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NGN Comparing barley yield gap and pre-harvest losses under water limiting and non-water limiting conditions

FAR2206-004RTX

Finley and Daysdale, NSW

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Contents

Summary

Between 2022 and 2023 we experienced two very different seasons although both provided similar outcomes. 2022 was high rainfall, so much so that it created water logging during September and October which limited yield. In contrast, 2023 had a very dry September period which also served to limit yield potential. These environmental conditions have acted as 'equalisers' for yield potential and have meant that there was little scope to improve grain yield through in-season management. Sowing on time (3 May) was the best strategy to maximise grain yield, followed by variety choice in 2023. In both years high nitrogen inputs and increased fungicide intensity did not increase grain yield.

Background

While it is assumed the new frontier for barley is 25kg.ha.mm this has rarely been demonstrated. Outside of variety selection, recent research has demonstrated that canopy management in barley through the use of fungicides, sowing time, and plant growth regulation can explain yield responses ranging from 3 – 8 t/ha within similar genetics in cooler and milder production environments. These factors have been more important than nitrogen management, particularly on fertile soils and where yield potential exceeds 5t/ha . This contrasts with recent yield gap simulation studies that have not taken into account issues of lodging, head loss, brackling, and disease in barley and suggest sowing time and nitrogen deficit are the biggest factors leading to the yield gap.

It is fair to say that water-limited potential yields determined with a crop simulation model have received more attention in field studies of wheat than barley, for example in early sowing research. Currently there are still limited genetics in barley to replicate the early sowing work in barley, however research by FAR Australia suggests there may be more scope to close the yield gap in the short to medium term with improvements in disease management, head loss, brackling and lodging control. This has not been replicated in yield environments of less than 5t/ha and in less fertile scenarios. Therefore, their interaction with nitrogen (N) becomes important; this also coincides at the same time as N prices skyrocket and become one of growers' greatest variable costs.

Objectives

This investment delivered a series of field trials and extension activities to reduce the yield gap between attainable yield and water limited yield potential in barley in the low – medium rainfall zones alongside virtual trial treatments derived from crop models to determine new attainable yield benchmarks for barley growers.

Methodology

In the first year of this project, two production environments were tested; MRZ dryland (3-6t/ha Potential), and non-water limited (Irrigated 10t/ha Potential) at Finley, NSW.

In the second year, the trial moved to Daysdale where two sowing dates were evaluated (on time sowing and delayed sowing dates) due to an inability to irrigate trials, and to align treatments with a similar GRDC investment in the southern region (Project code: FAR2204-002SAX).

Eight levels of increasing management intensity were applied to each environment that replicated standard through to intensive management (evaluating cultivar choice, nitrogen supply, fungicide use and canopy management strategies). All other factors were kept standard across treatments and were controlled as per best management for weed and pest control. A standard seeding rate of 180 seeds/m^2 was used across all sites.

Irrigation

In year one, trials were set up to be run as plus and minus irrigation. However, due to an unusually wet growing season (508mm rainfall April-October) the irrigated treatments only received an additional 25mm of water in August.

Sow Date

Two sowing dates were targeted; an on time sowing date of 20 April – 5 May, and a second sow date of mid-late May or at least two weeks post emergence of sow date one. The achieved sowing dates for both sites are in Table 1.

Table 1. Sowing dates achieved for both sites.

Year 1 (2022) Finley	Year 2 (2023) Daysdale	
TOS1	TOS1	TOS2
9 May	3 May	17 May

Barley Cultivar

Three cultivars were utilised for this project with each having different characteristics/plant types.

1. RGT Planet (High yielding, disease susceptible)
2. Cyclops (High yielding, erect type)
3. Leabrook (Vigorous lodging check)

In-Crop Management

Table 2. Summary of management levels evaluated.

Trt	Treatment name	Fungicide	Canopy	Nitrogen Supply
1	Nil Fungicide Low N	Nil	Nil	Low-Intermediate (Decide 4-5)
2	Intermediate Low N	1 Unit	Nil	Low-Intermediate (Decide 4-5)
3	Full Potential Low N	Full	Nil	Low-Intermediate (Decide 4-5)
4	Nil Fungicide High N	Nil	Nil	High (Decile 8-9)
5	Intermediate High N	1 Unit	Nil	High (Decile 8-9)
6	Full Potential High N	Full	Nil	High (Decile 8-9)
7	Full Potential Canopy	Full	PGR31/37*	High (Decile 8-9)
8	Dual Purpose System	Full	Defoliation	High (Decile 8-9)

- Treatment 2 is considered current practice for this zone
- Treatment 6 is considered adequate to achieve water limited yield potential
- Treatment 7 is considered the emerging practice to minimise preharvest yield losses

Nitrogen Management

Total nitrogen supply was calculated using Yield Prophet Lite and targeted yield deciles. Nitrogen application rates were varied each year based on starting soil N to meet calculated supply targets. Nitrogen rates were applied as a single application prior to GS31. Table 3 shows nitrogen supply targets.

Table 3. Initial yield targets and calculated nitrogen supply targets with actual N supply figures for both sites in 2022 and 2023.

	Finley – 2022	**Daysdale – 2023**

Yield Targets	Dryland	Irrigated	
Mid (Decile 4-5)	4t/ha	7t/ha	4t/ha
High (Decile 8-9)	7t/ha	10t/ha	7t/ha
Total Nitrogen Supply			
Mid (Decile 4-5)	160kg N/ha	240kg N/ha	160kg N/ha
Achieved	*156kg N (0 applied N)*	*244kg N (88kg N applied)*	*163kg N (80kg N applied)*
High (Decile 8-9)	240kg N/ha	360kg N/ha	280kg N/ha
Achieved	*244kg N (88kg N applied)*	*361kg N (205kg N applied)*	*283kg N (200kg N applied)*

Fungicide Management

Three levels of fungicide input were used to test the influence of disease management. These ranged from nil fungicide input, 1 fungicide unit, to 3-4 units of fungicide. Details of each fungicide program are in Table 4.

Table 4. Fungicide management strategies implemented at both sites.

Treatment	**Sowing**		**GS31**	**GS39-45**
Nil	Vibrance/Gaucho		---	---
1 Unit	Vibrance/Gaucho		Prosaro 300ml/ha	
Full	Vibrance/Gaucho	Systiva 150ml/100kg	Prosaro 300ml/ha	Aviator Xpro 500ml/ha

Due to the wet conditions in 2022, only one foliar fungicide was applied at GS39-45 where the one unit strategy had Prosaro at 300mL/ha (prothioconazole & tebuconazole) and the full control strategy had Aviator Xpro at 500mL/ha (prothioconazole & bixafen).

Canopy Management

Canopy management strategies evaluated included simulated grazing, and the application of plant growth regulators (PGRs).

Table 5. Canopy management strategies applied at both sites.

Treatment	**Sowing**	**GS16-22 (Vegetative)**	**GS30**	**GS33-37**
Nil	---	---	---	---
PGR	---	---	Moddus Evo 200ml/ha	Moddus Evo 200ml/ha
Defoliation		Yes*	Yes*	

*GS30 defoliation not conducted in 2022 at Finley.

*Vegetative defoliation only conducted on TOS1 at Daysdale in 2023.

Site Details

A summary of details for each site can be found below.

Finley

Table 6. Finley site details for 2022.

Seeding Date	Harvest Date	Seeding Fertiliser Rates
9 May	8 December	100kg/ha MAP

Table 7. Soil nitrogen status assessed pre-sowing in 2022 at the Finley site.

Starting Soil N (kg N/ha)	Depth (cm)				Total Soil N (0 – 100 cm)
	0 – 10	10 – 40	40 – 70	70 – 100	
Finley, 2022	44.0	56.9	29.9	25.2	**156.1**

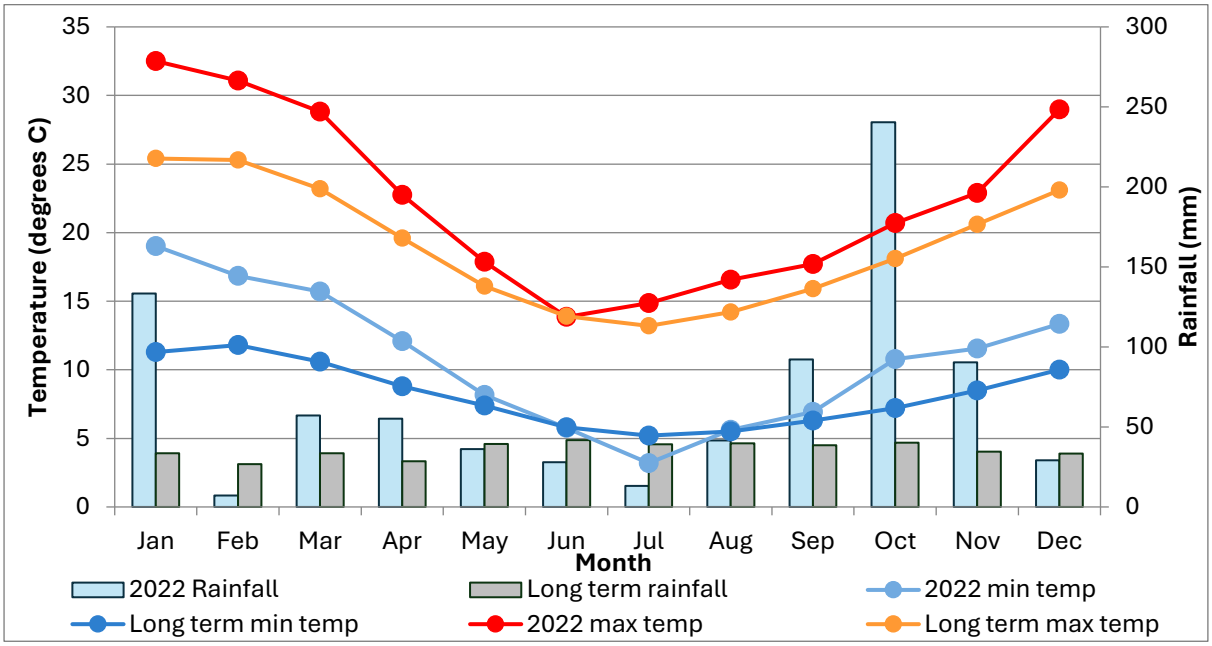

Figure 1. Monthly rainfall and temperature for 2022 and long term average for the Finley site.

Daysdale

Table 8. Daysdale site details for 2023.

	Seeding Date	Harvest Date	Seeding Fertiliser Rates
TOS1	3 May	12 December	100kg MAP/ha
TOS2	17 May	12 December	100kg MAP/ha

Table 9. Soil nitrogen status assessed pre-sowing in 2023 at Daysdale site.

Starting Soil N (kg N/ha)	Depth (cm)				Total Soil N (0 – 100 cm)
	0 – 10	10 – 30	30 – 60	60 – 100	
Daysdale, 2023	11.175	28.14	22.26	21.56	**83.1**

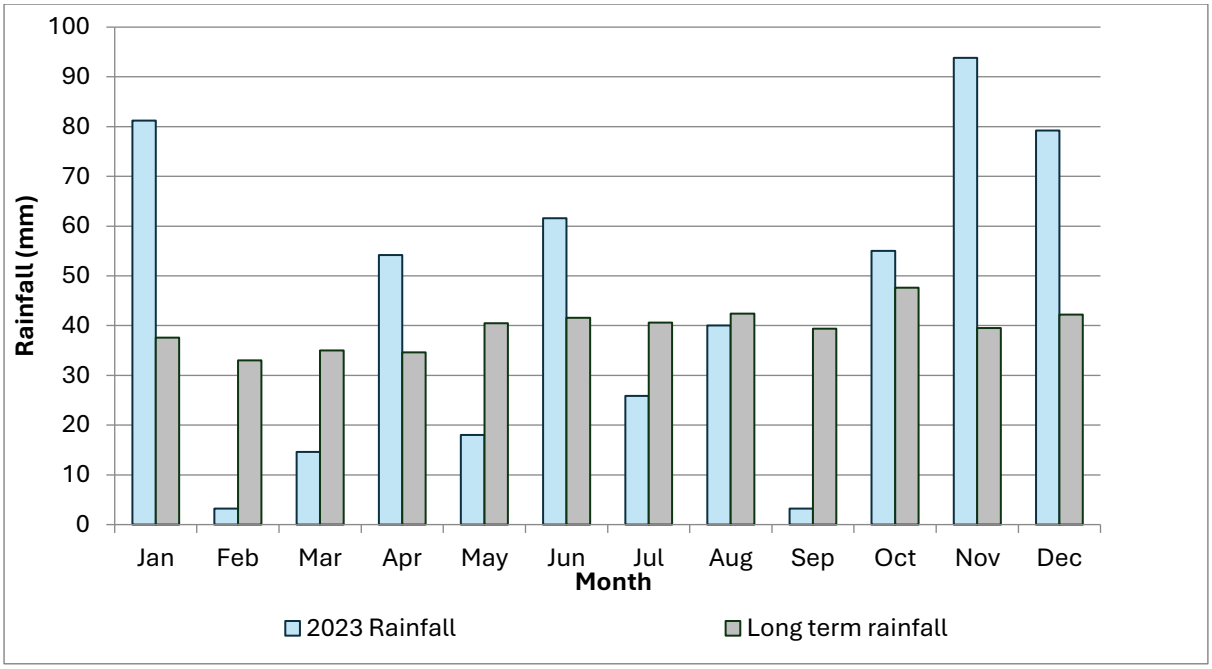

Figure 2. Monthly rainfall for Daysdale site in 2023 and the long term mean.

Assessments

A core set of assessments were completed across all treatments. These included regular NDVI assessments, disease assessments at GS31, GS49 and GS70, crop lodging and brackling scores, canopy height, and grain yield and quality assessments. Biomass cuts were taken pre and post defoliation to assess biomass removed by simulated grazing. Additional biomass samples were collected from selected treatments (trt 3,6,7) at GS49 and at maturity for the harvest index.

The results from these assessments have been analysed and presented in the rest of the report.

Statistical Analysis

Trial design and statistical analysis of trials was completed using an ANOVA in the statistics program ARM.

Results

Below are the results separated by trial site and year.

Year 1 – 2022 Finley

Between the two trials at the Finley Irrigated Research Centre, grain yields ranged from 3.73t/ha to 6.22t/ha. These yields were lower than expected and treatment differences were difficult to interpret due to the waterlogging experienced on the site.

Table 10. Influence of agronomic management and variety on grain yield (t/ha) of the irrigated trial.

			Yield t/ha			
Nitrogen Input	**Fungicide Intensity**	**Canopy Controls**	**Cyclops**	**Leabrook**	**RGT Planet**	**Mean**
Low	Nil		4.86 -	4.68 -	5.14 -	**4.89 b**
Low	Low		4.78 -	4.05 -	5.08 -	**4.64 bc**
Low	High		5.48 -	4.67 -	5.52 -	**5.22 a**
High	Nil		4.38 -	3.73 -	5.22 -	**4.44 cd**
High	Low		4.27 -	3.88 -	4.66 -	**4.27 d**
High	High		4.87 -	3.96 -	5.30 -	**4.71 bc**
High	High	PGR	4.48 -	3.98 -	5.40 -	**4.62 bc**
High	High	Defoliated	4.87 -	4.52 -	5.37 -	**4.92 ab**
Mean			**4.75 b**	**4.18 c**	**5.21 a**	
Cultivar			**LSD p=0.05**	0.40	**P val**	0.002
Treatment			**LSD p=0.05**	0.31	**P val**	<0.001
Cultivar x Treatment			**LSD p=0.05**	ns	**P val**	0.231

Table 11. Influence of agronomic management and variety on grain yield (t/ha) of the dryland trial.

			Yield t/ha			
Nitrogen Input	**Fungicide Intensity**	**Canopy Controls**	**Cyclops**	**Leabrook**	**RGT Planet**	**Mean**
Low	Nil		4.60 -	3.98 -	5.43 -	**4.67 cd**
Low	Low		4.92 -	4.17 -	5.02 -	**4.70 cd**
Low	High		5.52 -	4.05 -	5.58 -	**5.05 abc**
High	Nil		4.68 -	3.98 -	5.17 -	**4.61 d**
High	Low		4.68 -	4.06 -	4.77 -	**4.50 d**
High	High		4.81 -	4.39 -	5.36 -	**4.85 bcd**
High	High	PGR	5.26 -	4.27 -	5.91 -	**5.15 ab**
High	High	Defoliated	5.15 -	4.39 -	6.22 -	**5.25 a**
Mean			**4.95 a**	**4.16 b**	**5.43 a**	
Cultivar			**LSD p=0.05**	0.49	**P val**	0.002
Treatment			**LSD p=0.05**	0.40	**P val**	0.002
Cultivar x Treatment			**LSD p=0.05**	ns	**P val**	0.345

Fungicide Strategy

Responses to fungicide application were limited due to reduced capability to apply treatments but also due to the low levels of net blotches detected (Table 12) (spot form net blotch (SFNF) and net form net blotch (NFNB)).

Table 12. Influence of agronomic management on plot infection of net blotches (% Leaf Area Infected).

	SFNB (%LAI)		NFNB (%LAI)	
	Flag	**Flag-1**	**Flag**	**Flag-1**
Low N, 0F	2 -	3 b	1 -	2 -
Low N, 1F	3 -	4 a	1 -	3 -
Low N, 2 F	2 -	2 bc	1 -	2 -
High N, 0F	2 -	2 bc	1 -	3 -
High N, 1F	3 -	2 bc	1 -	3 -
High N, 2F	2 -	2 bc	1 -	3 -
High N, 2F, PGR	3 -	2 c	1 -	3 -
High N, 2F, Grazed	2 -	2 bc	1 -	4 -
Mean	2.4	2.4	1.1	2.9
LSD p=0.05	ns	1.2	ns	ns
P val	0.382	0.004	0.996	0.656

Whilst not statistically significant in most cases, there were yield gains from using SDHI chemistry (Systiva and Aviator Xpro) above the untreated control, which ranged from 0.24 t/ha to 0.38 t/ha. The yield responses to fungicide were highest under the low nitrogen strategies but only the irrigated scenario provided a statistical yield response (under high and low N supply). However, there were no reductions in disease levels noted (Table 12).

Nitrogen Management

The trials were established on a fertile irrigation block with 156kg of nitrogen already present in the soil. In the dryland trial, increasing the N supply from 156kg N/ha to 244kg N/ha did not provide any statistical yield gain. In the irrigated trial, increasing N supply from 244kg N/ha to 361kg N/ha gave a significant yield reduction of 0.43t/ha averaged across the 3 fungicide treatments. Lower grain yield coupled with higher nitrogen supply resulted in significantly higher grain protein levels (Table 13). The change in nitrogen management increased grain protein from 12.6% under low input, to 14.6% with high N input.

Table 13. Influence of agronomic management and variety on grain protein (%).

			Protein %			
Nitrogen Input	**Fungicide Intensity**	**Canopy Controls**	**Cyclops**	**Leabrook**	**RGT Planet**	**Mean**
Low	Nil		12.6 -	13.2 -	12.3 -	**12.7 b**
Low	Low		12.8 -	13.5 -	11.6 -	**12.6 b**
Low	High		13.2 -	11.8 -	13.0 -	**12.7 b**
High	Nil		14.7 -	15.4 -	13.8 -	**14.6 a**
High	Low		14.5 -	15.1 -	14.2 -	**14.6 a**
High	High		15.1 -	15.3 -	13.5 -	**14.6 a**
High	High	PGR	14.9 -	14.3 -	13.6 -	**14.3 a**
High	High	Defoliated	15.4 -	14.8 -	14.1 -	**14.7 a**
Mean			**14.1 -**	**14.2 -**	**13.2 -**	
Cultivar			**LSD p=0.05**	ns	**P val**	0.079
Treatment			**LSD p=0.05**	0.8	**P val**	<0.001
Cultivar x Treatment			**LSD p=0.05**	ns	**P val**	0.194

Increasing nitrogen supply had significant effects on grain quality. Increasing nitrogen supply reduced grain quality, producing lower test weights (Table 14) and higher screenings (Table 15) compared to the low N treatments.

Table 14. Influence of agronomic management and variety on grain test weight (kg/hL).

			Test Weight kg/hL			
Nitrogen Input	**Fungicide Intensity**	**Canopy Controls**	**Cyclops**	**Leabrook**	**RGT Planet**	**Mean**
Low	Nil		63.8 -	62.6 -	61.2 -	**62.5 a**
Low	Low		62.8 -	62.2 -	60.4 -	**61.8 ab**
Low	High		63.9 -	63.2 -	60.3 -	**62.4 a**
High	Nil		61.5 -	59.6 -	60.0 -	**60.4 cd**
High	Low		61.4 -	60.6 -	60.8 -	**61.0 bcd**
High	High		62.1 -	60.6 -	60.8 -	**61.2 bc**
High	High	PGR	62.0 -	58.6 -	59.7 -	**60.1 cd**
High	High	Defoliated	61.7 -	59.0 -	59.0 -	**59.9 d**
Mean			**62.4 a**	**60.8 b**	**60.3 b**	
Cultivar			**LSD p=0.05**	1.4	**P val**	0.025
Treatment			**LSD p=0.05**	1.2	**P val**	<0.001
Cultivar x Treatment			**LSD p=0.05**	ns	**P val**	0.279

Grain quality in general was poor from all treatments due to the severe water logging experienced during the grain fill period. Most treatments failed to make the feed grade BAR1 receival standards (test weight >62.5kg/hL, screenings <15%).

Table 15. Influence of agronomic management and variety on grain screenings (%).

			Screenings %					
Nitrogen Input	**Fungicide Intensity**	**Canopy Controls**	**Cyclops**		**Leabrook**		**RGT Planet**		**Mean**	
Low	Nil		19.5	-	11.9	-	14.2	-	**15.2**	**bc**
Low	Low		18.2	-	15.5	-	12.7	-	**15.5**	**bc**
Low	High		19.9	-	8.5	-	14.6	-	**14.3**	**c**
High	Nil		20.0	-	19.3	-	16.2	-	**18.5**	**ab**
High	Low		26.9	-	16.3	-	17.7	-	**20.3**	**a**
High	High		26.4	-	15.3	-	16.9	-	**19.5**	**a**
High	High	PGR	25.1	-	19.7	-	17.0	-	**20.6**	**a**
High	High	Defoliated	24.5	-	16.7	-	19.0	-	**20.0**	**a**
Mean			**22.6**	**a**	**15.4**	**b**	**16.0**	**b**		
Cultivar			**LSD p=0.05**		3.1		**P val**		0.002	
Treatment			**LSD p=0.05**		3.4		**P val**		<0.001	
Cultivar x Treatment			**LSD p=0.05**		ns		**P val**		0.300	

Nitrogen management as well as fungicide strategy had an influence on crop lodging (Figure 3). Higher N rates created a larger canopy making it more prone to lodging. In contrast, the application of foliar fungicides helped reduce crop lodging.

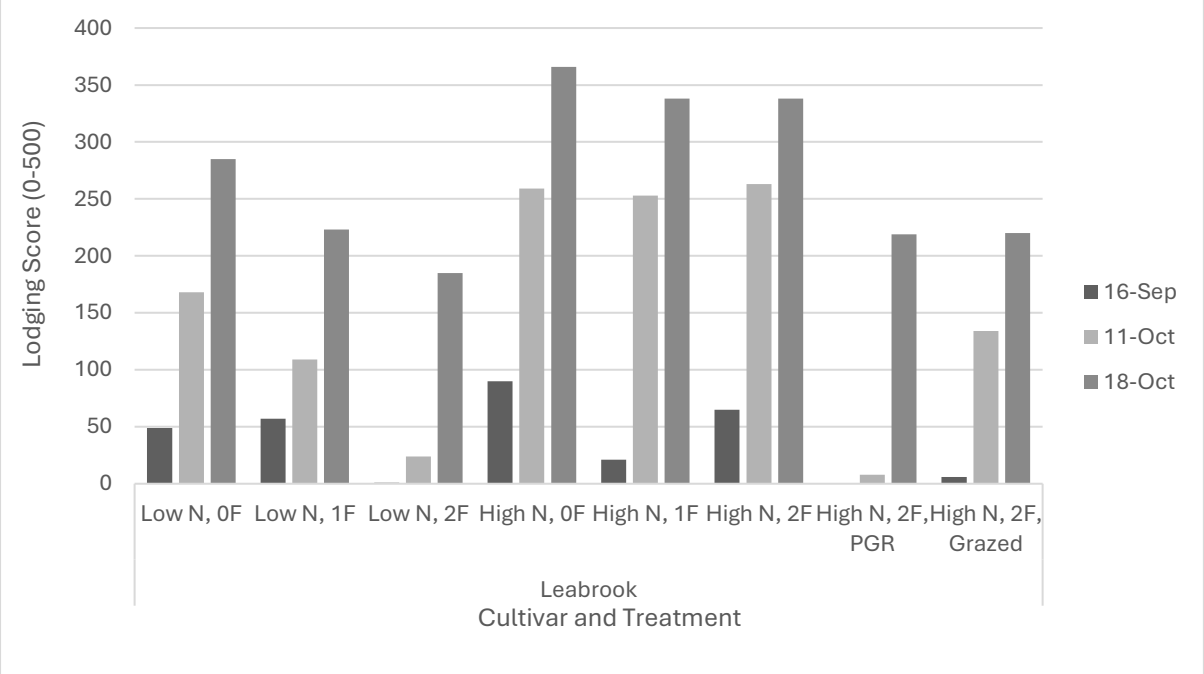

Figure 3. Influence of agronomic management on crop lodging on the weak strawed variety Leabrook.

Canopy Management

Simulated grazing during the vegetative growth period was the only canopy management technique that gave a statistical yield benefit, providing a 0.40t/ha yield gain in the dryland trial.

There were no statistical differences between varieties in terms of biomass production at the time of grazing or in the amount removed by defoliation (Table 16). On average, the process of defoliation removed about one-third of the canopy by weight, taking a canopy of 722kg DM/ha and removing 245kg DM/ha.

Table 16. Influence of variety on biomass production at time of defoliation. Plots grazed at GS24 on 30 June.

	Dry Matter kg/ha		
Cultivar	**Pre-graze**	**Post-graze**	**DM Removed kg/ha**
Cyclops	756 -	433 -	322 -
Leabrook	750 -	511 -	239 -
RGT Planet	661 -	489 -	173 -
Mean	722	478	245
LSD p=0.05	ns	ns	ns
P val	0.649	0.654	0.337

Plant growth regulators (PGRs) had a significant effect on improving the canopy standability, especially in the lodging susceptible variety Leabrook (Figure 4). The application of Moddus Evo substantially delayed lodging in Leabrook and while not statistically significant, there was a trend in lodging reduction across the other varieties.

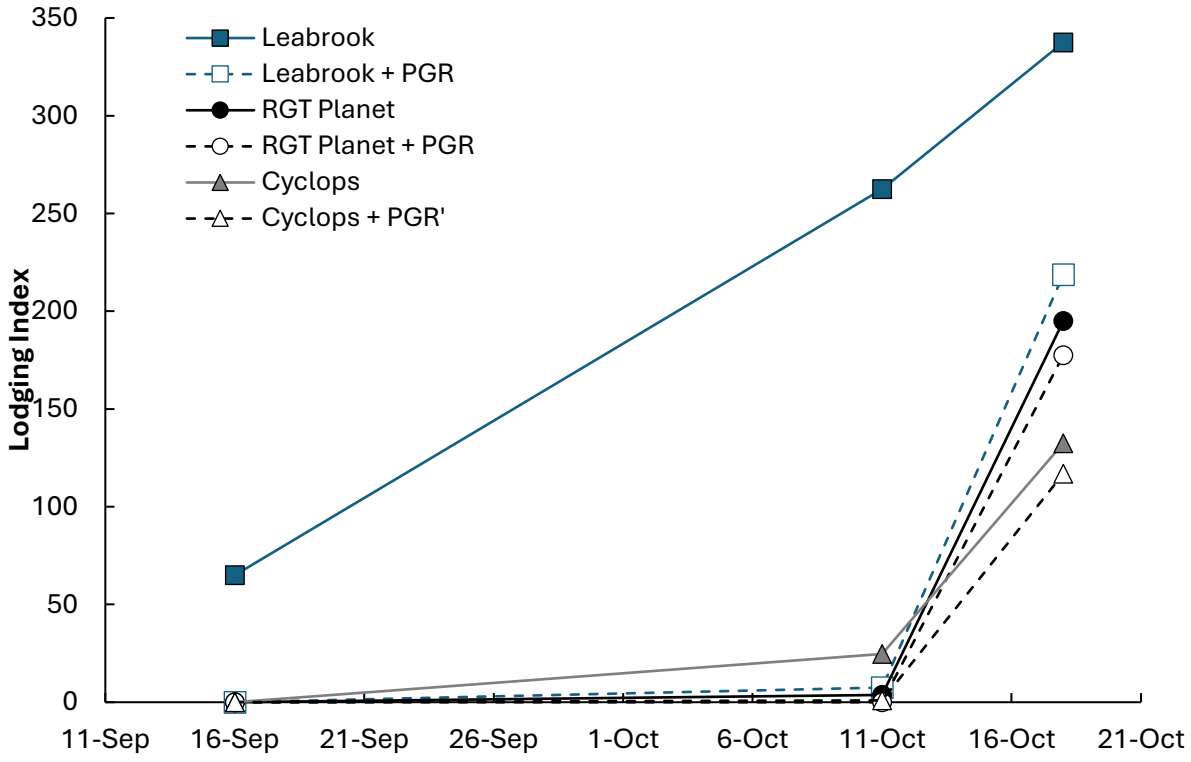

Figure 4. Influence of cultivar choice and PGR application on crop lodging (0-500) during the grain fill period.

Cultivar Choice

RGT Planet was the highest yielding variety in both trials achieving 6.22t/ha, while the lowest yielding variety was Leabrook.

In contrast, head counts conducted at harvest showed Cyclops as having the highest number of heads, with 867 heads/m^2 compared to Leabrook and RGT Planet (the highest yielding cultivar) which had statistically lower head counts at 698 and 649 heads/m^2 respectively. These results suggest that head number is not an absolute reflection of grain yield with grain number (a combination of heads/m^2 and grains per head) a bigger driver to maximise yield.

Leabrook suffered significantly from crop lodging earlier than other varieties (Figure 4) which likely caused shading during the critical growth period (stem elongation through to flowering), reducing grain yield.

Table 17. Influence of agronomic management and cultivar on head number at crop maturity.

			Heads/m^2			
Nitrogen Input	**Fungicide Intensity**	**Canopy Controls**	**Cyclops**	**Leabrook**	**RGT Planet**	**Mean**
Low	Nil		873 -	604 -	614 -	**697 -**
Low	Low		711 -	719 -	595 -	**675 -**
Low	High		896 -	714 -	653 -	**754 -**
High	Nil		810 -	700 -	672 -	**727 -**
High	Low		965 -	633 -	640 -	**746 -**
High	High		967 -	741 -	669 -	**792 -**
High	High	PGR	944 -	752 -	729 -	**808 -**
High	High	Defoliated	768 -	720 -	622 -	**703 -**
Mean			**867 a**	**698 b**	**649 b**	
Cultivar			**LSD p=0.05**	68	**P val**	0.019
Treatment			**LSD p=0.05**	ns	**P val**	0.316
Cultivar x Treatment			**LSD p=0.05**	ns	**P val**	0.763

Year 2 – 2023 Daysdale

Barley grain yields ranged from 4.55t/ha to 6.04t/ha across the trial at Daysdale in 2023. The highest yield came from RGT Planet sown 'on time' under high fungicide and low nitrogen input, while the lowest yields came from RGT Planet with 'delayed' sowing under intermediate fungicide and high nitrogen input.

Table 18. Influence of time of sowing, agronomic management and variety choice on barley grain yield (t/ha).

"On Time" Sowing (3 May)	Total N Supply	Fungicide	RGT Planet	Cyclops	Leabrook	Mean
Nil Fung Low N	163	Nil	5.79	5.27	5.43	**5.50**
Intermediate Fung Low N	163	1 Unit	5.74	5.18	5.24	**5.39**
High Fung Low N	163	3 Units	6.04	5.69	5.07	**5.60**
Nil Fung High N	283	Nil	5.45	5.65	5.38	**5.49**
Intermediate Fung High N	283	1 Unit	5.69	5.55	5.05	**5.43**
High Fung High N	283	3 Units	5.31	5.62	5.16	**5.36**
Full Potential + PGR	283	3 Units	5.88	5.74	5.38	**5.67**
Dual Purpose System	283	3 Units	5.44	5.30	5.34	**5.36**
Mean			**5.67**	**5.50**	**5.26**	

"Delayed" Sowing (17 May)	Total N Supply	Fungicide	RGT Planet	Cyclops	Leabrook	Mean
Nil Fung Low N	163	Nil	5.10	5.12	5.00	**5.07**
Intermediate Fung Low N	163	1 Unit	5.15	5.27	5.18	**5.20**
High Fung Low N	163	3 Units	4.78	5.28	4.62	**4.89**
Nil Fung High N	283	Nil	4.76	4.95	4.75	**4.82**
Intermediate Fung High N	283	1 Unit	4.55	5.17	4.94	**4.88**
High Fung High N	283	3 Units	4.55	5.05	4.75	**4.79**
Full Potential + PGR	283	3 Units	5.06	5.18	5.21	**5.15**
Dual Purpose System	283	3 Units	5.01	5.26	5.06	**5.11**
Mean			**4.87**	**5.16**	**4.94**	

Time of Sowing (TOS)	P val	0.014	LSD (p=0.05)	0.30
Cultivar	P val	<0.001	LSD (p=0.05)	0.12
Management	P val	0.014	LSD (p=0.05)	0.18
TOS x Cultivar	P val	0.001	LSD (p=0.05)	0.16
TOS x Management	P val	0.043	LSD (p=0.05)	0.25
Cultivar x Management	P val	0.040	LSD (p=0.05)	0.31
TOS x Cultivar x Management	P val	0.552	LSD (p=0.05)	ns

The trial produced significant yield differences that resulted from changing sowing date, changing cultivar and through different management strategies.

There was a significant interaction (p=<0.001) between time of sowing and cultivar, time of sowing and management, and management and cultivar.

Fungicide

Disease pressure in 2023 at Daysdale was very low; the highest levels of disease were found in the nil fungicide, low N treatment of RGT Planet (Table 19). The disease present was net form net blotch. Spot form net blotch was also detected but at extremely low levels. The nil fungicide treatments of Cyclops and Leabrook were clean from disease, with scald and leaf rust not detected in the trial.

Table 19. Influence of management strategy and time of sowing on net form net blotch infection in RGT Planet. Assessed 3 October at mid grain fill.

		Flag-1	Flag-2
TOS1	Nil Fung Low N	3.7 a	5.0 a
	Intermediate Fung Low N	0.7 bcd	1.0 cde
	High Fung Low N	0.0 d	0.0 e
	Nil Fung High N	1.7 bc	2.7 b
	Intermediate Fung High N	1.3 bcd	1.7 bcd
	High Fung High N	0.0 d	0.0 e
	Full Potential + PGR	0.0 d	0.0 e
	Dual Purpose System	0.3 cd	0.0 e
TOS2	Nil Fung Low N	2.0 b	2.3 bc
	Intermediate Fung Low N	1.3 bcd	0.3 de
	High Fung Low N	0.3 cd	0.0 e
	Nil Fung High N	1.3 bcd	0.7 de
	Intermediate Fung High N	0.7 bcd	0.3 de
	High Fung High N	0.0 d	0.0 e
	Full Potential + PGR	0.3 cd	0.3 de
	Dual Purpose System	0.0 d	0.0 e
	P val	<0.001	<0.001
	LSD (p=0.05)	1.4	1.4

High fungicide input was required to fully control the disease however, this was not economical as there was no grain yield fungicide responses in any of the varieties.

Nitrogen

Nitrogen supply had a small influence on grain yield in 2023, however this was a negative response to increasing nitrogen supply. RGT Planet showed a yield reduction from increasing nitrogen supply from 163kg N/ha to 283kg N/ha while Leabrook and Cyclops were statistically unaffected by nitrogen rate (Figure 5).

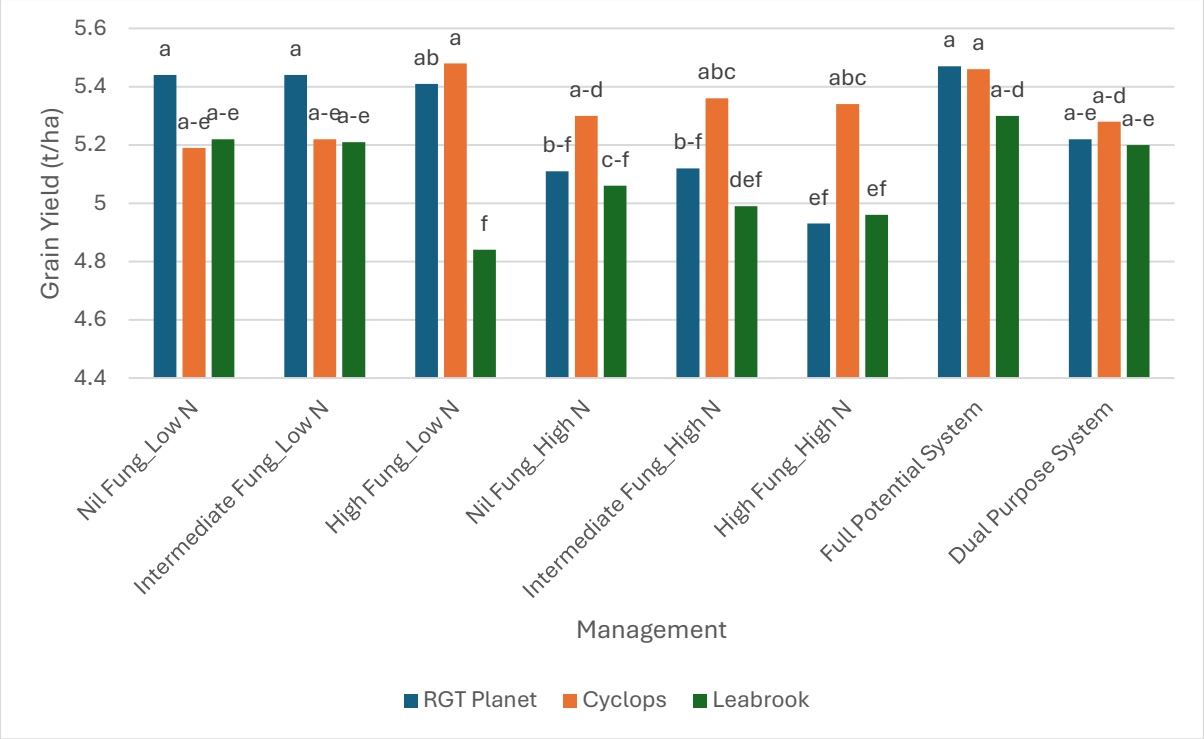

Figure 5. Influence of barley cultivar and management on grain yield (t/ha). Mean of both sow dates.

Increasing nitrogen supply also had a negative impact on grain quality (Table 20). Grain protein increased from 11.5% to 14.5% with increasing nitrogen supply, this increase in protein would result in missing out on malt classification. Retention and screenings were also negatively impacted by increasing nitrogen supply with a reduction in retention and an increase in screenings. These changes were statistically significant, however, these changes had no impact on grain classification.

Table 20. Influence of agronomic management on protein (%), test weight (kg/hL), retention (%) and screenings (%). Means of both sow dates.

	Protein (%)	Test Weight (kg/hL)	Retention (%)	Screenings (%)
Nil Fung_Low N	11.4 d	61.7 bc	90.5 a	2.6 bcd
Intermediate Fung_Low N	11.5 d	61.9 bc	90.8 a	2.6 bcd
High Fung_Low N	11.5 d	62.1 bc	91.9 a	2.4 cd
Nil Fung_High N	14.5 a	61.6 c	85.6 c	3.5 a
Intermediate Fung_High N	14.4 ab	61.7 bc	86.0 bc	3.5 a
High Fung_High N	14.2 b	61.8 bc	88.0 b	3.1 ab
Full Potential System	14.5 a	62.2 b	87.5 bc	2.8 bc
Dual Purpose System	13.8 c	63.1 a	91.2 a	2.2 d
Mean				
P val	<0.001	<0.001	<0.001	<0.001
LSD p=0.05	0.32	0.59	2.0	0.6

Canopy Management

The use of canopy management techniques was successful in 2023. The use of plant growth regulators provided a statistical yield increase in the more vigorous varieties Leabrook and RGT Planet (Figure 5).

The split application of Moddus Evo helped to reduce crop brackling (Figure 6) and reduced head loss (Figure 7). Despite the low disease pressure observed in the trials, Figure 6 shows the influence that increasing fungicide applications had on brackling. With the exception of Leabrook, which had very high levels of brackling, there was a significant reduction in brackling with increased fungicide applications.

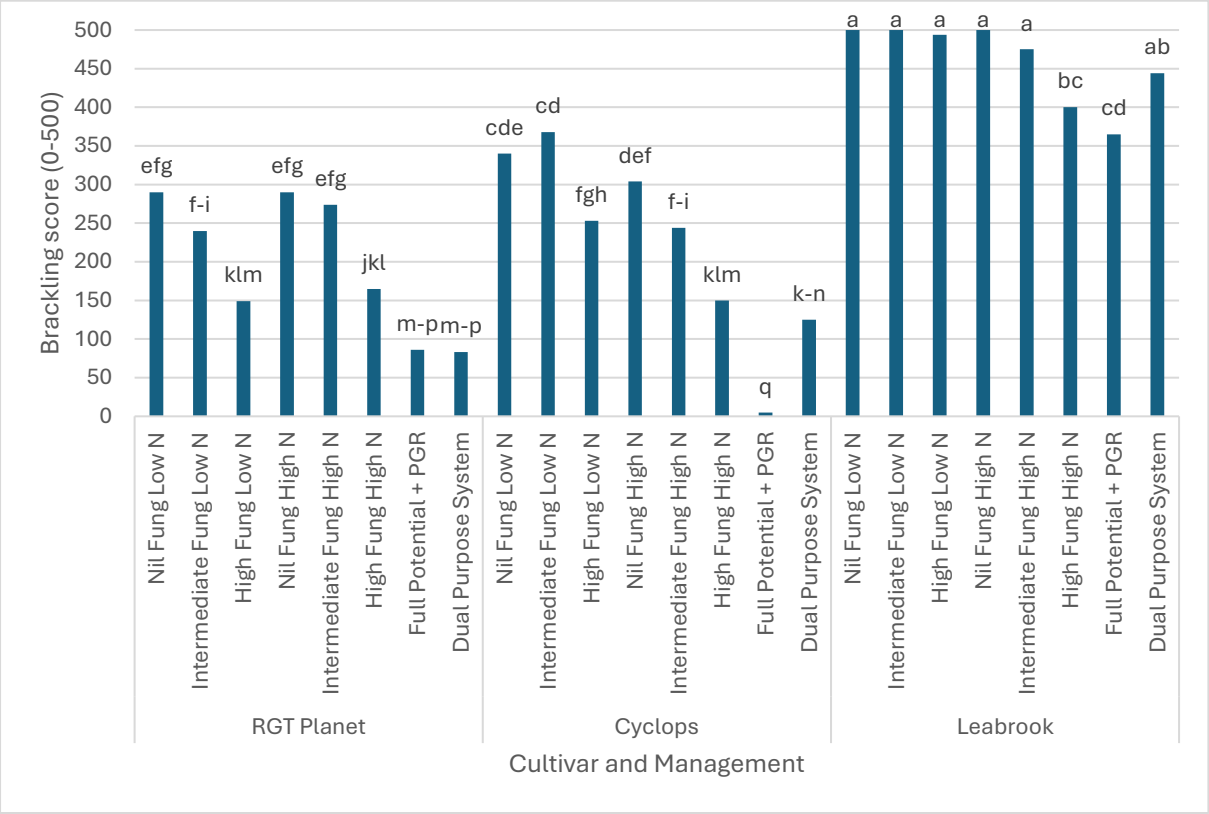

Figure 6. Influence of agronomic management of crop brackling of early sown barley (3 May), assessed 27 November 2023.

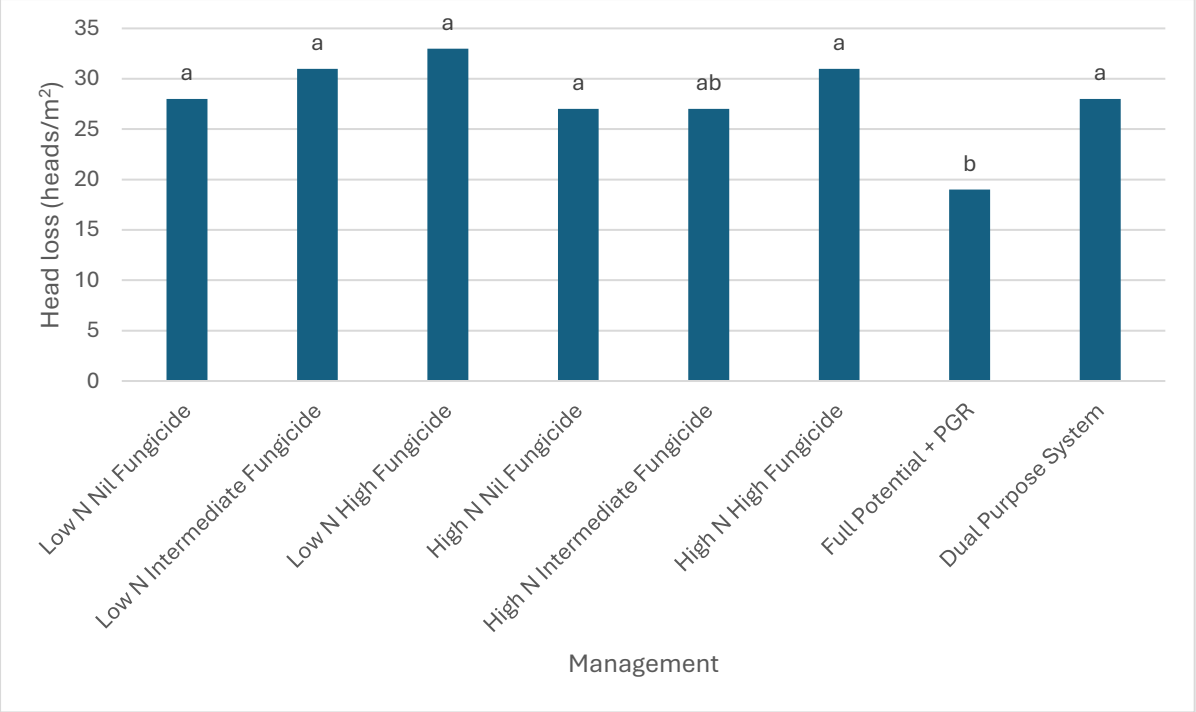

Figure 7. Influence of barley management strategies on head loss (heads/m^2), assessed post-harvest. Figures are means of sow date and variety.

Barley Cultivar

Cultivar choice had the least impact on grain yield. When averaged across management and sow date, variety choice only accounted for 0.23t/ha of the yield gap. Of the varieties tested, Cyclops had the most stable yield with no statistical differences amongst management strategies (Figure 5) and only 0.34t/ha difference between sow dates (Figure 8) compared to 0.80t/ha difference in RGT Planet.

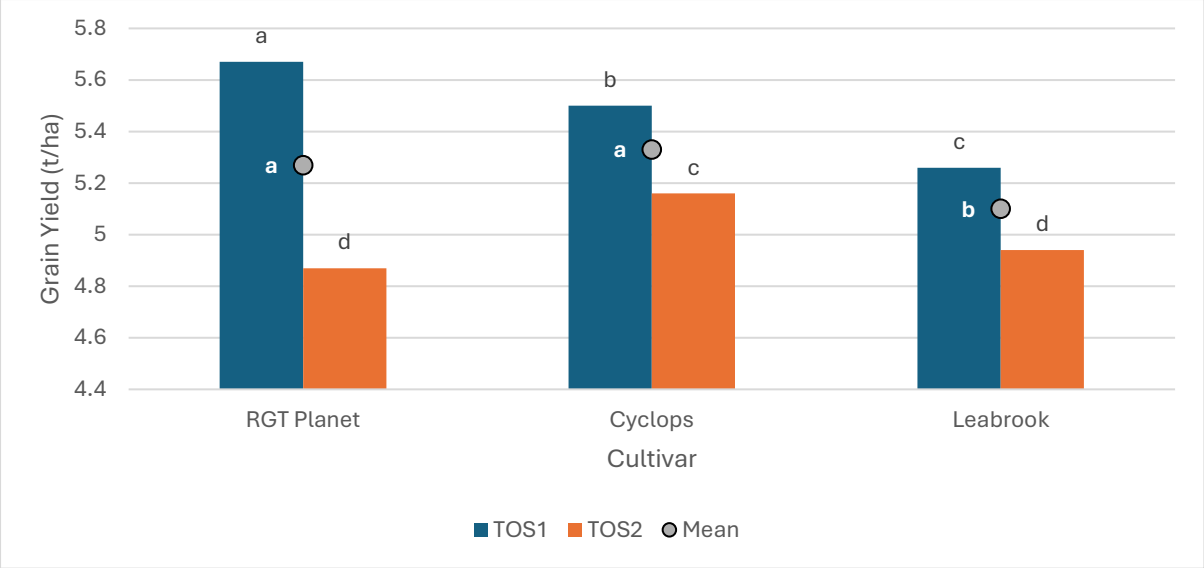

Figure 8. Influence of sow date and cultivar on barley grain yield (t/ha) – mean of all management treatments.

RGT Planet produced the highest yields, but also produced the lowest yields. Means of cultivars show that Cyclops and RGT Planet out yielded Leabrook.

Time of sowing

Time of sowing was responsible for the biggest yield gap, with 0.48t/ha difference between sow dates with TOS1 (3 May) averaging 5.47t/ha and TOS2 (17 May) 4.99t/ha. The effect of management strategies was influenced by sow date, with management strategies having a bigger influence on yield at the second sow date (Figure 9).

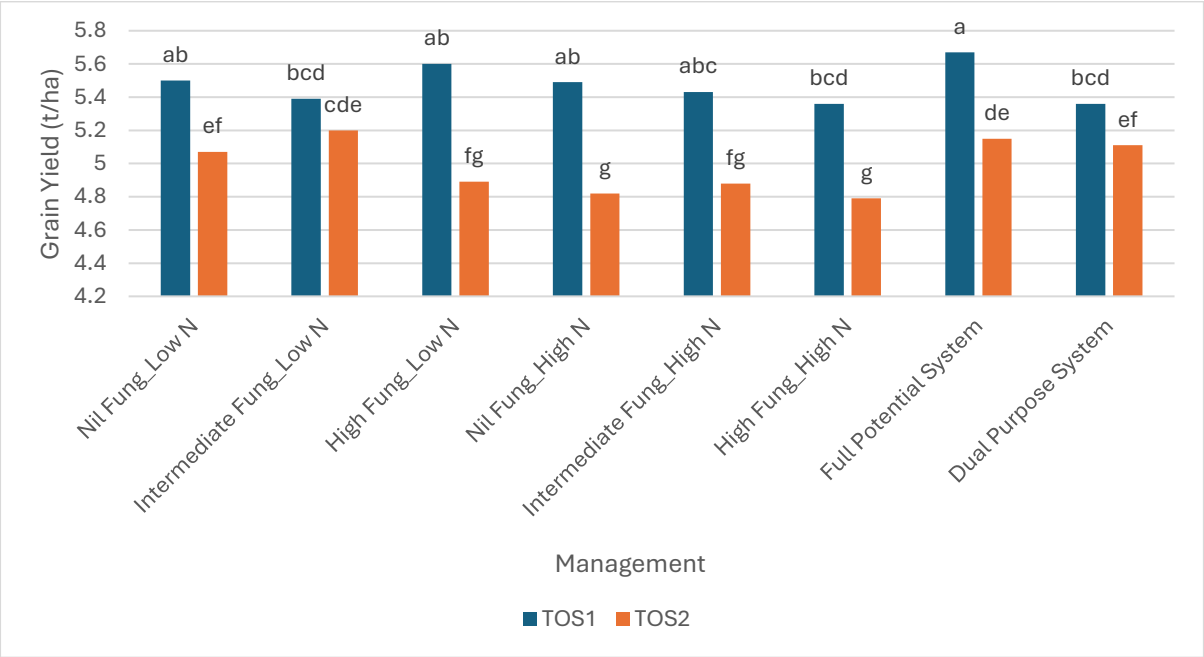

Figure 9. Influence of time of sowing and management strategies on barley grain yield (t/ha). Means of all cultivars.

Grain quality overall was poor with test weight being the biggest issue. Delaying sowing, while accompanied by a yield penalty, improved grain quality with improved test weight, retention and screenings across all three varieties (Table 21).

Table 21. Influence of barley cultivar and time of sowing on grain yield and quality. Means of both management strategies.

		Grain Yield (t/ha)	Protein (%)	Test Weight (kg/hL)	Retention (%)	Screenings (%)
RGT Planet	3 May Sowing	5.67 a	12.8 d	60.8 c	81.1 d	4.7 a
	17 May Sowing	4.87 d	13.5 a	63.6 a	91.2 b	2.4 cd
Cyclops	3 May Sowing	5.50 b	13.2 bc	62.3 b	84.1 c	3.2 b
	17 May Sowing	5.16 c	13.3 b	63.0 a	91.1 b	2.0 d
Leabrook	3 May Sowing	5.26 c	13.1 c	60.7 c	91.5 b	2.6 c
	17 May Sowing	4.94 d	13.3 b	61.7 b	94.5 a	2.0 d
Mean		**5.23**	**13.2**	**62.0**	**88.9**	**2.8**
P val		0.001	<0.001	0.002	<0.001	0.001
LSD p=0.05		0.16	0.2	0.7	1.1	0.6

Modelling Component

Modelling completed by an APSIM model predicted maximum yield potentials of 5.87t/ha and 5.66t/ha for 3 May and 17 May sow dates in 2023 (Figure 10). In the trials we were able to achieve 6.04t/ha and 5.28t/ha suggesting we were able to maximise grain yield on the site at Daysdale.

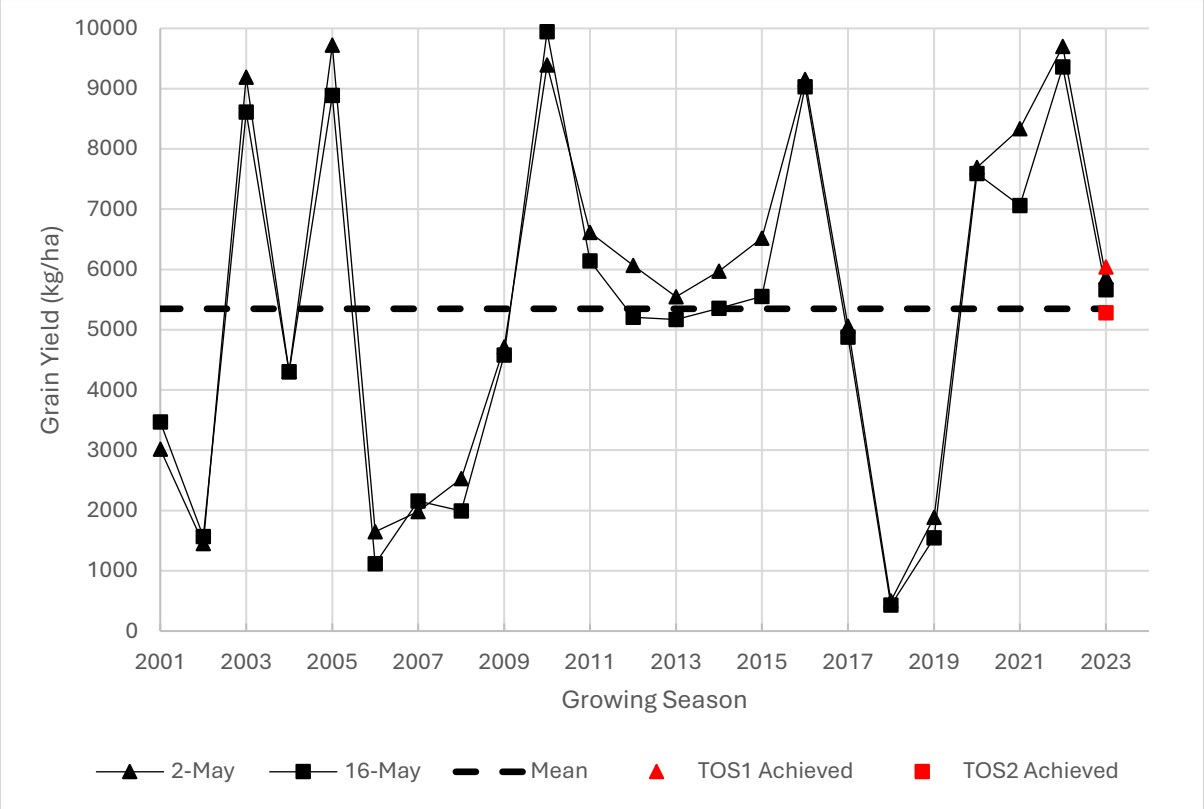

Figure 10. Maximum water limited yield potential determined by APSIM crop simulation model for the past 23 years (2001-2023) at the Daysdale, NSW site, with comparison to highest yields achieved in both sow dates of 2023.

Looking at Figure 10, it is evident that environmental conditions and season variability have a massive effect on grain yield of barley in the southern NSW region of Daysdale with maximum yields ranging from <2.5t/ha in 6 out of 23 years and >8t/ha in 6 out of 23 years.

Economic Attainable Yields

A very basic economic analysis was completed on treatments from Daysdale by calculating total income from grain yield (grain yield x grain price) and total variable costs (cost of treatment variable inclusive of application costs) to give a partial gross margin ($/ha) and return on investment (ROI) ($ income per $ spent, e.g. income of $100, spent $40 to give ROI of 2.5). The three core treatments from Table 2 – current practice, high input, and emerging practice – have been compared in Table 22.

Table 22. Partial gross margin ($/ha) and return on investment (ROI) for core treatments at each time of sowing at Daysdale in 2023.

	3 May Sown		**17 May Sown**		**Mean**	
	Gross Margin	ROI	Gross Margin	ROI	Gross Margin	ROI
Current Practice	$ 1,374.81	8.6	$ 1,321.61	8.2	$ 1,348.21	8.4
High Input	$ 1,113.77	2.7	$ 948.47	2.3	$ 1,031.12	2.5
Emerging Practice	$ 1,136.24	2.4	$ 988.99	2.1	$ 1,062.62	2.2

With the first time of sowing producing higher yields, the economics favour this sow date with a slightly higher gross margin and return on investment at each treatment. All treatments returned a

profit, however, with little increases in grain yield as a result of increased input. The gross margin and return on investment reduced with increased management intensity.

Moving from the high input practice to the emerging practice increased the gross margin by approximately $30/ha but reduced the return on investment. This suggests that the incorporation of a PGR into the barley program has increased our risk. If we strategically use the emerging practice in varieties that are more likely to get a response (Leabrook and RGT Planet) to PGR applications we can see bigger increases in gross margin and smaller differences in ROI (Table 23).

Table 23. Gross margin ($/ha) and return on investment (ROI) for each variety under core management treatments at Daysdale in 2023.

	RGT Planet		**Cyclops**		**Leabrook**	
	Gross Margin	ROI	Gross Margin	ROI	Gross Margin	ROI
Current Practice	1391.44	8.7	1328.74	8.3	1324.46	8.3
High Input	990.27	2.4	1105.70	2.7	997.40	2.4
Emerging Practice	1080.19	2.3	1077.34	2.3	1030.32	2.2
Mean	**1153.97**	**4.5**	**1170.59**	**4.4**	**1117.39**	**4.3**

There was very little difference between varieties in terms of overall profitability with Cyclops coming out in front by approximately $20/ha.

In this environment where disease levels have been low in both 2022 and 2023, the value of fungicides has been very low. However, in environments with high disease pressure, increased fungicide expense has been one of the major drivers in barley grain yield and profitability as shown in another the southern region GRDC investment 'Barley management options to close the yield gap and reduce pre-harvest losses' (FAR2204-002SAX).

Discussion

The results from this project have shown that conditions during flowering and early grain fill are ultimately what determines yield in barley. In 2022 the site experienced severe water logging during this period and in 2023 the site was exposed to hot dry conditions. These conditions have acted as 'equalisers', resulting in only small changes in yield as a result of the management strategies adopted. Figure 10 shows that in 2022 we were able to achieve the simulated yields from APSIM which were close to average yield. Although the simulation was not run in the Finley environment, it is evident that yields were below what would have been estimated by the simulation and this is likely due to the simulation's inability to account for the impact of water logging and the conditions associated with high rainfall seasons.

Both years provided no yield gains to increased nitrogen supply. 2022 had a high starting fertility with 156kg N/ha (0-100cm) while in 2023 starting fertility was lower at 83kg N/ha (0-100cm). In both environments a nitrogen supply of approximately 160kg/ha was sufficient to achieve potential yield. Increasing nitrogen supply above 160kg/ha was detrimental to yield in some situations tested. With nitrogen making up a large proportion of the costs of growing a crop, it is important not to overspend on nitrogen and not get a return financially. Regardless of yield penalty or not, increasing N supply significantly reduced gross margin and return on investment.

Similar to nitrogen supply, there was limited response to fungicide during the project. This is likely due to the low levels of barley disease present in both years. Low levels of net form net blotch were assessed in the trials, particularly in RGT Planet, however infection did not progress to levels that impacted grain yield. Despite low levels of infection, increased fungicide applications were able to

achieve complete control of disease (Table 19). This serves to demonstrate that it is not always economic to completely control disease. Ultimately, we apply fungicides to make money and when levels are low it can be uneconomical to try and control disease.

Despite limited responses to nitrogen and fungicide, both years showed the benefits of plant growth regulator (PGR) applications. While this response was not always evident in grain yields, there was a consistent reduction in lodging/brackling in both years. The application of PGRs as a split application also helped to reduce harvest losses through head loss. In lodging susceptible varieties (Leabrook and RGT Planet) the application of PGRs provided an increase in gross margin. In contrast, the application of PGRs to the erect plant type of Cyclops was uneconomical despite reductions in observed brackling. Fungicide applications also proved to help strengthen the canopy and help reduce observed brackling (Figure 6).

In 2023, where two sow dates were evaluated, the 14 day delay in sowing resulted in significant yield differences, with plots sown 3 May consistently out yielding plots sown 17 May. RGT Planet was most affected by sow date as it was the highest yielding variety when sown 3 May and was then the lowest yielding variety when sowing was delayed to 17 May. Time of sowing also influenced the effects of management strategies, with bigger differences observed at the delayed sow date compared to plots sown on time.

Over both years of the project we were able to keep the same three varieties, these being RGT Planet, Leabrook and Cyclops. Over both years, Leabrook was the lowest yielding variety and RGT Planet was able to produce the highest yields. Cyclops was the most stable variety with small differences between sow dates and no statistical differences noted between management strategies.

Acknowledgements
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