Barley management options to close the yield gap and reduce pre-harvest losses

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Key findings

- Barley grain yield averaged 4.61 t/ha and ranged from 3.82 to 5.42 t/ha resulting from variety choice and management strategies.
- High fungicide inputs were required to maximise grain yield for RGT Planet, Cyclops and Leabrook across two consecutive years. High fungicide input was most profitable in varieties with leaf rust susceptibility and with high infection levels during grain fill. In the absence of leaf rust, high fungicide inputs were not profitable.
- There were no yield gains resulting from increasing nitrogen (N) application from low to high (60 – 140 kg N/ha). RGT Planet grain yields decreased in response to increasing nitrogen supply. High N supply also increased grain protein for all varieties, preventing them from meeting malt receival specifications.
- The application of plant growth regulators (PGRs) reduced crop lodging at the early time of sowing, however no yield increases were observed.
- The use of simulated grazing at GS 30 (beginning of stem elongation) resulted in a significant yield reduction for RGT Planet and Leabrook of 220 kg/ha and 180 kg/ha, respectively. No yield reduction was observed for Cyclops.

Introduction

While it is assumed that the new frontier for barley water use efficiency is 25 kg/ha/mm, this has rarely been demonstrated. Outside of variety selection, recent GRDC research (FAR2204-002SAX – Online Farm Trials HART and BCG 2022) has demonstrated that canopy management in barley, through the use of fungicides, sowing time, and plant growth regulators, can explain yield responses. These responses range from 3.5 – 7 t/ha using similar genetics in cooler and milder (high yield potential) production environments (T Price at al, 2022 Hart Trial Results). These factors have been more important than N management, particularly where yield potential exceeds 5 t/ha and crops are grown on fertile soils. 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 in these lower yielding environments. It is this rationale that lies behind the second and final year of this GRDC National Grower Network (NGN) project.

Methodology

Site selection and rainfall

A barley trial was located at Hart, SA in 2022 and 2023 investigating management strategies to close the yield gap and reduce pre-harvest losses. Starting soil nitrogen (N) was measured at the start of each season to determine in-crop N management (Table 1).

Table 1. Starting soil mineral N (kg N/ha) for barley trials in 2022 and 2023.

Starting soil N (kg N/ha)	Depth (cm)					Total soil N (0 – 120 cm)
	0 – 10	10 - 30	30 – 60	60 - 90	90 - 120	
2022	19.6	14.5	14.4	13.7	12.0	**74.2**
2023	31.8	17.9	20.2	15.9	17.6	**103.3**

The site received above average annual rainfall in 2022 with 519 mm (Decile 10), compared to the long-term average of 400 mm (Figure 1). Growing season rainfall (GSR) was 355 mm (April – October), 55 mm above Hart's long-term average of 300 mm. In contrast, the 2023 season had below average annual and GSR and was in the lowest 40% of rainfall records (Decile 4). Below average rainfall from August – November resulted in reduced yield potential, particularly for late sown crops.

Figure 1. Monthly rainfall at the Hart field site for 2022 and 2023 seasons (Source: Mid North Mesonet). Cumulative 2023 and long-term average annual rainfall (400 mm) at site is also shown.

Trial design and treatments

The trial was designed and analysed as a replicated split-plot design (Table 1). The trial investigated two times of sowing (TOS), three varieties and nine management treatments over two growing seasons from 2022 – 2023. Varieties trialed were RGT Planet, Cyclops and Leabrook (Table 2).

The nine management treatments (Table 3) included various seed treatments, in-crop fungicides (Table 4), nitrogen and canopy management (Table 5) by either defoliation or application of plant growth regulators (PGR) (Table 6). Defoliation was conducted by mowing plots to simulate the biomass removal by grazing at the start of stem elongation (GS 30).

Assessments conducted include NDVI (Normalised Difference Vegetation Index) as a measure of crop ground cover (associated with crop biomass) and canopy greenness, lodging scores, head loss assessment (heads/m^2), grain yield (t/ha) and quality analysis.

Table 2. Barley variety descriptions and disease ratings (as per GRDC's 2024 South Australian Crop Sowing Guide).

Variety	Description	Disease ratings			
		Leaf scald	Spot form net blotch (SFNB)	Net form net blotch (NFNB)	Leaf rust
RGT Planet	High yielding but disease susceptible	R-SVS	SVS	MRMS-SVS	MRMS-MS
Cyclops	High yielding low rainfall erect variety	S	MS	MR-MS	VS
Leabrook	Vigorous and lodging susceptible	MRMS-SVS	MS	MR-MSS	SVS

R= resistant, MR=moderately resistant, MS=moderately susceptible, S=susceptible, SVS=susceptible to very susceptible, VS= very susceptible.

Table 3. Site details for 2022 and 2023 barley management trial at Hart, SA.

2022	**Plot size**	1.75 m x 10.0 m	**Fertiliser**	Seeding: DAP + Zn 1% + Flutriafol @ 80 kg/ha
	TOS 1: Seeding date	April 17, 2022		
	TOS 1: Harvest date	November 28, 2022	**Low N:**	55 kg N/ha
	TOS 2: Seeding date	June 17, 2022	**High N:**	135 kg N/ha
	TOS 2: Harvest date	December 1, 2022		
2023	**Plot size**	1.75 m x 10.0 m	**Fertiliser**	Seeding: MAP @ 60 kg/ha
	TOS 1: Seeding date	April 27, 2023		
	TOS 1: Harvest date	October 23, 2023	**Low N:**	60 kg N/ha
	TOS 2: Seeding date	June 1, 2023	**High N:**	140 kg N/ha
	TOS 2: Harvest date	November 3, 2023		

Table 4. Summary of management levels.

Treatment	Fungicide	Canopy	Nitrogen	
			Applied N (kg N/ha)	Total N Supply*
Nil Fungicide Low N	Nil	Nil	60	150
Intermediate Low N	1 Unit	Nil	60	150
High Fungicide Low N	Full	Nil	60	150
Nil Fungicide High N	Nil	Nil	140	230
Intermediate High N	1 Unit	Nil	140	230
High Fungicide High N	Full	Nil	140	230
High Fungicide Canopy Management	Full	PGR @ GS 31 and GS 37	140	230
Dual Purpose System	Full	Defoliation#	140	230
Nil N	Full	Nil	0	86

*Total N supply considering soil N levels (0 – 90 cm) taken prior to sowing on April 13, 2023.
PGR= Plant growth regulator
# Defoliation = Simulated grazing

Table 5. Fungicide strategies applied.

Fungicide Treatment	Sowing	GS 31	GS 39-49
Nil	---	---	---
Intermediate (1 unit)	---	Prosaro @ 300 ml/ha	---
Full protection (3 units)	Systiva @ 150 ml/100 kg	Prosaro @ 300 ml/ha	Aviator Xpro @ 500 ml/ha

Table 6. Canopy intervention strategies applied.

Canopy intervention treatment	GS 30	GS 33 - 37
Nil	---	---
PGR	Moddus Evo @ 200ml/ha	Moddus Evo @ 200ml/ha
Defoliation[#]	Yes	---

[#] *Mechanical Defoliation = Simulated grazing*

Results and discussion

Barley grain yields ranged from 3.82 t/ha to 5.42 t/ha across the trial at Hart in 2023 (Table 7). The highest grain yield came from Leabrook sown early (April 27) with high fungicide (3 units), high N supply (225 kg N/ha) and two PGR applications. Lowest yields came from Leabrook sown late (June 1) under low N supply (150 kg N/ha) and no fungicide management.

The trial produced significant yield differences that resulted from changing sowing date, variety selection and management decisions.

There was a significant interaction (P=<0.001) between management and barley variety indicating that the varieties responded differently to the management applied.

Photo: Aerial view of the barley management trial at the Hart field site, 2023.

Table 7. Influence of agronomic management and variety choice on barley grain yield (t/ha).

TOS 1	Nitrogen	Fungicide	Cyclops	RGT Planet	Leabrook	Average
Nil Fungicide_Low N	60N	0 units	4.62	5.03	4.63	**4.76**
Intermediate F_Low N	60N	1 unit	5.11	5.18	5.08	**5.12**
High Fungicide_Low N	60 N	3 units	5.19	5.33	5.30	**5.27**
Nil Fungicide_High N	140 N	0 units	4.67	4.99	4.58	**4.75**
Intermediate F_High N	140 N	1 unit	4.90	4.99	5.04	**4.97**
High Fungicide_High N	140 N	3 units	5.24	5.09	5.38	**5.24**
Full Potential + PGR	140 N	3 units	5.11	5.01	5.42	**5.18**
Dual Purpose System	140 N	3 units	4.96	4.91	5.12	**5.00**
Nil N	0N	3 units	4.38	5.06	4.26	**4.57**
Average			**4.91**	**5.06**	**4.98**	

TOS 2	Nitrogen	Fungicide	Cyclops	RGT Planet	Leabrook	Average
Nil Fungicide_Low N	60N	0 units	4.06	4.20	3.82	**4.03**
Intermediate_LowN	60N	1 unit	4.17	4.34	4.18	**4.23**
High Fungicide_Low N	60 N	3 units	4.62	4.61	4.56	**4.60**
Nil Fungicide_High N	140 N	0 units	3.92	4.17	3.97	**4.02**
Intermediate F_High N	140 N	1 unit	4.13	4.31	4.19	**4.21**
High Fungicide_High N	140 N	3 units	4.36	4.47	4.66	**4.50**
Full Potential + PGR	140 N	3 units	4.46	4.54	4.63	**4.54**
Dual Purpose System	140 N	3 units	4.35	4.22	4.56	**4.37**
Nil N	0N	3 units	4.32	4.59	4.33	**4.41**
Average			**4.26**	**4.38**	**4.32**	

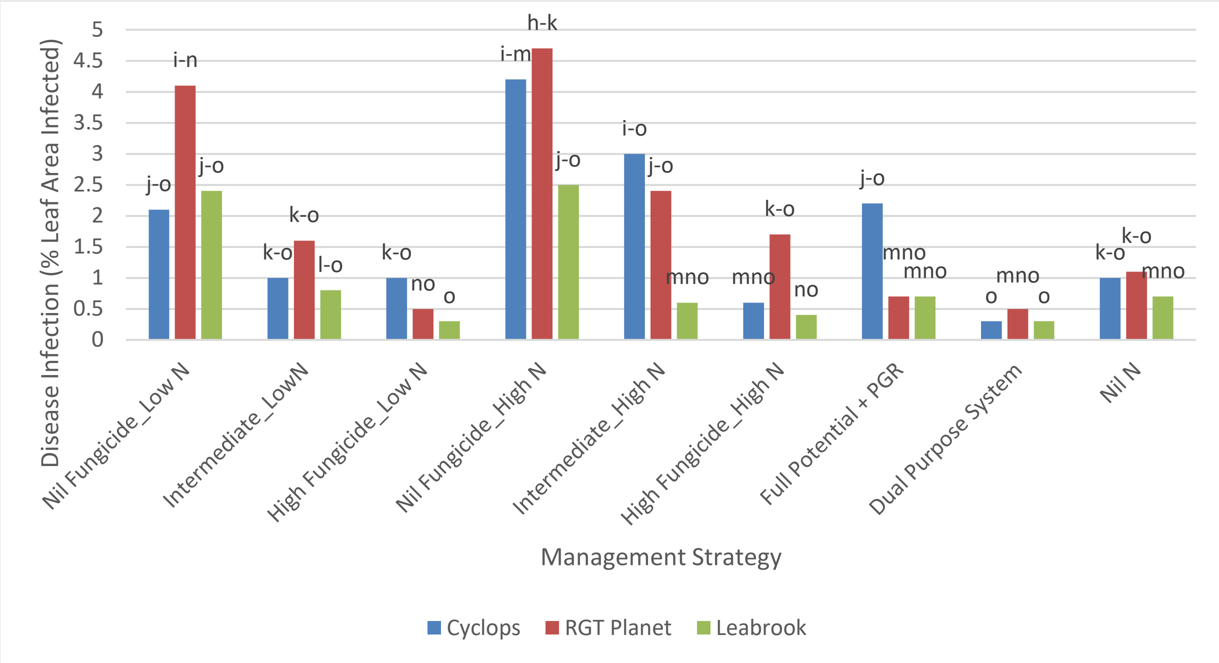
Time of Sowing	P Value	0.001	LSD (P=0.005)	0.17
Management	P Value	<0.001	LSD (P=0.005)	0.22
Variety	P Value	<0.001	LSD (P=0.005)	0.05
TOS x Management	P Value	0.095	LSD (P=0.005)	ns
TOS x Variety	P Value	0.776	LSD (P=0.005)	ns
Variety x Management	P Value	<0.001	LSD (P=0.005)	0.16
Variety x Management	P Value	0.073	LSD (P=0.005)	ns

Intermediate F = 1 unit of fungicide (single application timing)

Fungicide

The fungicide strategies investigated included nil fungicide, a single foliar fungicide at early stem elongation, and up to 3 fungicide units which included Systiva seed treatment plus two foliar fungicides applied at the start of stem elongation and at flag leaf (1st awn emergence).

Disease pressure in 2023 was lower than levels experienced in 2022 (leaf area infection for 2023 presented in Figure 2). However, the disease observed were similar; net form of net blotch (NFNB) and spot form of net blotch early (primarily in RGT Planet) with high levels of leaf rust present later in the season (primarily in Leabrook and to a lesser extent Cyclops).



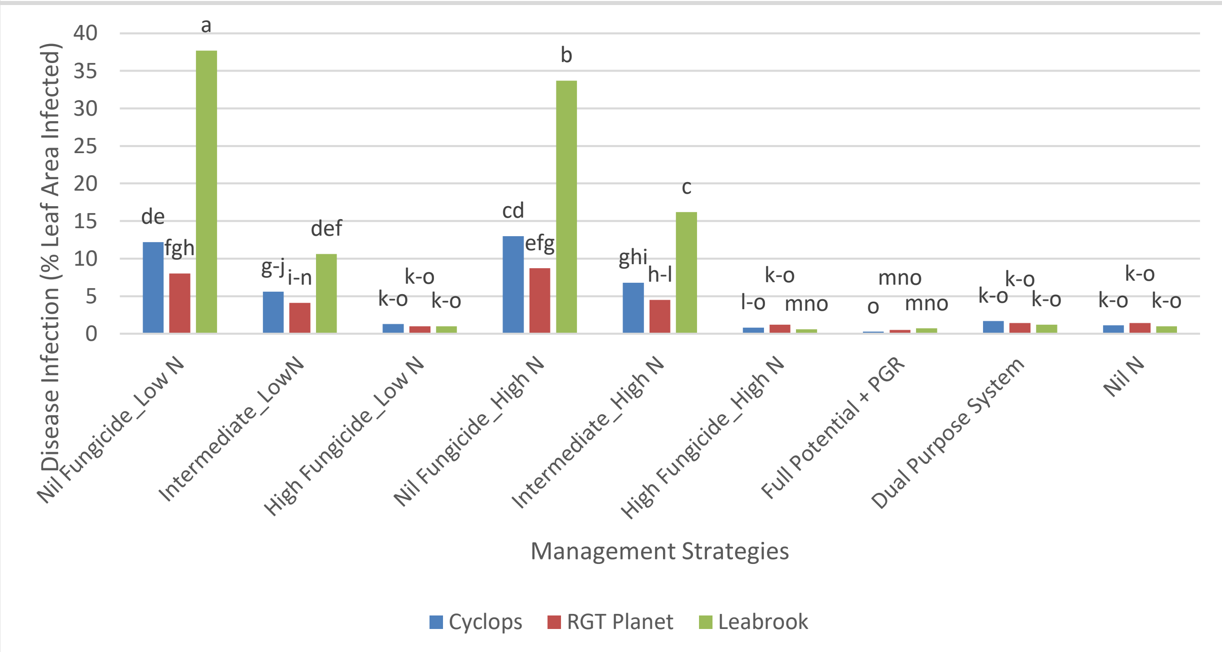


Figure 2. Influence of time of sowing (top: TOS 1, bottom: TOS 2) and management strategy on plot disease infection (% leaf area infection). Disease assessed at start of flowering (August 30: TOS 1, September 22: TOS 2). Bars with different letter are statistically different, P<0.001, LSD=3.7%.

**Note assessments conducted on different calendar dates, TOS 1 also saw high levels of disease later in the season as shown in TOS 2 assessment.*

Note: Bar graphs primarily represent the most important diseases in each variety, leaf rust in Leabrook and Cyclops and low levels of NFNB/SFNB in RGT Planet.

In 2023, fungicide management was the most important management practice with yield responses of up to 800 kg/ha (Leabrook, TOS1, High N, High fungicide). RGT Planet was least responsive to fungicide (0.1 – 0.4t/ha response) and provided the highest yields under the nil fungicide program (Figure 3), however the same trial conducted at Birchip showed RGT Planet to be the lowest yielding under nil fungicide management due to much higher levels of NFNB infection.

The most responsive variety to fungicide was Leabrook, with yield responses of 0.7 to 0.8 t/ha from nil to high. Although all three varieties maximised their grain yield under high fungicide input, it was uneconomic where the cultivar had leaf rust resistance (RGT Planet). The cost benefit ratio (money back for money spent) was greatest in varieties with leaf rust susceptibility in this trial (Table 8).

The best return for fungicide $ spent was for the GS 31 Prosaro (300 ml/ha) application with only two out 24 scenarios not providing a financial benefit (RGT Planet TOS 1, high N and Cyclops TOS 2 low N). In most cases, high fungicide input was not economical for RGT Planet due to generally low levels of disease, while Leabrook saw an increase of over $300/ha increase in income (almost 3 times the amount spent) due to high fungicide application.

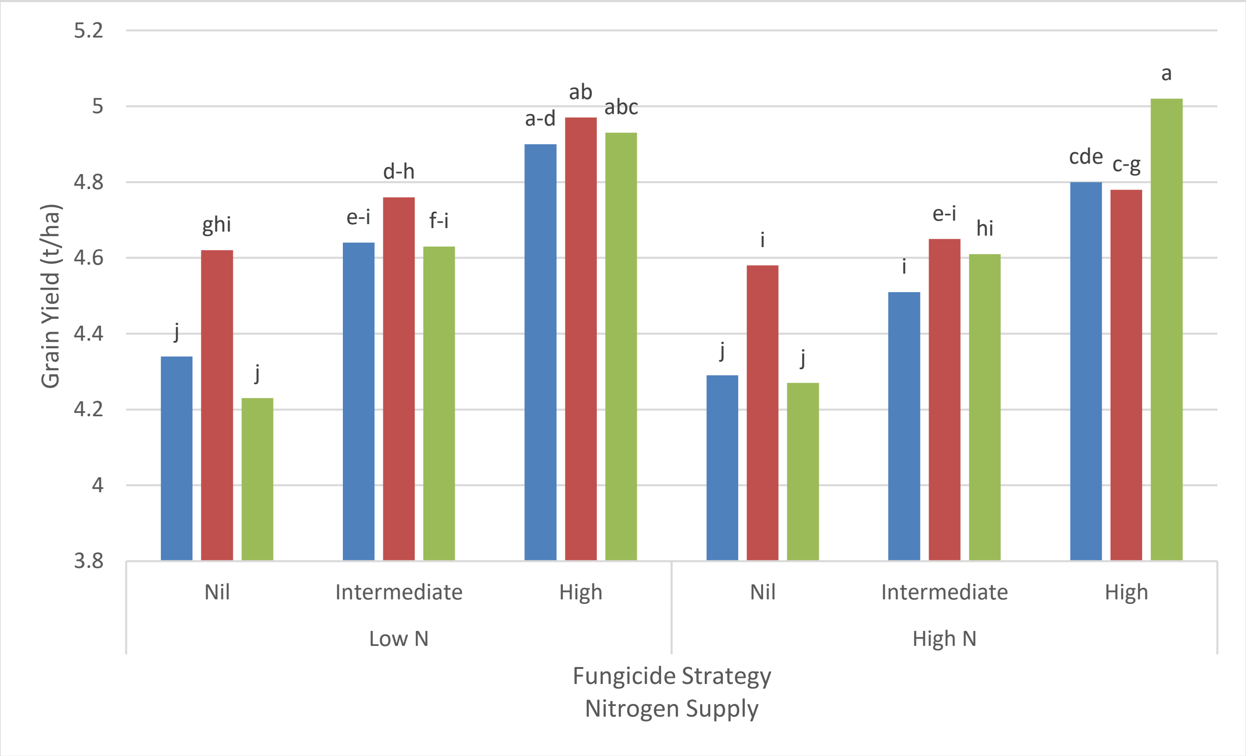


Figure 3. Influence of fungicide strategy on grain yield (t/ha) of three barley varieties under high and low nitrogen supplies. Values averaged across both sow dates. Bars with different letter are statistically different, P<0.001, LSD=0.16t/ha.

Table 8. Economic figures showing additional income resulting from different fungicide strategies at each TOS and nitrogen supply scenario, and the return ratio for each dollar spent on fungicides. Figures based on Intermediate fungicide program cost $32/ha and high fungicide program cost $105/ha. Income calculated on yield (t/ha) x grain price ($/t) taking into account bin grade. Highlighted cells show scenarios where applying fungicide was not economical.

	Cyclops		**RGT Planet**		**Leabrook**	
	Additional income ($/ha)	**Cost benefit ratio**	**Additional income ($/ha)**	**Cost benefit ratio**	**Additional income ($/ha)**	**Cost benefit ratio**
TOS 1 LOW N						
Intermediate	139.65	4.38	45.75	1.44	137.25	4.31
High	162.45	1.55	91.50	0.87	204.35	1.95
TOS 1 HIGH N						
Intermediate	65.55	2.06	-	-	131.10	4.11
High	162.45	1.55	28.50	0.27	228.00	2.17
TOS 2 LOW N						
Intermediate	31.35	0.98	39.90	1.25	186.20	5.84
High	159.60	1.52	116.85	1.11	302.10	2.88
TOS 2 HIGH N						
Intermediate	59.85	1.88	39.90	1.25	62.70	1.97
High	125.40	1.19	85.50	0.81	196.65	1.87

Nitrogen

Nitrogen supply was less important in 2023, especially when comparing low N supply (60 N + 85 soil N in 0 – 90 cm) to high N supply (140 N + 85 soil N in 0 – 90cm). There was no grain yield benefit resulting from increased N supply in 2023, with RGT Planet recording a yield reduction as N was increased (Figure 4). In treatments with no applied N, there was a grain yield loss of 440 kg/ha.

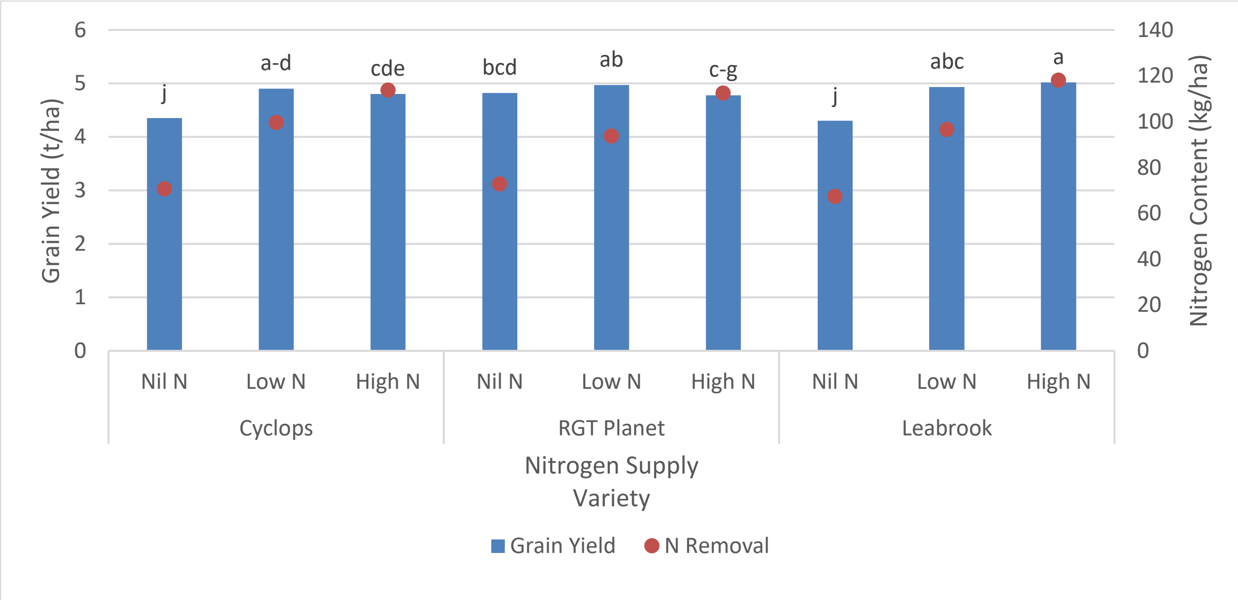


Figure 4. Influence of barley variety and nitrogen supply (under high fungicide input) on grain yield (t/ha) and total nitrogen content of crop (assuming 25% N in crop residues). Figures are averages of both TOS. Bars with different letters are statistically different, P<0.001, LSD=0.16 t/ha. Nitrogen content not statistically analysed.

Increasing N rate had a significant effect on grain quality (Table 9). Across all varieties, increasing N supply from low to high resulted in a grain protein increase of approximately 2%. In all cases this resulted in protein levels above maximum malt receival specifications, resulting in a decreased grain price. High N supply in RGT Planet increased screenings and decreased retention, likely due to an increase in grain number (through increased tillering as a result of high N) and being unable to fill all grains resulting in smaller grain size. In contrast, decreased screenings, increased retention, and increased test weight was observed as a result of being able to fill grains set where no fertilser N was applied. In addition to the observed yield penalty for nil N treatments, there was also a reduction in grain protein, dropping it below malt specifications.

Treatments with no applied N averaged 4.49 t/ha (ranging from 4.26 – 5.06 t/ha) and had grain protein levels of 8.4% (ranging from 7.9 – 8.9%). Based on these figures, it was calculated that the crop removed 53 kg N/ha. If it was assumed 25% of N was present in crop residue the N uptake would amount to approximately 70 kg N/ha. Given that the soil test showed 103 kg N/ha (0-120cm) the crop was likely not limited by nitrogen and nitrogen uptake was limited by either soil moisture and/or root exploration.

Table 9. Influence of variety and management choice (averaged across both TOS) on grain quality (retention (%), screenings (%), protein (%), and test weight (kg/hL)). Red figures and blue shading denote quality results outside of malt specification.

Variety	Fungicide Mgmt	N Supply	Canopy Mgmt	Retention (%)		Screenings (%)		Protein (%)		Test Weight (kg/hL)	
Cyclops	Nil	Low	---	71.4	gh	5.4	fgh	11	f	69.0	fg
Cyclops	Intermediate	Low	---	75.9	fg	4.4	hij	10.8	fgh	69.8	de
Cyclops	High	Low	---	81.4	de	3.4	ijk	10.9	fg	70.5	bc
Cyclops	Nil	High	---	56.5	lm	9.5	b	13.3	a	66.9	no
Cyclops	Intermediate	High	---	62.8	jk	6.9	def	12.9	ab	68.5	ghi
Cyclops	High	High	---	71.9	gh	5.1	gh	12.7	bc	69.4	ef
Cyclops	High	High	PGR	70.1	hi	5.3	gh	12.9	abc	69.2	ef
Cyclops	High	High	Defoliation	68.1	hi	5.2	gh	12.2	de	68.3	hij
Cyclops	High	Nil	---	91.4	b	1.6	lmn	8.7	j	71.9	a
RGT Planet	Nil	Low	---	60.4	kl	7.7	de	10.6	fgh	67.1	lmn
RGT Planet	Intermediate	Low	---	66.3	ij	6.3	efg	10.4	hi	67.7	jkl
RGT Planet	High	Low	---	70.5	hi	5.3	gh	10.1	i	68.0	ijk
RGT Planet	Nil	High	---	45.7	n	13.0	a	13.0	ab	65.6	q
RGT Planet	Intermediate	High	---	52.3	m	10.0	b	12.9	bc	66.4	op
RGT Planet	High	High	---	55.7	m	8.5	bcd	12.6	bcd	66.9	mno
RGT Planet	High	High	PGR	54.7	m	7.9	cd	12.9	bc	67.1	lmn
RGT Planet	High	High	Defoliation	54.5	m	9.4	bc	12.5	cde	66.6	no
RGT Planet	High	Nil	---	83.6	d	2.0	k-n	8.1	k	70.2	cd
Leabrook	Nil	Low	---	85.2	cd	2.9	jkl	10.5	ghi	67.1	lmn
Leabrook	Intermediate	Low	---	90.8	b	1.7	lmn	10.4	hi	68.9	fgh
Leabrook	High	Low	---	94.3	ab	1.0	mn	10.5	gh	70.0	cd
Leabrook	Nil	High	---	78.1	ef	4.4	hi	12.5	cde	65.9	pq
Leabrook	Intermediate	High	---	86.1	cd	2.5	klm	12.9	bc	67.5	klm
Leabrook	High	High	---	91.0	b	1.6	lmn	12.6	bcd	68.9	fg
Leabrook	High	High	PGR	91.4	b	1.5	lmn	12.8	bc	69.1	fg
Leabrook	High	High	Defoliation	89.7	bc	1.8	k-n	12.0	e	67.7	kl
Leabrook	High	Nil	---	96.6	a	0.7	n	8.4	jk	70.9	b
Average				**73.9**		**5.0**		**11.5**		**68.3**	
P Value				**<0.001**		**<0.001**		**0.028**		**<0.001**	
LSD (P≤0.05)				**4.7**		**1.6**		**0.4**		**0.6**	

Canopy management

There were no yield gains resulting from canopy management strategies (based on high N, high fungicide and PGR) in 2023. The application of plant growth regulators (PGR) was not effective at reducing lodging.

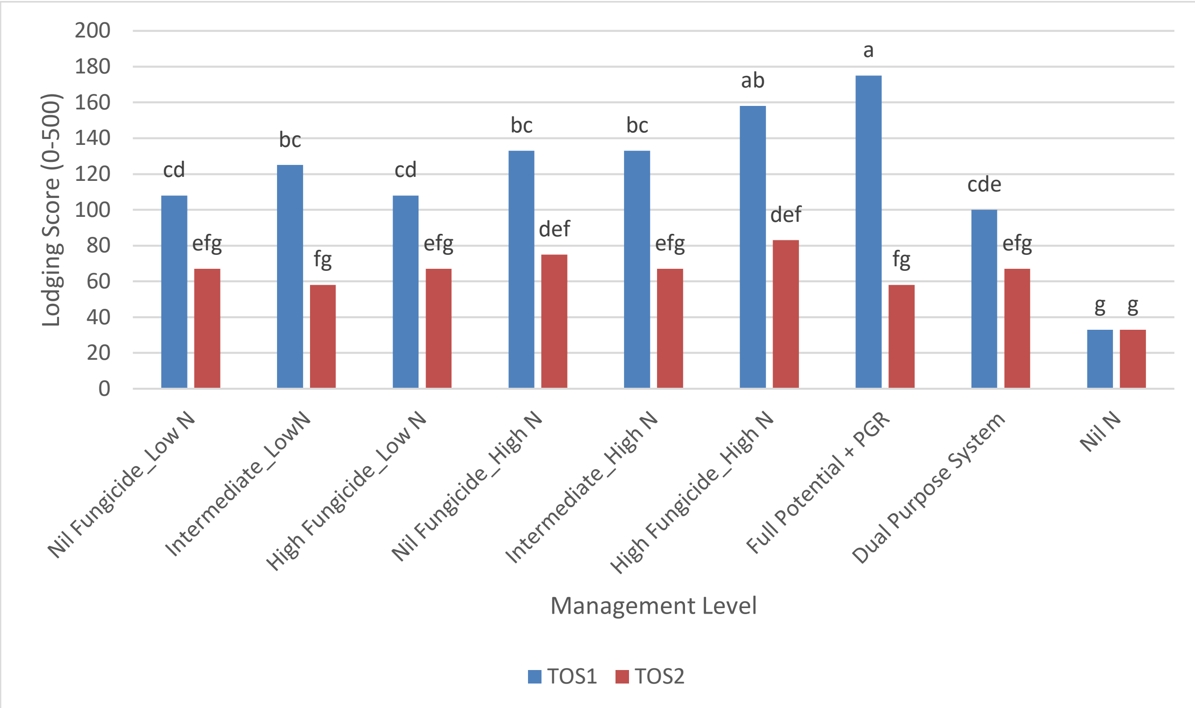


Figure 5. Influence of sowing date and management strategies on crop lodging (averaged across varieties).

The use of simulated grazing did result in a reduction of crop lodging, however this also came with a yield penalty for RGT Planet and Leabrook. The most effective way to reduce lodging when sowing early was to select a stronger strawed variety. Cyclops had significantly less lodging than RGT Planet, which also had less lodging than Leabrook (data not shown).

At TOS 2, no management strategy affected crop lodging (Figure 5), likely a result of delayed sowing time and below average spring rainfall. In 2022, highest grain yields were achieved through simulated grazing. This treatment reduced overall biomass production improving conversion to grain yield in a Decile 8 growing season.

Variety

Variety choice was a significant factor influencing grain yield at Hart in 2023. The highest yielding variety was RGT Planet, achieving 5.06 t/ha at TOS 1 and 4.38 t/ha at TOS 2. While RGT Planet was the highest yielding variety, only one of nine management strategies achieved malt quality (Low N, high fungicide). Despite Cyclops having the lowest levels of disease and crop lodging, it was the lowest yielding variety achieving 4.91 t/ha at TOS 1 and 4.26 t/ha at TOS 2.

Time of sowing

Sowing date had a significant effect on grain yields achieved in 2023. Delaying sowing to June 1 resulted in an average yield penalty of 660 kg/ha.

Time of sowing also influenced disease levels. It is generally expected that early sown crops experience higher disease pressure however that wasn't the case in this trial. With low levels of NFNB present in the trial, the delayed sowing plots experienced higher levels of barley leaf rust, with warmer temperatures during stem elongation and flowering period favouring leaf rust.

Summary

The season in 2023 highlighted the importance of early sowing and variety selection to maximise yield potential. Measuring the level of nitrogen supply from the soil is essential to manage N application. In 2023 the level of N supply from the soil was slightly higher across the soil profile than in 2022 (approx. 30 N). Despite lower yield potential in 2023 compared to 2022 (average yields of 4.65 t/ha vs. 5.51 t/ha), protecting the upper canopy (flag sheath, flag-1 and flag-2) with higher fungicide input was the most important management decision to close the yield gap after variety and sowing date. This was done using an SDHI seed treatment (Systiva) and two in crop fungicide applications. The use of plant growth regulators provided no yield benefit and did not provide any advantages to help prevent crop lodging in this experiment.

References

T. Price., N. Poole., (2022). NGN Barley management options to close the yield gap and reduce pre-harvest losses. *https://www.farmtrials.com.au/trial/37618*

Acknowledgements

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Photo: Aerial view of the barley management trial at the Hart field site, 2023.