How reliable are plant growth regulators (PGRs) in dryland barley?

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Take home message

- PGRs can be used as an effective tool to minimise lodging in barley crops, can increase grain yield even in the absence of lodging, under the right condition can significantly increase net returns (even without accounting for reduced harvest costs) and that responses vary greatly depending on variety
- One of the most consistent differences observed was the variation in yield response between varieties, where Leabrookⓓ was the most responsive and Maximus CLⓓ was the least responsive
- Decisions on PGR application must be made early in the season (during tillering) when the final yield and lodging susceptibility and the likely response to a PGR is uncertain
- Most advisors and growers favour using agronomic factors to reduce lodging risk including variety and paddock selection, nutrition management and time of sowing. While positive results have been achieved at paddock scale, PGR adoption remains limited to situations where other management strategies have been insufficient to prevent a major lodging event.

Abstract

Lodging risk constrains production of high yielding dryland barley crops in northern NSW. While plant growth regulators (PGRs) can reduce lodging and increase yield, responses are highly variable. Trials (n=6) in 2022 and 2023 identified three factors to maximise PGR responses.

1. Understand varietal PGR responses: Leabrookⓓ has reliable yield and lodging responses to PGRs; RGT Planetⓓ has smaller yield and lodging responses than Leabrookⓓ; Laperouseⓓ has lodging but not yield responses; Maximus CLⓓ has small or nil responses.
2. Match the PGR to the variety: Leabrookⓓ is best suited to Moddus® Evo at GS31 (400 mL/ha) and will respond to GS37 applications; RGT Planetⓓ responds to Moddus Evo at GS37 and not to GS31 applications; Laperouseⓓ lodging will improve in response to Moddus Evo at GS31 or GS37.
3. Know the conditions where a PGR response is likely. The largest responses were in conditions yielding >6 t/ha with a high lodging risk, with Moddus Evo increasing Leabrookⓓ yield 0.7–0.8 t/ha and partial gross margin by $153–193/ha. Ethephon should be used with caution due to risk of yield penalties. PGRs provide the opportunity to reduce lodging and improve grain yield for high yielding dryland barley crops in northern NSW.

Background

Growers engaged in the National Grower Network (NGN) identified lodging in commercial barley crops as a constraint to high production levels in the warmer areas of the northern grains region.

Lodging susceptibility is driven by rapid growth in early crop development through to head emergence and is exacerbated in high yielding conditions. Lodging causes losses in crop production through reduced water and nutrient movement and reduced translocation of stored carbohydrates from the stem to head. Lodging can also reduce grain quality, increase harvest losses, as well as harvest costs.

Commercial plant growth regulators (PGRs) can be used to reduce crop height and lodging and increase grain yield. PGRs used in Australia block the biosynthesis of plant hormone gibberellin (trinexapac-ethyl, Moddus Evo) or increase the concentration of ethylene (ethephon), which reduces internode length and decreases plant height. PGRs are reported to increase the proportion of crop dry matter that is partitioned to yield and may also increase root growth, improving water and nutrient extraction from the soil (GRDC 2014). However, previous research indicated yield responses in the northern grains region are highly variable, ranging from -40% to +15% (Gardner *et al.,* 2013, Jones 2014).

Variable lodging and yield results make it hard to predict the financial benefit of PGR use in barley. Thus, in the northern grains region, low confidence in PGR products and use patterns means few growers and advisors apply/recommend them. When PGRs are applied, application is often reactive rather than proactive resulting in later than ideal application timing and lower product efficacy.

In response to lodging and yield losses observed in 2020 and 2021, GRDC funded research to evaluate PGR use to reduce lodging and yield loss in high yielding barley crops. The investment aimed to test use patterns for commercial PGRs across a range of varieties and growing conditions. Ultimately, this research aimed to identify conditions where PGRs provide reliable benefits, improving yield and reducing lodging risk for dryland barley in the warm grain growing regions of northern NSW and southern QLD.

The overarching objective of this project was to provide information that increases grower and advisor confidence in using PGRs to manage high yielding barley crops in the northern grains region. This includes, identifying opportunities for repeatable and reliable return on investment from PGR treatments to reduce crop lodging and increase yield.

What was done

Seven barley PGR trials were run in 2022–23 at a range of locations in northern NSW. In 2022, three trials assessed the PGRs Moddus Evo (250 g/L trinexapac-ethyl) and ethephon (Promote® Plus 900, 900 g/L ethephon) and a range of use patterns across 4 barley varieties. Following high levels of lodging in 2022, four trials in 2023 quantifed the impact of PGR treatments on different varieties, times of sowing and nitrogen levels.

Trial management

Four varieties – Leabrook⊕, Laperouse⊕, RGT Planet⊕, Maximus CL⊕ – were selected to represent the range of lodging susceptibilities in commercial barley varieties. Moddus Evo and ethephon use patterns were tested to allow for early and late control of barley biomass production as well as bounce back, where compensatory growth occurs under favourable conditions following a PGR application (Table 1). In 2022, the impact of PGR treatments (n=6) on four barley varieties were tested at three locations in northern NSW. In 2023 trial sites were established at Boomi, Gurley and Breeza.

Table 1. PGR use patterns (product, application rate and timing) tested on dryland barley in 2022 and 2023.

PGR treatment name	Application 1			Application 2		
	PGR	Rate (ml/ha)	Growth stage	PGR	Rate (ml/ha)	Growth stage
Moddus 31	Moddus Evo	400	31			
Moddus 300 @ 31	Moddus Evo	300	31			
Moddus 37	Moddus Evo	400	37			
Moddus 31 + 37	Moddus Evo	300	31	Moddus Evo	300	37
Ethephon 41	Ethephon*	400	41			
Ethephon 45	Ethephon*	400	45			

* Ethephon 900 g/L

Climate

Seasonal conditions in 2022 and 2023 differed markedly for both in-crop temperatures and rainfall. In 2022, cooler than average spring maximum temperatures were experienced at Tulloona and Gurley while at Spring Ridge maximum spring temperatures were warmer than average. In contrast, in 2023 maximum winter and spring temperatures were 1.5 °C higher than monthly averages between June and October.

There were large differences in annual and growing season rainfall (May–October, GSR) between 2022 and 2023. In 2022, annual rainfall was 62–241 mm above the long-term average while in 2023 annual rainfall was 163–195 mm below the long-term average. Of more importance was the differences in growing season rainfall. In 2022 growing season rainfall was 202–242 mm above average (Decile 10) while in 2023 it was 136–175 mm below average (Decile 1). However, high levels of stored soil water in 2023 compensated for the lack of in-crop rain.

Measurements

Plant height was measured during early grain fill, from ground level to the top of the spike excluding awns, of the main tiller. Lodging was scored visually with a 0 for no lodging and 10 for 100% of the crop completely lodged and flat on the ground. In 2023 no lodging was evident at Boomi or Gurley thus scores were not recorded. Grain yield and quality were recorded for each trial.

Statistics

Multiyear, multi-site statistical analysis prepared by UQ-AAGI involved two stage analysis. First fitting the design for each trial, which obtained an adjusted mean and weight for each treatment in each trial. Second, combined analysis across trials where a model was built to obtain variance components for each term and grand mean and trial means were fitted as fixed terms. Predicted means were modelled to obtain the prediction (Best Linear Unbiased Prediction, BLUP) and grand mean and trial means were fitted as fixed terms. Predicted mean and twice standard error were plotted. In figures presented below, if bars do not overlap the two means are statistically significant at 5%.

Results

Yield and lodging

Average grain yield in 2022 was 6.8 t/ha compared to 4.9 t/ha in 2023. Yield differences between the two years were primarily due to growing season rainfall, which was decile 10 in 2022 and decile 1 in 2023. Yield in 2023 was primarily driven by stored soil water, with Gurley and Breeza sites still yielding >5 t/ha.

Across the six trials, there were clear trends in varietal yield and lodging responses to PGRs (Figure 1). For yield, Leabrook⦶ was most responsive to PGRs, while responses in Laperouse⦶, Maximus CL⦶ and RGT Planet⦶ were more variable. For lodging, PGRs had the largest benefit for Leabrook⦶ and Laperouse⦶. Comparing PGR treatments, Moddus Evo (400 ml/ha) applied at GS31 had the largest yield benefit, increasing average grain yield by 0.4 t/ha. Ethephon had the largest impact on lodging; it decreased average yield by 0.2 t/ha, although yield penalties were reduced when it was applied at GS41, though not significantly (Figure 1, top).

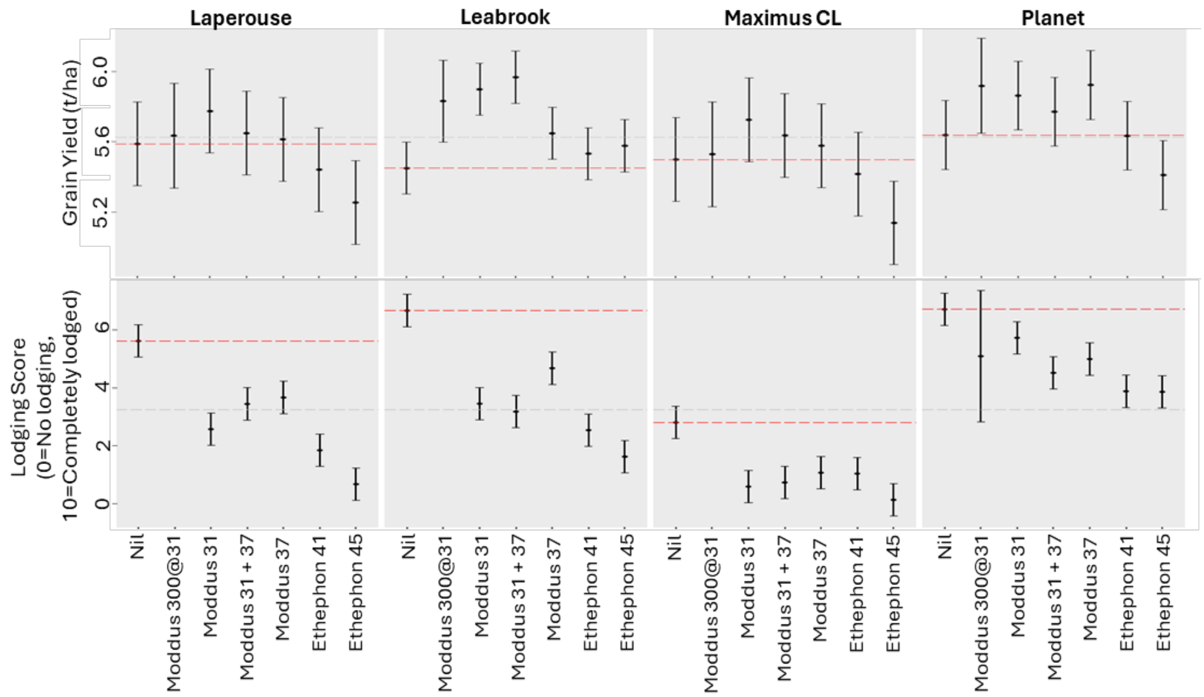

Figure 1. Average barley yield (top) and lodging (bottom) responses to PGR treatment in six trials across 2022 and 2023 growing seasons.

Grey (pale) dashed line indicates the mean yield across treatments, red (darker) dashed line indicates mean yield for the Nil PGR treatment. If bars do not overlap, the two means are statistically significant at 5%.

While there were trends in varietal and PGR responses, there were clear interactions between variety, PGR treatment and season (Figure 2). Thus, the impact of PGR treatments for each variety is discussed separately below.

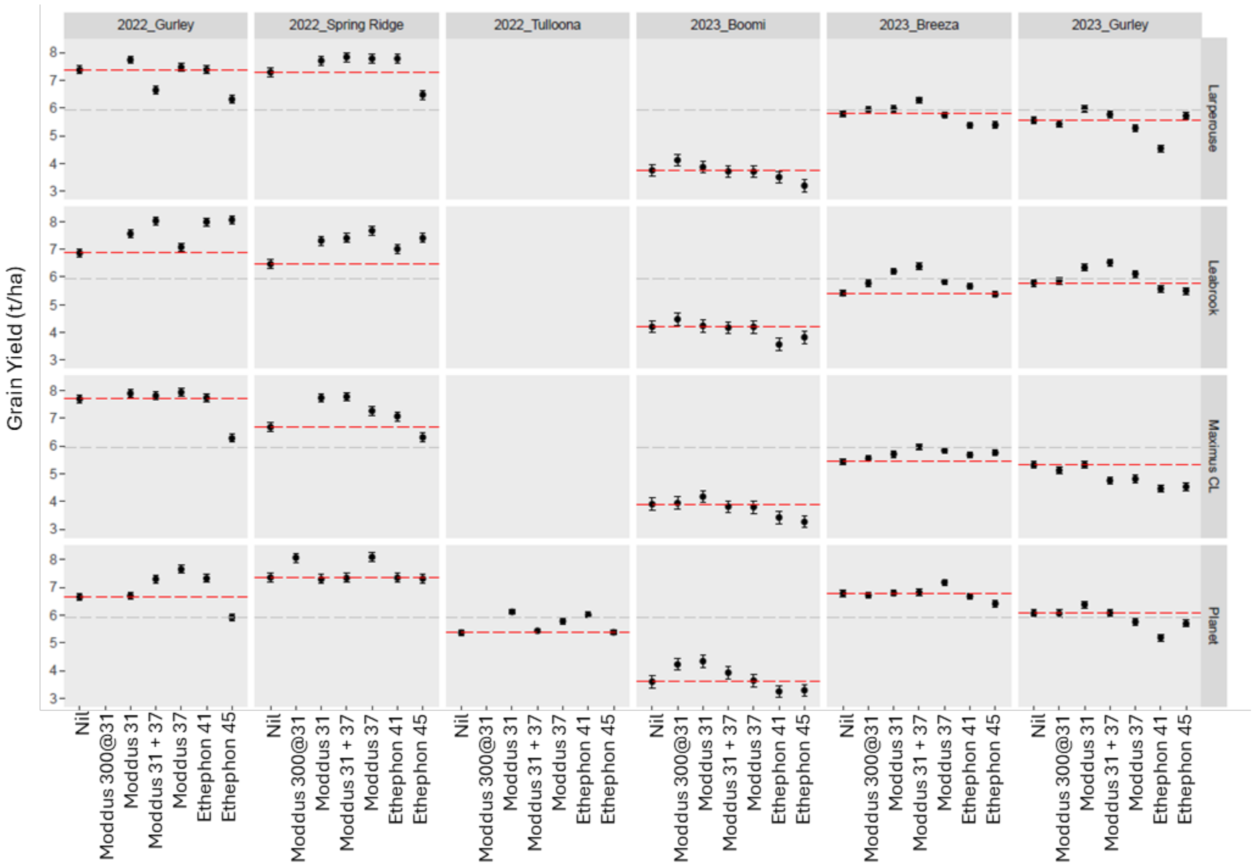

Figure 2. Average barley variety yield response to PGR treatment in six trials across 2022 and 2023 growing seasons.

Grey (light) dashed line indicates the mean yield across treatments, red (darker) dashed line indicates mean yield for the Nil PGR treatment in that trial. If bars do not overlap, the two means are statistically significant at 5%.

Leabrookϕ

Leabrookϕ was the most responsive variety to PGRs (Table 2). Under high yielding conditions, Moddus Evo applied at GS31 (400 ml/ha) increased grain yield by 0.7–0.8 t/ha (6.5–6.9 t/ha to 7.3–7.6t/ha). However, under moderate yielding conditions in 2023 the response to Moddus Evo at GS31 was variable increasing yield at Breeza (5.4 t/ha to 6.2t/ha) but not at Gurley or Boomi. Moddus Evo at GS31 was the most effective option for reducing lodging. Comparing other Moddus Evo treatments for Leabrookϕ, a second Moddus Evo application at GS37 did not consistently increase Leabrookϕ grain yield. In addition, reducing the Moddus Evo rate from 400 ml/ha to 300 ml/ha significantly reduced the yield benefit under moderate yielding conditions, although this lower rate was only tested in 2023.

While ethephon reduced lodging in Leabrookϕ, yield responses were variable. In 2022 ethephon increased grain yield by 0.5–1.1 t/ha applied at GS41 and by 0.9–1.2 t/ha applied at GS45. However, in 2023 ethephon generally had nil or negative impacts on yield.

Table 2. Leabrook⦶ yield responses to PGR treatments. Data represents yield differences from the Nil PGR treatment*

Trial	Nil PGR yield (t/ha)	Difference in Leabrook⦶ grain yield from Nil PGR (t/ha)					
		Moddus 300 @ 31	**Moddus 31**	**Moddus 37**	**Moddus 31 + 37**	**Ethephon 41**	**Ethephon 45**
2022 Spring Ridge	6.4[a]		0.8[b]	1.2[b]	0.9[b]	0.5[b]	0.9[b]
2022 Gurley	6.8[a]		0.7[b]	0.2[ab]	1.2[b]	1.1[b]	1.2[b]
2023 Breeza	5.4[a]	0.4[a]	0.8[bc]	0.4[ab]	1.0[c]	0.2[a]	0.0[a]
2023 Gurley	5.8[a]	0.1[a]	0.6[ab]	0.3[ab]	0.7[b]	-0.2[a]	-0.3[a]
2023 Boomi	4.2[a]	0.3[a]	0.0[a]	0.0[a]	0.0[a]	-0.6[b]	-0.4[ab]
Average		**0.2**	**0.6**	**0.4**	**0.8**	**0.2**	**0.3**

* Letters denote yield means for an individual trial are significantly different at 5%. Significance was calculated on predicted grain yield, not change in yield from the Nil PGR.

Laperouse⦶

Laperouse⦶ lodging was reduced but there was little or no yield response to PGRs. Moddus Evo at GS31, GS37 or a double application (GS31 + GS37) generally did not increase grain yield (Table 3). However, under lodging conditions Moddus Evo did reduce lodging scores from 5.5 to ~3.5. Moddus Evo at GS31 had the largest impact on lodging, although GS37 applications were also effective. Ethephon reduced lodging in Laperouse⦶ but production risk means it should only be applied early in the window (GS41) and in high yielding, lodging susceptible conditions.

Table 3. Laperouse⦶ yield responses to PGR treatments. Data represents yield differences from the Nil PGR treatment*.

Trial	Nil PGR yield (t/ha)	Difference in Laperouse⦶ grain yield from Nil PGR (t/ha)					
		Moddus 300 @ 31	**Moddus 31**	**Moddus 37**	**Moddus 31 + 37**	**Ethephon 41**	**Ethephon 45**
2022 Spring Ridge	7.3[a]		0.4[a]	0.5[a]	0.5[a]	0.5[a]	-0.8[b]
2022 Gurley	7.4[a]		0.4[a]	0.1[a]	-0.7[b]	0.0[a]	-1.1[b]
2023 Breeza	5.8[a]	0.1[ab]	0.2[ab]	-0.1[a]	0.5[b]	-0.4[a]	-0.4[a]
2023 Gurley	5.6[abc]	-0.1[ac]	0.4[b]	-0.3[c]	0.2[ab]	-1.0[d]	0.2[abc]
2023 Boomi	3.8[a]	0.4[a]	0.1[a]	0.0[a]	0.0[a]	-0.2[a]	-0.6[a]
Average		**0.1**	**0.3**	**0.0**	**0.1**	**-0.2**	**-0.5**

* Letters denote yield means for an individual trial are significantly different at 5%. Significance was calculated on predicted grain yield, not change in yield from the Nil PGR.

RGT Planet⦶

RGT Planet⦶ had improved yield and reduced lodging in response to Moddus Evo at GS37, but only under high yielding (>6t/ha), lodging susceptible conditions (Table 4). To demonstrate, in 2022 Moddus Evo at GS37 improved yield by 0.7–1.0 t/ha and decreased lodging from 6.5 to 5. Importantly, Moddus Evo applied at GS31 or a double application (GS31 + GS37) did not improve yield or lodging in the 2022/23 trials. Ethephon reduced lodging in RGT Planet⦶ but had variable and often negative yield impacts.

Table 4. RGT Planetⓓ yield responses to PGR treatments. Data represents yield differences from the Nil PGR treatment.

Trial	Nil PGR yield (t/ha)	Difference in RGT Planetⓓ grain yield from Nil PGR (t/ha)					
		Moddus 300 @ 31	Moddus 31	Moddus 37	Moddus 31 + 37	Ethephon 41	Ethephon 45
2022 Spring Ridge	7.4^{a}	0.7^{b}	-0.1^{a}	0.7^{b}	0.0^{a}	0.0^{a}	0.0^{a}
2022 Gurley	6.7^{a}		0.0^{a}	1.0^{b}	0.6^{b}	0.7^{b}	-0.7^{c}
2023 Breeza	6.8^{ab}	-0.1^{ab}	0.0^{ab}	0.4^{a}	0.0^{ab}	-0.1^{b}	-0.4^{b}
2023 Gurley	6.1^{ab}	0.0^{ab}	0.3^{a}	-0.3^{b}	0.0^{ab}	-0.9^{c}	-0.4^{b}
2022 Tulloona	5.3^{a}		0.7^{a}	0.4^{a}	0.1^{a}	0.6^{a}	0.0^{a}
2023 Boomi	3.6^{a}	0.6^{b}	0.7^{b}	0.0^{ab}	0.3^{ab}	-0.3^{a}	-0.3^{a}
Average		**0.3**	**0.3**	**0.4**	**0.2**	**0.0**	**-0.3**

* Letters denote yield means for an individual trial are significantly different at 5%. Significance was calculated on predicted grain yield, not change in yield from the Nil PGR.

Maximus CLⓓ

Maximus CLⓓ is unlikely to have PGRs applied due to low lodging risk. While Moddus Evo at GS31 or GS37 increased Maximus CLⓓ yield by 0.2 to 1.0 t/ha under high yielding conditions (>6 t/ha), results were inconsistent (Table 5). All other PGR use patterns increased production risk, especially in lower yielding conditions.

Table 5. Maximus CLⓓ yield responses to PGR treatments. Data represents yield differences from the Nil PGR treatment.

Trial	Nil PGR yield (t/ha)	Difference in Maximus CLⓓ grain yield from Nil PGR (t/ha)					
		Moddus 300 @ 31	Moddus 31	Moddus 37	Moddus 31 + 37	Ethephon 41	Ethephon 45
2022 Spring Ridge	6.6^{ab}		1.1^{c}	0.6^{cd}	1.1^{c}	0.4^{ad}	-0.4^{b}
2022 Gurley	7.7^{a}		0.2^{a}	0.2^{a}	0.1^{a}	0.0^{a}	-1.4^{b}
2023 Breeza	5.4^{a}	0.1^{ab}	0.3^{ab}	0.4^{ab}	0.5^{b}	0.2^{ab}	0.3^{ab}
2023 Gurley	5.3^{a}	-0.2^{ab}	0.0^{a}	-0.5^{bc}	-0.6^{bc}	-0.9^{c}	-0.8^{c}
2023 Boomi	3.9^{ab}	0.0^{ab}	0.3^{a}	-0.1^{abc}	-0.1^{abc}	-0.5^{bc}	-0.6^{c}
Average		**0.0**	**0.4**	**0.1**	**0.2**	**-0.1**	**-0.6**

* Letters denote yield means for an individual trial are significantly different at 5%. Significance was calculated on predicted grain yield, not change in yield from the Nil PGR.

Sowing timing

In 2023, sowing timing affected yield responses to PGR treatment. At Gurley, early sown (26 April) Leabrookⓓ yield increased by 0.5 t/ha in response to Moddus Evo applied at GS31 (Figure 3). However, there was no yield response to any PGRs when sowing was delayed to mid May (12 May). This was despite similar Nil PGR yields for the early (5.8 t/ha) and mid times of sowing (5.7 t/ha) at Gurley. In comparison, at Boomi lower Nil PGR yields for Leabrookⓓ (3.5–4.2 t/ha) meant there was no yield response to PGRs for either the early of mid times of sowing. However, at both sites yield variability (standard error) increased when sowing was delayed from late April to mid May.

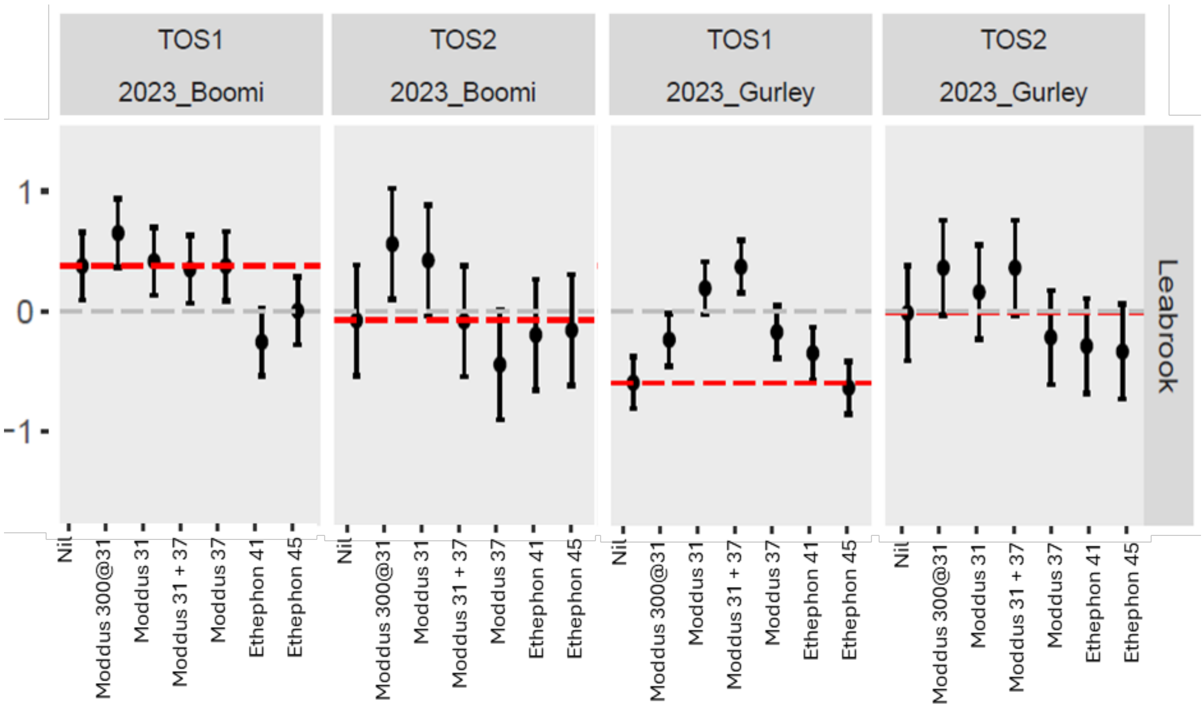

Figure 3. Change in barley yield from mean treatment yield in response to PGR treatment for early (25–26 April) and mid (12 May) times of sowing at Boomi and Gurley in 2023.
Grey (light) dashed line indicates the mean yield across treatments (set at Nil), red (dark) dashed line indicates mean yield for the Nil PGR treatment in that trial. If bars do not overlap, the two means are statistically significant at 5%.

Grain quality

Protein

Grain protein averaged 12.4% (range 9.9–14.4%). PGRs had a small effect on grain protein, with significant changes in protein in 8% of site x variety x PGR combinations. There was only one case of reduced grain protein, -0.8% in Leabrook⦶ at Gurley in response to Moddus Evo at GS31 + GS37. Increases in grain protein (0.6–1.2%) were observed in response to ethephon at GS41 and Moddus Evo at GS37 in Laperouse⦶, Maximus CL⦶ and RGT Planet⦶ in 2023 at Gurley and Boomi. However, in only two cases did a change in grain protein alter delivery grading.

Retention & screenings

Grain retention averaged 96% (range 86–99%), which is considerably higher than the 70% required for Malt1 barley. In 2022 PGR treatment did not affect retention. In 2023 retention was largely unaffected except for select Moddus Evo treatments which reduced retention by 2 to 5 percentage points when applied at GS31, GS37 and GS31 + GS37 to Maximus CL⦶ (Boomi and Gurley) and Leabrook⦶ (Breeza).

Screenings averaged 1.3% (range 0.5–2.7%), well below the maximum 7% for Malt1. They were largely unaffected by PGR treatment with the only 1 case (ethephon at GS45 on RGT Planet⦶, Gurley 2022) where screenings increased (+0.7%). Thus, changes in retention and screenings were small and occurred infrequently, with no changes in barley grading due to changes in retention and screenings.

Test weight

Across the trials test weight averaged 65 kg/hL, ranging from 63–75 kg/hL (Malt1 test weight minimum 70 kg/hL). There were no sites where a significant change in test weight caused the barley to change grades. However, there were cases where ethephon and Moddus Evo significantly reduced test weight. Ethephon at GS45 reduced test weight by 0–3 kg/hL at Gurley in 2022. For Moddus Evo, in 2023 test weight was reduced by 1 kg/hL at Gurley and Breeza in response to applications at GS31, GS37 and GS31 + GS37.

Economic analysis

Leabrookⓓ

Economic analysis clearly demonstrated that the highest returns from PGRs were in Leabrookⓓ, with PGRs increasing the partial gross margin by up to $295/ha across the two years of trials (Table 6). Moddus Evo at GS31 increased partial gross margins by $112–295/ha in moderate to high yielding conditions (5–8 t/ha) but reduced partial gross margins by $80–31/ha in lower yielding conditions (4 t/ha). Ethephon partial gross margins under high yielding, lodging susceptible conditions (7–8 t/ha) increased by $319/ha. However, there were severe financial penalties where ethephon was applied in lower yielding conditions.

Table 6. Leabrookⓓ partial gross margin (additional gross income – PGR product & application cost) for PGR treated barley. Nil PGR Gross income ($/ha) shows the gross income for Nil PGR; PGR columns show the difference in the partial gross margin from the Nil PGR ($/ha)*

	Nil PGR		**Moddus 300 @ GS31**	**Moddus GS31**	**Moddus GS37**	**Moddus GS31 + 37**	**Ethephon GS41**	**Ethephon GS45**
Trial	**Yield (t/ha)**	**Gross income ($/ha)** *(=yield x grain price)*	**Change in *partial* gross margin from Nil PGR ($/ha)** *= (change in yield from Nil PGR x grain price) – (PGR & application cost)*					
2022 Spring Ridge	6.4	1,811		193	295	189	137	247
2022 Gurley	6.8	1,922		153	17	253	298	319
2023 Breeza	5.4	1,517	66	179	76	199	53	-28
2023 Gurley	5.8	1,621	-12	112	49	135	-76	-97
2023 Boomi	4.2	1,177	42	-31	-42	-80	-194	-121
Average		**1,609**	**32**	**121**	**79**	**139**	**44**	**64**

** **Assumptions**: barley $280/t; ethephon $10/L; Moddus Evo $75/L; application cost $12/ha. **PGRs** Ethephon (900 g/L ethephon) and Moddus Evo (250 g/L trinexapac-ethyl).*
***GS** – growth stage.*

Laperouseⓓ

Laperouseⓓ return on investment from PGR treatment was substantially lower than for Leabrookⓓ. Only Moddus Evo applied at GS31 increased average partial gross margins, with an increase of $8–76/ha with yields >5t/ha (Table 7). Moddus Evo decreased partial gross margins in low yielding conditions compared to Nil PGR. Importantly, ethephon at either GS41 or GS45 decreased partial gross margins, even under high yielding conditions.

Table 7. Laperouse partial gross margin (net income – PGR cost) for PGR treated barley. Nil PGR Gross income ($/ha) shows the gross income for Nil PGR; PGR columns show the difference in gross income from the Nil PGR*

	Nil PGR		Moddus 300 @ GS31	Moddus GS31	Moddus GS37	Moddus GS31 + 37	Ethephon GS41	Ethephon GS45
Trial	**Yield (t/ha)**	**Gross income ($/ha)** *(=yield x grain price)*	**Change in *partial* gross margin from Nil PGR ($/ha)** *= (change in yield from Nil PGR x grain price) – (PGR & application cost)*					
2022 Spring Ridge	7.3	2,041		74	95	80	121	-243
2022 Gurley	7.4	2,065		59	-16	-277	-14	-314
2023 Breeza	5.8	1,620	5	8	-56	68	-130	-128
2023 Gurley	5.6	1,554	-71	76	-120	-12	-300	29
2023 Boomi	3.8	1,050	68	-9	-55	-82	-84	-171
Average		**1,666**	**1**	**41**	**-30**	**-45**	**-81**	**-165**

Assumptions: *Barley $280/t; Ethephon $10/L, Moddus Evo $75/L; Application cost $12/ha.* ***PGRs*** *Ethephon (900g/L ethephon) and Moddus Evo (250 g/L Trinexapac-Ethyl).* ***GS*** *– Growth Stage.*

RGT Planet

RGT Planet demonstrated inconsistent financial returns to both Moddus Evo and ethephon at all yield ranges. Under high yielding conditions, Moddus Evo at GS37 increased partial gross margins compared to Nil PGR by $164–238/ha (Table 8). However, under lower yielding conditions financial outcomes were more variable. Financial returns from Moddus Evo at GS31 were variable and ethephon decreased average partial gross margins, especially at GS45.

Table 8. RGT Planet partial gross margin (net income – PGR cost) for PGR treated barley. Nil PGR Gross income ($/ha) shows the gross income for Nil PGR; PGR columns show the difference in gross income from the Nil PGR*

	Nil PGR		Moddus 300 @ GS31	Moddus GS31	Moddus GS37	Moddus GS31 + 37	Ethephon GS41	Ethephon GS45
Trial	**Yield (t/ha)**	**Gross income ($/ha)** *(=yield x grain price)*	**Change in *partial* gross margin from Nil PGR ($/ha)** *= (change in yield from Nil PGR x grain price) – (PGR & application cost)*					
2022 Spring Ridge	7.4	2,060	166	-58	164	-77	-19	-27
2022 Gurley	6.7	1,863		-30	238	109	171	-222
2023 Breeza	6.8	1,899	-52	-39	70	-63	-46	-119
2023 Gurley	6.1	1,700	-36	46	-129	-68	-261	-121
2022 Tulloona	5.3	1,504		168	74	-54	163	-13
2023 Boomi	3.6	1,008	140	165	-29	19	-114	-102
Average		**1,672**	**54**	**42**	**64**	**-22**	**-18**	**-101**

Assumptions: *Barley $280/t; Ethephon $10/L, Moddus Evo $75/L; Application cost $12/ha.* ***PGRs*** *Ethephon (900g/L ethephon) and Moddus® Evo (250 g/L Trinexapac-Ethyl).* ***GS*** *– Growth Stage.*

Maximus CL

Comparing Maximus CL financial returns, Moddus Evo at GS31 was the only PGR treatment that increased average partial gross margin above Nil PGR levels (+$59/ha). However, even then negative returns (-$41/ha) occurred under moderate yielding conditions. All other Moddus Evo as well as ethephon treatments provided inconsistent financial returns and, on average, decreased net income.

Table 9. Maximus CL⦶ partial gross margin (net income – PGR cost) for PGR treated barley. Nil PGR Gross Income ($/ha) shows the gross income for Nil PGR, PGR columns show the difference in gross income from the Nil PGR*

	Nil PGR		**Moddus 300 @ GS31**	**Moddus GS31**	**Moddus GS37**	**Moddus GS31 + 37**	**Ethephon GS41**	**Ethephon GS45**
Trial	**Yield (t/ha)**	**Gross income ($/ha)** *(=yield x grain price)*	**Change in *partial* gross margin from Nil PGR ($/ha)** *= (change in yield from Nil PGR x grain price) – (PGR & application cost)*					
2022 Spring Ridge	6.6	1,871		253	122	235	93	-119
2022 Gurley	7.7	2,155		15	26	-40	-5	-412
2023 Breeza	5.4	1,522	-1	35	73	78	53	75
2023 Gurley	5.3	1,489	-89	-41	-182	-229	-255	-236
2023 Boomi	3.9	1,094	-23	34	-72	-97	-151	-195
Average		**1,626**	**-38**	**59**	**-7**	**-11**	**-53**	**-178**

***Assumptions**: Barley $280/t; Ethephon $10/L, Moddus Evo $75/L; Application cost $12/ha. **PGRs** Ethephon (900g/L ethephon) and Moddus Evo (250 g/L Trinexapac-Ethyl). **GS** – Growth Stage.*

Discussion

The results from these trials reinforce that PGRs can be used as an effective tool to minimise lodging in barley crops, can increase grain yield even in the absence of lodging, under the right condition can significantly increase net returns (this is even without taking into account reduced harvesting costs) and that responses vary greatly depending on variety. Not surprisingly, greater yield responses were observed to PGR applications under the more favourable seasonal conditions in 2022 compared to 2023. In either season, one of the most consistent differences observed was the difference in yield response between varieties, where Leabrook⦶ was the most responsive and Maximus CL⦶ was the least responsive. Both of these varieties are quicker varieties but Leabrook⦶ has a high susceptibility to lodging. The difference in variety response highlights variety as an important consideration when deciding on the use of a PGR in a commercial situation.

While there is variability in financial returns, if seasonal conditions, variety and PGR treatment line up then positive financial returns are achievable with reduced risk. To demonstrate, for Moddus Evo applied to Leabrook⦶ at GS31, partial gross margins increased by +$153 to +193/ha in 2022, but under more marginal conditions in 2023 the change in partial gross margin ranged from -$31/ha to +$179/ha. For Moddus Evo applied to RGT Planet⦶ at GS37 partial gross margins increased by +$164/ha to +$238/ha in 2022, but in lower yielding conditions in 2023 the change in partial gross margin ranged from -$31/ha to +$179/ha.

While substantially cheaper than Moddus Evo, ethephon carries a much higher production and financial risk. In 2022 and 2023 applications at GS41 and GS45 decreased partial gross margins in >80% of cases, with large increases in partial gross margin only occurring under high yielding, lodging susceptible conditions for Leabrook⦶.

Consistent lodging and yield responses as well as financial returns are the key constraint to PGR use in dryland barley in the northern grains region. There are three key factors driving the variability of these responses. Firstly, variable responses to PGRs exist even in experimental conditions and must be factored into PGR programs. Secondly, decisions on PGR application must be made early in the season (during tillering) when the final yield and lodging susceptibility and the likely response to a PGR is uncertain. Thirdly, on-farm logistics mean PGRs are often applied late and thus the maximum benefit is not achieved.

While variable responses and difficulty forecasting PGR responses early in the season are the key adoption barrier, there are other factors that affect adoption. These include, product cost, ability to execute on time due to logistics and trafficability, low confidence in the spring forecast and thus the forecast yield, yield penalties as well as difficulty assessing the cost benefit ratio of PGRs early in the season. As a result, most advisors and growers favour using agronomic factors to reduce lodging risk including variety and paddock selection, nutrition management and time of sowing. While positive results have been achieved at paddock scale, PGR adoption remains limited to situations where other management strategies have been insufficient to prevent a major lodging event.

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