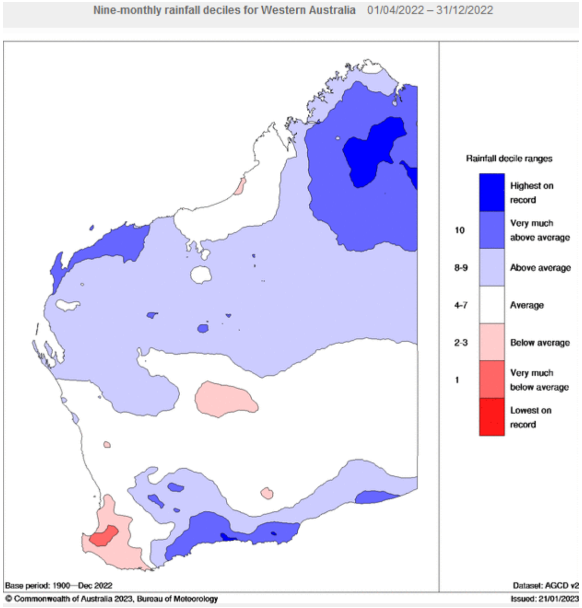
Binnu rainfall



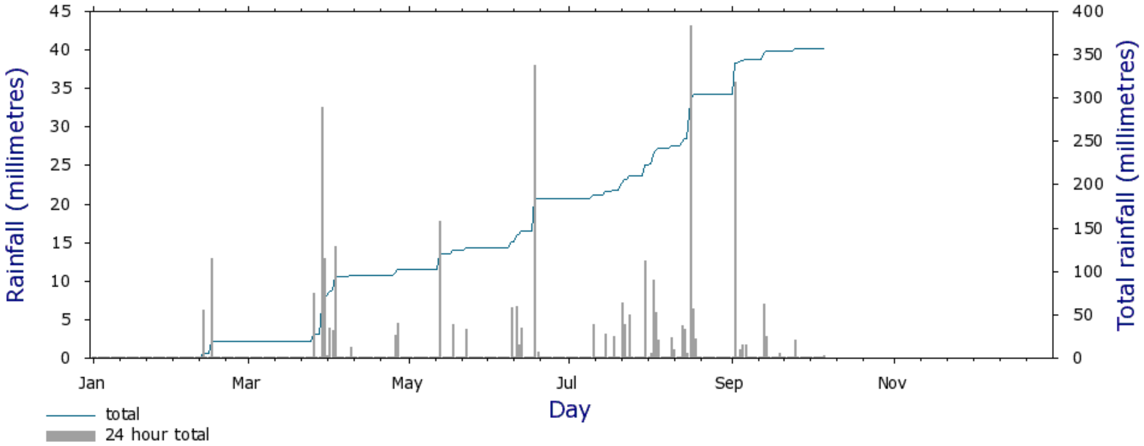
Tenindewa rainfall



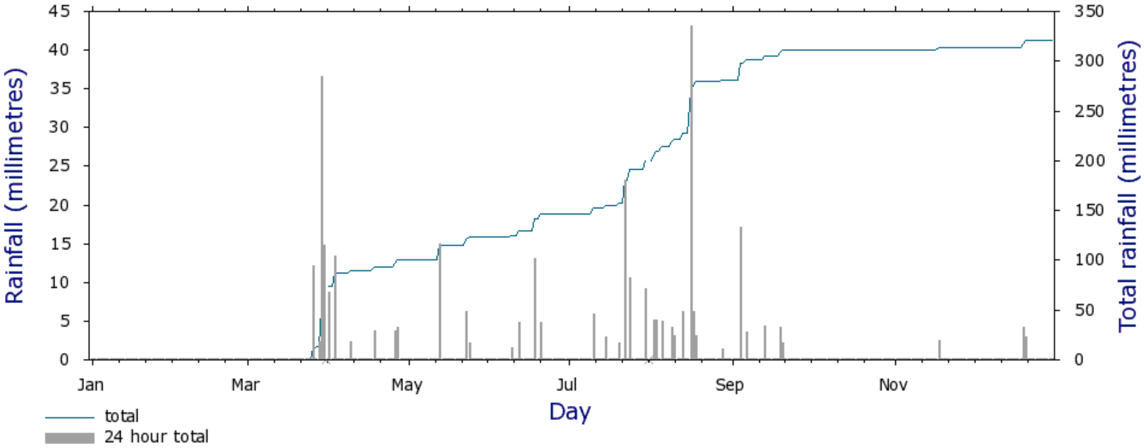
Rainfall Deciles for growing season 2022 with Binnu and Tenindewa as examples



Binnu rainfall



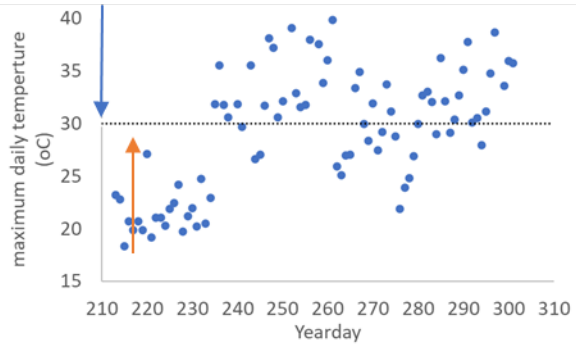
Tenindewa rainfall



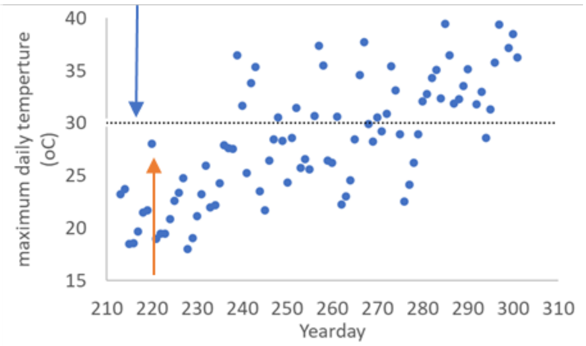
APPENDIX B: Maximum temperature during the grain filling period (1st Aug – 31 Oct) in each year with Binnu and Tenindewa locations as examples with anthesis indicated

Growing season 2020

Binnu

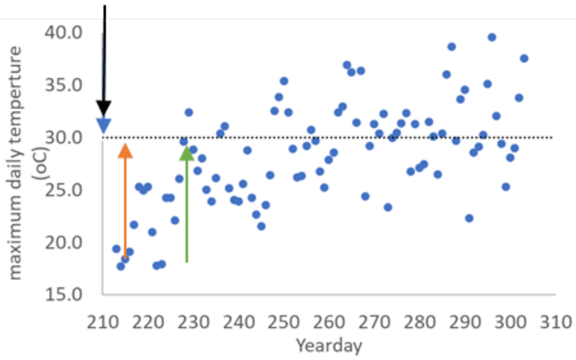


Tenindewa

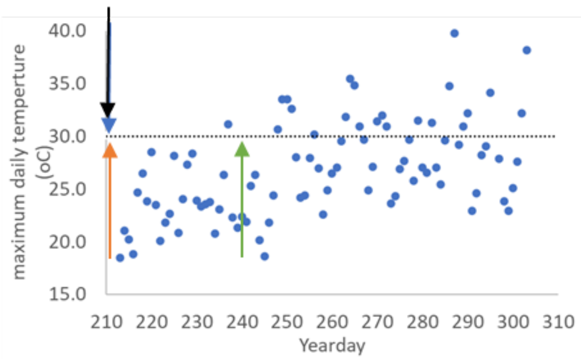


Growing season 2021

Binnu

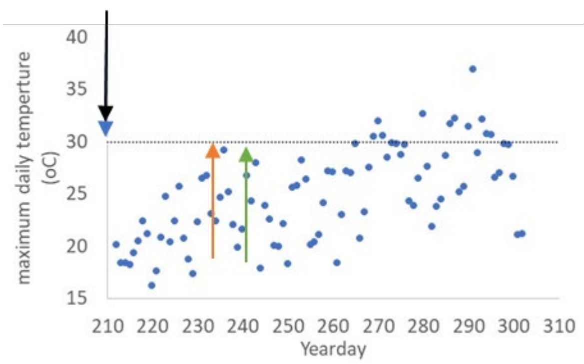


Tenindewa

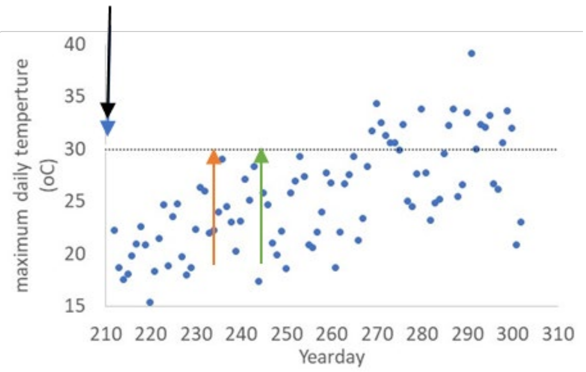


Growing season 2022

Binnu



Tenindewa



Note:- Anthesis is shown in each graph as wheat (black is TOS1, green is TOS2) and barley (blue is TOS1, orange is TOS2)

APPENDIX C: GRDC Project 9178054 Barley Agronomic Strategies in the Geraldton Port Zone – Grower Survey

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GLOSSARY AND ACRONYMS

Below is a sample abbreviations and acronyms list. Be sure to include all abbreviations and acronyms that appear in the report.

GS	Growth stage using the decimal key
TOS	Time of sowing
N1, N2, N3	The three nitrogen treatments
GSR	Growing season rainfall, nominally May to October
Exch Al	Exchangeable Aluminum
WHC	Soil water holding capacity
SAGI WEST	Statistics for the Australian Grains Industry western region

REFERENCES

This section provides the information a reader would need to locate the articles, journals, and/or other publications referred to in the report.