Project Identification

1. **Project Title:** Enhanced Barley Variety Trials-Plant Growth Regulators
2. **Project number:** ADOPT 20211031
3. **Producer Group Sponsoring the Project:** Saskatchewan Barley Development Commission
4. **Project Location(s):** Outlook, Melfort (RM#428), Prince Albert (RM #461), Scott (RM# 380) and Indian Head (RM# 458), SK
5. **Project start and end dates (month & year):** March 2022 to April 15, 2023
6. **Project contact person & contact details:**

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Objectives and Rationale

7. Project objectives:

The objective of this demonstration was to compare the responsiveness of 3 malt and 3 feed barley varieties to a plant growth regulator (PGR) applied at early stem elongation (Zadoks 30-32). The malt varieties to be screened included AAC Synergy, AAC Connect, CDC Fraser, and the feed varieties included CDC Austenson, Claymore, and Oreana. These varieties were selected as they are increasing in popularity based on 2021 insured seeded acres (Canadian Grain Commission). This demonstration project is part of a series of project proposed by SaskBarley to generate variety specific recommendations for barley management.

8. Project Rationale:

The response of cereals to differing levels of management can differ between varieties. In wheat for example, Dr. Sheri Strydhorst has identified varieties that are most responsive to additional management inputs (such as higher seeding rates, higher fertilizer rates, plant growth regulator and fungicide application). In one of Dr. Strydhorst's projects, yield responses to additional management ranged from 6-17% depending on variety – this is valuable information for producers. Link to data

Currently, the plant growth regulators chlormequat chloride (Manipulator) and trinexapac-ethyl (Moddus) are the only plant growth regulators registered for use on barley in Canada. Chlormequat chloride has not been well received by end users and as a result has been flagged by the Market Access Committee of Cereals Canada, in their Keep it Clean campaign. Recently published research has also shown it to be inconsistent at preventing lodging in barley, but that may have been due to barley variety (Tidemann et. Al. 2020). Plant growth regulator effects on malt quality were limited and small, leaving an opportunity to continue to explore PGRs as an agronomic management tool for lodging in barley production (McMillan et. Al. 2013).

Trinexapac-ethyl was found to be more effective than either chlormequat chloride or ethephon (Ethrel), with the largest number of height reductions and scale of reductions. Effects on maturity were minimal and no significant effects were found on grain yield or protein due to treatment effect. The researchers noted that plant growth regulators did not appear to be a viable solution to consistently managing lodging for the variety CDC Copeland. The researchers also noted that previous research has shown there to be variable responses to PGR, depending on the variety, and that it is possible that CDC Copeland is a variety that does not respond to PGR application as much as other varieties might (Tidemann et. Al. 2019).

Anecdotally, in 2021, some producers saw significant harm to their barley following application of trinexapac-ethyl. Plant growth regulators are not supposed to be applied when plants are under stress. Due to extreme heat and drought in 2021, it is likely that the PGR was applied when it should not have been. It is also possible that there was a variety effect.

Yield and quality loss due to lodging in barley continues to be a problem for farmers and creates hesitation for farmers when choosing to grow barley. Research continues towards developing better resistance to lodging, such as the work that Drs. Allan Feurtado and Aaron Beattie are undertaking. Despite optimism for genetic solutions, as producers continue to strive for higher yields, and grow higher yielding varieties, the risks of lodging will continue in some environments. The varieties tested in this proposal all have high yield potential and represent the future of barley production in Saskatchewan. Farmers will need to know if PGRs can be effective tools to manage lodging in these varieties.

This information will become part of a variety specific approach to crop management recommendations being developed by SaskBarley.

Methodology and Results

9. Methodology:

The demonstration was conducted at five locations including Melfort, Indian Head, Prince Albert, Outlook and Scott, SK in 2022. Scott and Outlook are in the dark brown soil zone, with the remaining sites located in the black soil zone. Within the dark brown soil zone, Scott is northern and Outlook is central, and within the black soil zone, Prince Albert and Melfort are northern and Indian Head is southern. These locations were chosen to allow us to demonstrate responses to plant growth regulators across a wide range of environmental conditions, including under irrigation at Outlook.

The demonstration was set-up as a split-plot with twelve treatments and four replications at all locations (Table 1). The main plot of the split-plot was the application of a plant growth regulator, and the sub-plot was barley variety. Within barley varieties, there were three malt (AAC Synergy, CDC Fraser and AAC Connect) and three feed (Oreana, Claymore and CDC Austenson) varieties. The plant growth regulator used was trinexepac-ethyl (Moddus), which was to be applied as GS 30-32 (1st node/early stem elongation) at 0.42L/ac (11.3% trinexepac-ethyl). Furthermore, each site applied a base level of nitrogen to the trial area based on their barley yield potential. Melfort and Outlook were considered the high yield potential sites and applied total nitrogen at 146 kg/ha (soil & applied) and Prince Albert, Scott, and Indian Head were considered mid-range in their yield potential and applied total nitrogen of 135 kg/ha (soil & applied). The nitrogen from the soil at each location was based on a 0-to-60-centimeter depth. All other fertility was side band at seeding to be non yield limiting.

Table 1. Treatments used in Enhanced Barley Variety Trials-Plant Growth Regulators at multiple locations in 2022.

TRT #	Variety	Type	PGR[1]
1	AAC Synergy	Malt	None
2	AAC Connect	Malt	None
3	CDC Fraser	Malt	None
4	CDC Austenson	Feed	None
5	Claymore	Feed	None
6	Oreana	Feed	None
7	AAC Synergy	Malt	Yes
8	AAC Connect	Malt	Yes
9	CDC Fraser	Malt	Yes
10	CDC Austenson	Feed	Yes
11	Claymore	Feed	Yes
12	Oreana	Feed	Yes

[1]PGR applied was Moddus (trinexapac-ethyl) at GS 30-32 (stem elongation)

Seeding equipment and crop management varied by location. All agronomic information and dates of operations are included in Table 2. All sites were seeded between May 10th and 16th, except for Prince Albert where the demonstration was seeded on June 3rd due to late snow melt and wet spring conditions. The demonstration was direct seeded into canola stubble at all sites. Weeds, insects and disease were controlled using registered products at each participating site at the discretion of the site managers. Desiccants were not used at any of the sites and all plots were harvested between August 18th and September 6th.

Table 2. Agronomic information and date of operation for Enhanced Barley Variety Trials-Plant Growth Regulators at all locations in 2022.

	Melfort	**Outlook**	**Prince Albert**	**Indian Head**	**Scott**
Stubble	Canola	Canola	Canola	Canola	Canola
Row spacing	0.3048m	0.254m	0.254m	0.3m	0.254m
Plot size	14.0m^2	12m^2	14m^2	25.6m^2	12.2m^2
Fertility (N-P2O5-K2O-S kg/ha)	30-49-11-0	134-35-0-0	34-45-0-0	134-35-17.5-17.5	38-17-0-6
Seeding date	May 16	May 10	June 3	May 16	May 12
Pre-emergent herbicide	Avadex at 1.2L/ac May 12 Glyphosate 540 at 0.67L/ac May 21	Glyphosate 540 at 1L/ac May 2	Glyphosate 540 at 1L/ac on May 21	Glyphosate 540 at 0.67L/ac May 22	Glyphosate 540 at 1L/ac and AIM at 35mL/ac on May 9
Plant counts	June 7	May 30	June 22	June 1	June 2
Post-emergent herbicide	Axial at 0.5L/ac June 22 Prestige XL at 947mL/ac on June 28	Buctril M at 0.4L/ac and Puma Advance at 0.35L/ac on June 8	Infinity at 0.33L/ac and Puma Advance at 413 mL/ac on June 28	Pixarro (125mL/ac A + 235mL/ac B) and 0.5L/ac Axial on June 11	Axial at 0.5L/ac and Infinity at 0.33L/ac on June 16 Buctril M at 0.4L/ac June 22
PGR Application	June 22	June 11	July 6	June 16	June 16
Fungicide	None	None	None	Nexicor at 0.2L/ac July 1 Prosaro XTR 325mL/ac July 17	Caramba at 160mL/ac July 14
Insecticide	None	None	None	Decis 5 EC at 60mL/ac July 9 for grasshoppers	None
Heights	August 8	August 3	August 24	July 25	July 28
Lodging	August 31	August 3	July 22	August 29	August 18
Harvest	August 31	August 18	September 6	August 31 & September 1	August 22

Table 3. Soil information for all sites in Enhanced Barley Variety Trials-Plant Growth Regulators in 2022.

Depth	NO3-N (kg/ha)	Olsen-P (ppm)	K (ppm)	S (kg/ha)	pH	Organic Matter (%)	Salts (mmho/cm)
	Melfort						
0-15cm	44	13	453	36	5.8	9.5	0.35
15-60cm	72				6.1 (15-30cm)		0.38 (15-30cm)
	Scott						
0-15cm	23	20	474	6	6.0	4.6	0.2
15-60cm	66				7.1		0.36 (15-30cm)
	Indian Head						
0-15cm	5	3	487	11	8.1	4.5	0.53
15-60cm	14			67	8.2		0.58
	Outlook						
0-15cm	15	8	360	22	7.1	2.7	0.25
15-60cm	40				7.5		0.29 (15-30cm)
	Prince Albert						
0-15cm	63	5	248	135+	6.4	5.5	1.3
15-60cm	110				7.1		1.27 (15-30cm)

Data collection in the demonstration consisted of plant density, plant height, lodging, grain yield, protein, test weight, seed size, and plump kernels. Plant density was measured by counting the seedlings along two 1-meter sections of crop row per plot after crop emergence. The average of the two rows was divided by the crop row spacing to determine the plants/m^2. Lodging was determined by rating every plot for severity of lodging prior to harvest. A scale of 1 to 9 was used where 1 equated to no lodging, and 9 equated to the whole plot laying flat. Plant height was measured at every site by measuring the height of plants within six locations per plot to the nearest centimeter. Outlook was the only site where plant height was only recorded in two locations per plot. Plant height was recorded once the plants were closer to maturity and were no longer growing in height. Height was averaged between the six or two locations and reported as an average per plot. Grain yield was determined at each site by weighing each harvested plot sample and converting the grams per plot to a kg/ha equivalent, while correcting for dockage and to a consistent moisture (13.5%). Grain quality analysis, which included protein, test weight, seed weight and plump kernels, was completed by the Canadian Malting Barley Technical Centre and was completed using standard Canadian Grain Commission practices for each measure of grain quality. Protein was reported as a percentage, test weight was reported in grams/0.5L, seed weight was reported at grams/1000 seeds, and plump was reported as a percentage of plump kernels in a sample.

Data were analyzed with the R statistical program, version 4.2.2 (R Core Team 2022), using the *lme4* package (Bates et al. 2015) for fitting mixed-effects models, the *lmerTest* package (Kuznetsova et al. 2017) for assessing model fit and treatment differences, and the *emmeans* package (Length 2023) for means separation. Data from all site-years were combined for a multi-site analysis. To assess the overall response across environments and determine the presence of significant site interactions, mixed effects models were fitted for each response variable with site, variety and PGR treatment, all two-way interactions, and the three-way interaction as fixed effects, and replicate within site, and PGR within replicate within site (PGR was blocked in the split-plot design) as random effects. If significant site interactions were identified, then sites were analyzed separately, with variety, PGR, and the variety by PGR interaction as fixed effects, and replicate and PGR within replicate (split-plot design) as random effects. PGR and interactions with PGR were not included as fixed effects for plant density. Estimated marginal means were determined and means were separated using multiple pairwise comparisons with the Tukey method for P-value adjustment and the Satterthwaite method for determining degrees of freedom. Treatments were considered significantly different at $P \leq 0.05$.

10. Results

Environmental Conditions

The 2022 season was marked by warmer than average temperatures at all sites, with some sites experiencing an increase in cumulative precipitation (Melfort and Indian Head), and some sites experiencing a deficit of cumulative precipitation (Scott, Outlook and Prince Albert) as compared to the long-term average (Table 4). Although Outlook experienced below average precipitation (83% of the long-term), the location received 165mm of precipitation in the form of irrigation, which brought the cumulative precipitation to 336mm, which was the greatest of all sites. For the remaining sites, Prince Albert received 81% of long-term precipitation amount and Scott received 82% of long-term amount, while Melfort received 106% of the long-term and Indian Head received 117% of the long-term precipitation. For average temperature, Outlook was the warmest of the sites with an average temperature from May to August of 17.1°C, and Melfort was the coolest with an average temperature

from May to August of 15.5°C. Average growing season temperature at the remaining sites was 15.6°C at Scott, 15.7°C at Prince Albert and 15.8°C at Indian Head, all of which were above the long-term average.

Table 4. Mean Temperatures and precipitation collected from the nearest weather station at Melfort, Indian Head, Scott, Yorkton, and Outlook from May to August of 2022.

	May	June	July	August	Total/Average
--Temperature (°C)--					
Melfort 2022	9.9	15.2	18.2	18.7	15.5
Long-term[x]	10.7	15.9	17.5	16.8	15.2
Indian Head 2022	10.9	16.1	18.1	18.3	15.8
Long-term[x]	10.8	15.8	18.2	17.4	15.6
Scott 2022	10.0	15.0	18.3	18.9	15.6
Long-term[x]	10.8	14.8	17.3	16.3	14.8
Prince Albert 2022	10.5	15.5	18.3	18.5	15.7
Long-term[x]	11.3	16.2	17.1	17.1	15.8
Outlook 2022	11.8	16.3	19.7	20.5	17.1
Long-term[x]	11.2	16.1	18.7	17.8	16.0
--Precipitation (mm)--					
Melfort 2022	90.8	78.1	34.9	36.5	240.3 (106%)
Long-term[x]	42.9	54.3	76.7	52.4	226.3
Indian Head 2022	97.7	27.5	114.5	45.9	285.6 (117%)
Long-term[x]	51.7	77.4	63.8	51.2	244.1
Scott 2022	11.0	57.1	86.5	32.1	186.7 (82%)
Long-term[x]	38.9	69.7	69.4	48.7	226.7
Prince Albert 2022	17.9	75.7	63.7	37.8	195.1 (81%)
Long-term[x]	39.4	79.7	77.0	44.6	240.7
Outlook 2022[y]	35.7	75.2	53.2	7.0	171.1 (83%)
Long-term[x]	42.0	63.9	56.1	45.3	207.3

[x]Long-term average is anywhere from the years 1980-2021, but exact range of years varies by site

[y]Outlook also received a total of 6.5-inches (165mm) of cumulative precipitation as irrigation

The combined multi-site analysis showed significant site interactions for height, lodging, and yield (Table 5).

Table 5. F-test results of mixed-effects model analysis of crop response variables assessing the presence of site interactions with variety and PGR. Effects are considered statistically significant if P<0.05 and significant effects are bolded for emphasis.

	Plant density	Height	Lodging	Yield
Fixed effects	---------- *Pr(>F)* ----------			
Variety (V)	**<0.001**	**<0.001**	**0.028**	0.677
PGR (P)	-	**<0.001**	**<0.001**	0.108
Site (S)	**<0.001**	**<0.001**	**0.011**	**<0.001**
V x P	-	**0.003**	0.110	**0.039**
V x S	0.845	**0.017**	**0.023**	**<0.001**
P x S	-	0.070	**0.004**	0.421
V x P x S	-	0.355	0.180	**0.004**

Plant density

Plant density differed between varieties and sites overall, but the interaction was not significant, indicating the difference between varieties was similar among sites (Table 5). When sites were analyzed individually, only two sites had differences in plant density between varieties (Table 6).

The two sites with significant varietal differences in plant density were Indian Head (p=0.039) and Prince Albert (p=0.026). At Indian Head AAC Synergy (230 plants/m^2) had significantly greater plant density than AAC Connect (206 plants/m^2) and CDC Fraser (206 plants/m^2), but was comparable to all feed varieties (CDC Austenson, Claymore and Oreana). At Prince Albert AAC Synergy (224 plants/m^2) and Claymore (225 plants/m^2) had significantly greater plant density than AAC Connect (190 plants/m^2), but were comparable to all other varieties. Other sites demonstrated a similar trend where AAC Synergy and Claymore had the greatest average plant density in comparison to other varieties; however, the difference was not significant at Melfort, Outlook and Scott.

Table 6. Tests of significance and estimated marginal means for the effect of variety on plant density at each site individually. F-test results for individual sites are considered significant at P<0.05. 'S.E.' indicates the standard error. Letters indicate the separation of the estimated marginal means within individual sites.

	Indian Head	Melfort	Outlook	Prince Albert	Scott
P(>F)	**0.039**	0.409	0.473	**0.026**	0.118
S.E.	*6.55*	*7.42*	*10.5*	*8.12*	*8.16*
Variety		---------- *plants m^{-2}* ----------			
AAC Synergy	230 a	201	150	224 a	207
AAC Connect	206 b	190	148	190 b	195
CDC Fraser	206 b	180	134	205 ab	185
CDC Austenson	216 ab	188	143	220 ab	193
Claymore	226 ab	193	162	225 a	200
Oreana	224 ab	197	146	221 ab	193

Height

11. PGR application significantly affected height across locations (Table 5). There was a significant variety by site interaction indicating that differences in varietal heights varied by site, as would be expected. However, the two- and three-way site interactions with PGR were not significant, indicating the effect of PGR and its interaction with variety were similar across sites, and so the response to PGR at individual sites will not be discussed. There was, however, a significant overall variety by PGR interaction. When combined across sites, the height of all varieties except for Oreana decreased significantly with a PGR application (Figure 1). Oreana was also significantly shorter than all other varieties without a PGR application. Individual site responses to the main effects of variety and PGR, and their interaction, are summarized in the appendix (**Appendices**

Table A-1).

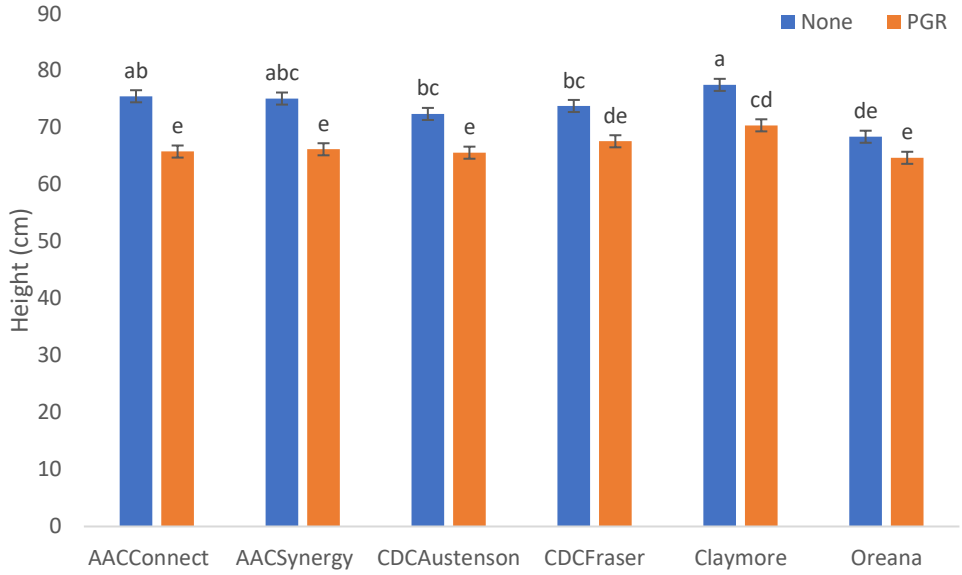

Figure 1. The interaction of variety with PGR application across all sites. Error bars indicate the standard error. Letters indicate the separation of estimated marginal means using the Tukey method.

Lodging

Lodging did not occur or did not differ between treatments at three locations, and these sites were not included in the combined analysis. When the remaining two sites were analyzed together, the effects of variety and PGR on lodging both varied by site, but there was no interaction of variety with PGR either across or within sites (Table 5), indicating that all varieties responded similarly to a PGR application. The PGR by site interaction was such that the effect of PGR on lodging was only significant at Outlook (Figure 2), but when the sites were analyzed individually, the effect of PGR was also significant at Indian Head (Table A-2). Individual site responses to the main effects of variety and PGR, and their interaction, are summarized in the appendix (Table A-2).

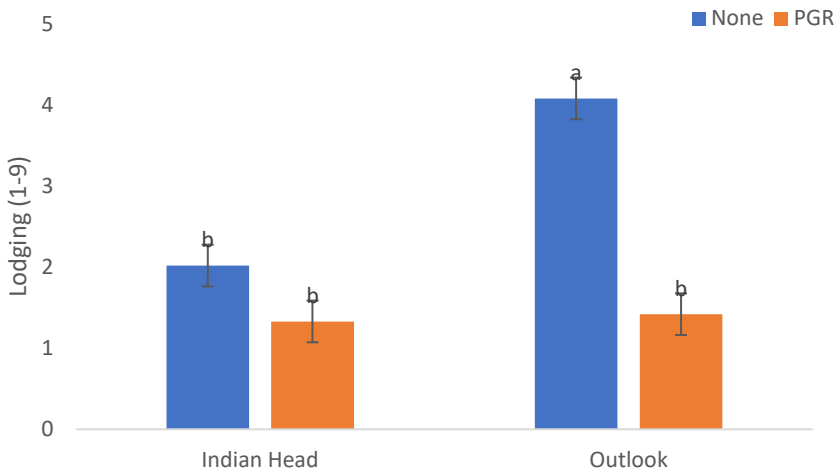

Figure 2. The effect of PGR on lodging at Indian Head and Outlook. Error bars indicate the standard error. Letters indicate the separation of estimated marginal means using the Tukey method.

Yield

The three-way interaction of variety and PGR with site was significant for yield (

12. Results

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[y]Outlook also received a total of 6.5-inches (165mm) of cumulative precipitation as irrigation

The combined multi-site analysis showed significant site interactions for height, lodging, and yield (Table 5).

Table), so the sites were analyzed individually. Responses were quite variable across sites. There was no significant difference in yield between varieties or PGR treatment at Scott, while at Indian Head, Melfort, and Prince Albert, yield differed significantly between varieties only (Table A-3). At Outlook, the variety by PGR interaction was significant, indicating that the effect of PGR on yield differed between varieties. The effect was such that a PGR application increased yield of Austenson only, while the yield of all other varieties was not affected by PGR application. Keeping in consideration the variable response across sites, we see that overall, the variety by PGR interaction was significant (**Table**), and results were the same as was seen in Outlook, where a yield increase with PGR was only significant for Austenson (Figure 3). Individual site responses to the main effects of variety and PGR, and their interaction, are summarized in the appendix (Table A-3).

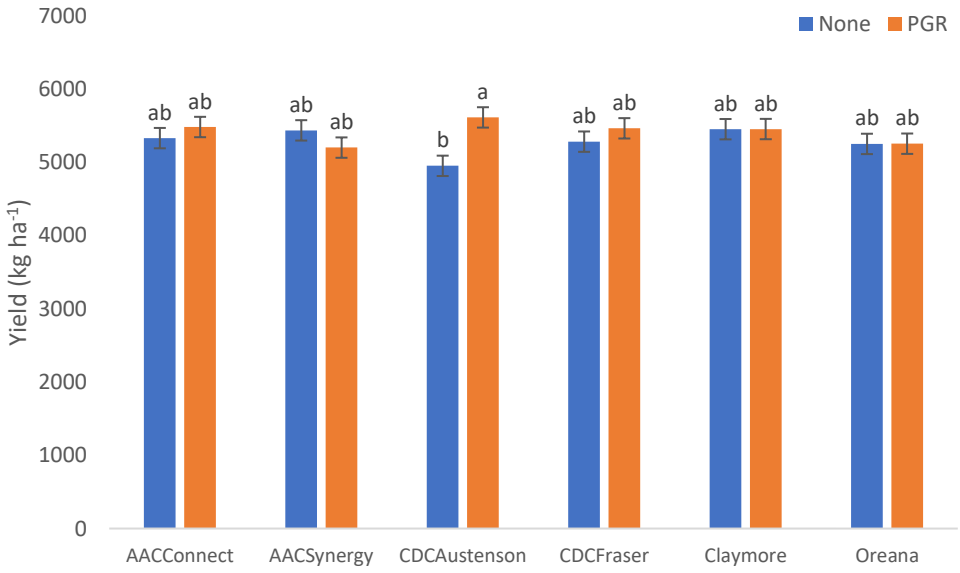

Figure 3. The interactive effect of PGR and variety on yield across all sites. Error bars indicate the standard error. Letters indicate the separation of estimated marginal means using the Tukey method.

Malt grain quality

Grain quality was assessed for malt varieties only. Overall, there were no significant variety by PGR interactions, indicating that varieties responded similarly to PGR application across locations (**Table 1**).

Table 1. F-test results of mixed-effects model analysis of grain quality of malt varieties assessing the presence of site interactions with variety and PGR. Effects are considered statistically significant if P<0.05 and significant effects are bolded for emphasis.

	Protein	Test Weight	Seed size	Plumps
Fixed effects	---------- *Pr(>F)* ----------			
Variety (V)	**0.007**	**0.013**	**<0.001**	**<0.001**
PGR (P)	0.249	**0.010**	**<0.001**	**<0.001**
Site (S)	**<0.001**	**<0.001**	**<0.001**	**<0.001**
V x P	0.719	0.303	0.962	0.206
V x S	0.486	**<0.001**	**0.029**	**<0.001**
P x S	0.413	**<0.001**	**<0.001**	**<0.001**
V x P x S	0.850	0.145	0.225	0.396

Protein

Protein varied with location and variety overall, but PGR application did not significantly affect protein, regardless of variety or location (**Table 1**). Protein level was most highly influenced by the environment, as even when sites were analyzed individually, protein only differed with variety at Indian Head, and there were no other significant effects (Table A-4).

Test weight

PGR application affected test weight equally across varieties, as there were no significant interactions between PGR and variety (**Table 1**). However, the effect of PGR and variety varied across sites. When sites were analyzed individually, PGR had a positive effect on test weight at Scott, a negative effect on test weight at Melfort and Outlook, and no effect on test weight at Indian Head and Prince Albert (Figure 4). Test weight also varied with variety at all sites but Prince Albert. There was a significant interaction of PGR with variety at Outlook only (Table A-5). At Outlook, PGR application had a negative effect on test weight for all varieties, but AAC Connect was more severely affected than the other two varieties (Figure 5).

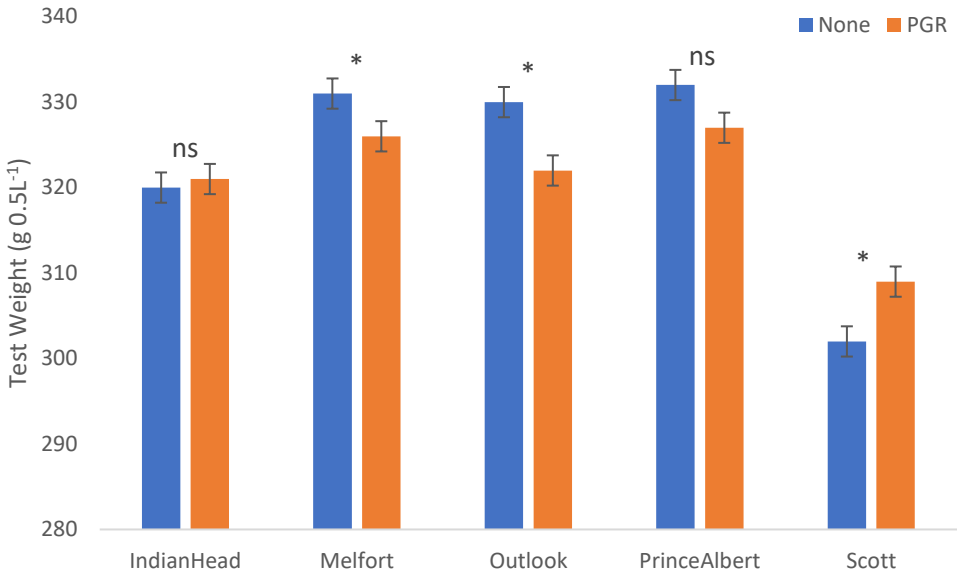

Figure 4. The effect of PGR on test weight across malt varieties at all sites. Error bars indicate the standard error of the combined analysis. Within individual sites, ns indicates a non-significant effect of PGR, and * indicates a significant effect of PGR.

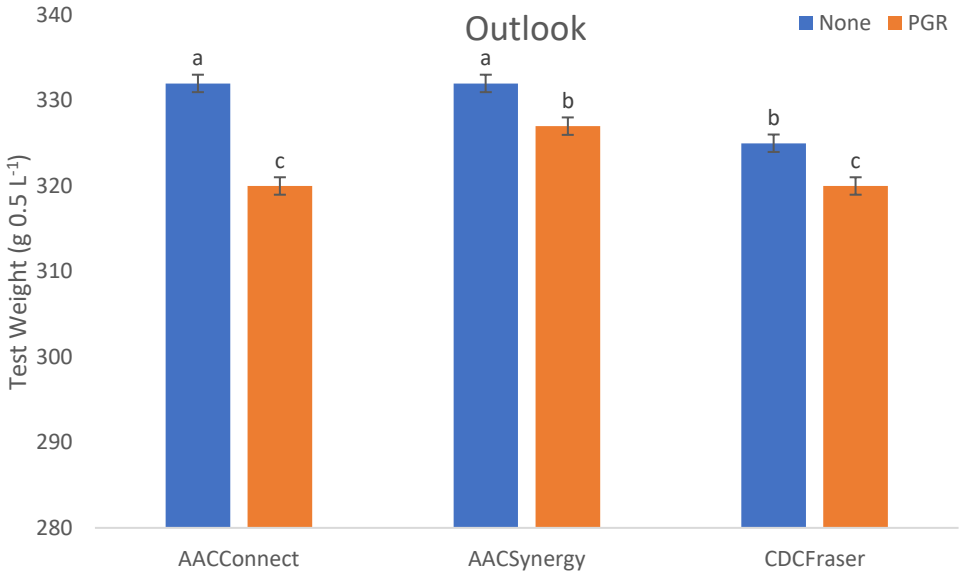

Figure 5. The effect of PGR on test weight of malt varieties at Outlook. Error bars indicate the standard error (within site). Letters indicate the separation of estimated marginal means using the Tukey method.

Seed size (TKW)

Similar to test weight, PGR application affected seed size equally across varieties, as there were no significant interactions between PGR and variety, but the effect of PGR and varieties on seed size varied across sites (**Table 1**). When sites were analyzed individually, PGR application had a negative effect on seed size and also varied with variety at Indian Head and Melfort, while at Scott, seed size varied with variety but was not affected by PGR, and at Prince Albert, seed size was not affected by variety or PGR

application (Table A-6, Figure 6). At Outlook, there was again a significant interaction of PGR with variety (Table A-6). At Outlook, PGR application had a negative effect on seed size of Synergy and Connect, but did not significantly affect the seed size of Fraser (Figure 7).

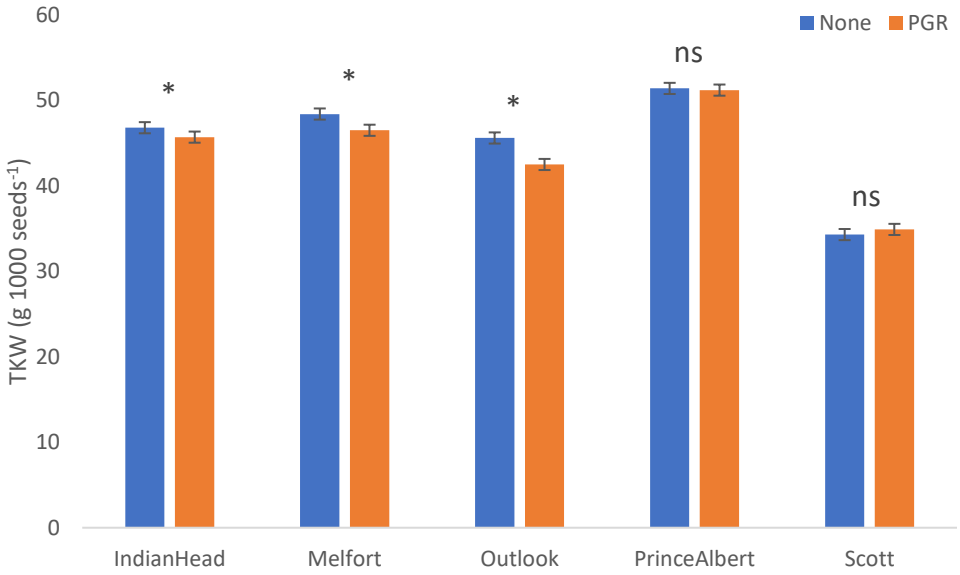

Figure 6. The effect of PGR on seed size across malt varieties at all sites. Error bars indicate the standard error of the combined analysis. Within individual sites, ns indicates a non-significant effect of PGR, and * indicates a significant effect of PGR.

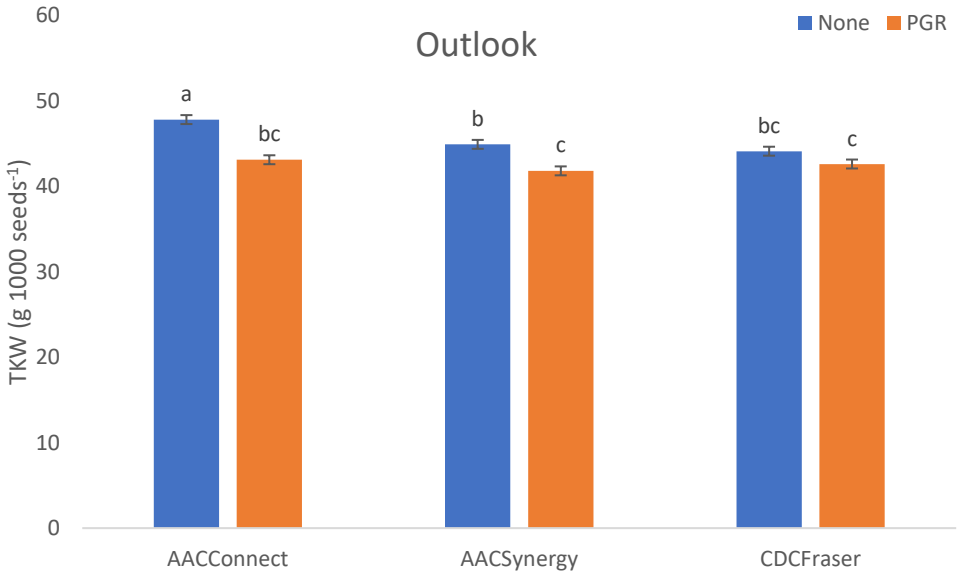

Figure 7. The effect of PGR on seed size of malt varieties at Outlook. Error bars indicate the standard error (within site). Letters indicate the separation of estimated marginal means using the Tukey method.

Percent plump kernels

Again, similar to test weight and seed size, PGR application affected percent plumps equally across varieties, as there were no significant interactions between PGR and variety, but the effect of PGR and

varieties on percent plumps varied across sites (**Table 1**). When sites were analyzed individually, percent plumps was negatively affected by PGR application and also varied with variety at Melfort, while at Indian Head and Scott, plumps varied with variety but was not affected by PGR, and at Prince Albert, plumps was not affected by variety or PGR application (Table A-7). At Outlook, there was again a significant interaction of PGR with variety (Table A-7). Similar to test weight at Outlook, PGR application had a negative effect on percent plumps for all varieties, but AAC Connect was more severely affected than the other two varieties (Figure 8).

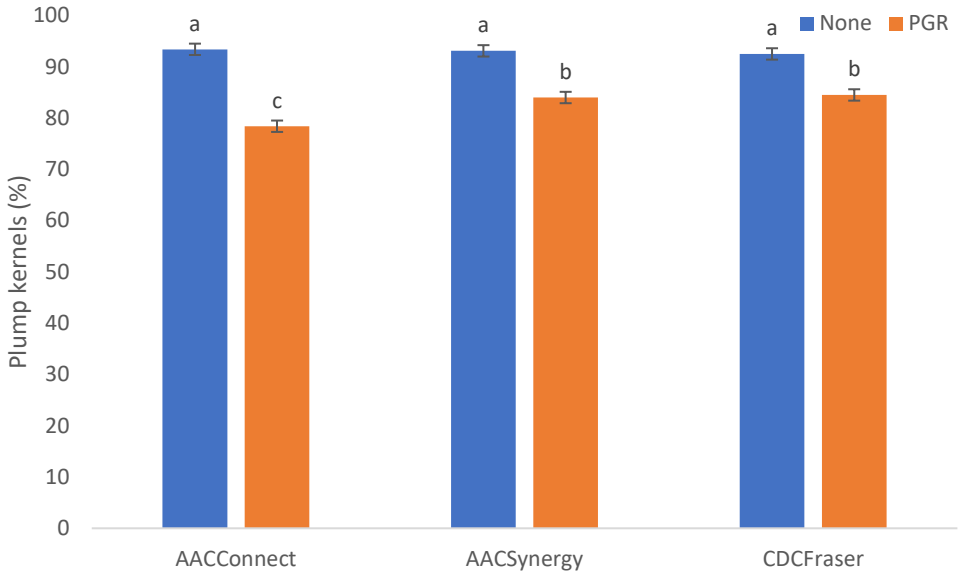

Figure 8. The effect of PGR on percent plumps of malt varieties at Outlook. Error bars indicate the standard error (within site). Letters indicate the separation of estimated marginal means using the Tukey method.

Conclusions and Recommendations

Across sites, a PGR application significantly impacted barley height, lodging, yield and quality, with some significant variety by PGR interactions, most notably for height and grain yield. Across sites a PGR application significantly reduced height for all varieties, except for Oreana. This may have been due to the fact that Oreana was significantly shorter than all other varieties without a PGR application. When PGR and site were significant for the combined analysis, lodging was only significantly reduced at Outlook when a PGR was applied; however, when sites were analyzed individually, a PGR application also significantly reduced lodging at Indian Head. The remaining sites were much drier in 2022 and did not observe lodging in any of the treatments. As for grain yield, Scott had no significant treatment differences, and Indian Head, Melfort and Prince Albert only had significant varietal differences. Outlook was the only site to have a significant variety by PGR interaction where CDC Austenson demonstrated significantly increased grain yield when a PGR was applied. For grain quality, PGR had no effect on protein, but often affected test weights, seed weight and percent plump kernels. The results across sites were often not consistent and were very dependent on location; however at most sites, a PGR application decreased average seed weights (3/5 sites), decreased average test weights (3/ 5 sites), and decreased % plump seed.

Supporting Information:

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https://keepitclean.ca/product-advisory#cereals

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13. Ackowledgements

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Chrisitiane Catellier of IHARF for statistical analysis, and to all participating sites staff for their hard work in completing this project.

14. Appendices

Table A-1. F-test results and estimated marginal means for the main effects of variety and PGR, and their interaction on height at individual sites. Means separation is indicated by letters where F-test results were significant at P<0.05. S.E. indicates the standard error.

	Indian Head	Melfort	Outlook	Prince Albert	Scott
Variety			*Height (cm)*		
AAC Synergy	72.4 ab	58.2 a	81.1 ab	72.8 bc	68.6 ab
AAC Connect	70.6 b	57.3 ab	84.2 ab	73.6 bc	67.4 ab
CDC Fraser	72.4 ab	55.8 ab	81.8 ab	76.4 ab	67.5 ab
CDC Austenson	71.4 ab	54.6 bc	83.8 ab	70.8 c	64.5 b
Claymore	74.3 a	56.7 ab	88.5 a	79.0 a	71.2 a
Oreana	67.4 c	51.7 c	77.8 b	70.8 c	65.2 b
Pr (>F)	***<0.001***	***<0.001***	***0.008***	***<0.001***	***0.002***
S.E.	*0.92*	*0.97*	*2.66*	*1.45*	*2.28*
PGR					
None	73.1 a	61.5 a	87.9	76.8 a	69.6
Yes	69.7 b	49.9 b	77.8	71.0 b	65.3
Pr (>F)	***0.017***	***<0.001***	*0.070*	***0.039***	*0.169*
S.E.	*0.73*	*0.82*	*2.76*	*1.22*	*2.38*
V x F					
AAC Synergy – None	73.9	65.8 a	87.8	76.3	71.5
AAC Connect – None	73.0	64.6 ab	91.8	77.1	70.9
CDC Fraser – None	74.6	62.5 ab	84.9	78.2	69.0
CDC Austenson – None	72.8	59.4 bc	87.6	75.0	67.2
Claymore – None	74.7	63.0 ab	95.4	80.9	73.5
Oreana – None	69.6	54.0 cd	80.1	73.2	65.2
AAC Synergy – PGR	70.9	50.6 d	74.5	69.2	65.7
AAC Connect – PGR	68.2	50.1 d	76.8	70.1	64.0
CDC Fraser – PGR	70.1	49.0 d	78.6	74.5	66.0
CDC Austenson – PGR	70.0	49.8 d	80.0	66.5	61.8
Claymore – PGR	74.0	50.4 d	81.6	77.2	69.0
Oreana – PGR	65.1	49.4 d	75.4	68.3	65.2
Pr (>F)	*0.349*	***0.001***	*0.234*	*0.695*	*0.308*
S.E.	*1.18*	*1.36*	*3.63*	*2.03*	*2.76*

Table A-2. F-test results and estimated marginal means for the main effects of variety and PGR, and their interaction on lodging at individual sites. Means separation is indicated by letters where F-test results were significant at P<0.05. S.E. indicates the standard error.

	Indian Head	Outlook
Variety	------- *Lodging (1-10)* -------	
AAC Synergy	1.69 ab	3.25 ab
AAC Connect	1.94 a	2.38 ab
CDC Fraser	1.69 ab	2.00 b
CDC Austenson	1.94 a	3.12 ab
Claymore	1.38 b	2.12 ab
Oreana	1.44 ab	3.62 a
Pr(>F)	***0.013***	***0.038***
S.E.	*0.13*	*0.47*
PGR		
None	2.02 a	4.08 a
Yes	1.33 b	1.42 b
Pr(>F)	***<0.001***	***0.008***
S.E.	*0.08*	*0.36*
Var x PGR		
AAC Synergy – None	1.88	4.50
AAC Connect – None	2.38	3.25
CDC Fraser – None	2.12	3.00
CDC Austenson – None	2.50	5.25
Claymore – None	1.62	3.00
Oreana – None	1.62	5.50
AAC Synergy – PGR	1.50	2.00
AAC Connect – PGR	1.50	1.50
CDC Fraser – PGR	1.25	1.00
CDC Austenson – PGR	1.38	1.00
Claymore – PGR	1.12	1.25
Oreana – PGR	1.25	1.75
Pr(>F)	*0.223*	*0.150*
S.E.	*0.18*	*0.64*

Table A-3. F-test results and estimated marginal means for the main effects of variety and PGR, and their interaction on yield at individual sites. Means separation is indicated by letters where F-test results were significant at P<0.05. S.E. indicates the standard error.

	Indian Head	Melfort	Outlook	Prince Albert	Scott
Variety			*Yield (kg ha^{-1})*		
AAC Synergy	7289 c	4415 ab	5202	6661 a	3071
AAC Connect	7222 cd	4451 ab	5528	6969 a	2855
CDC Fraser	7050 d	4253 ab	5523	7037 a	2996
CDC Austenson	7562 ab	4565 a	4495	6938 a	2848
Claymore	7721 a	4057 b	5531	6900 a	3050
Oreana	7373 bc	4656 a	5778	5456 b	2994
Pr(>F)	***<0.001***	***0.024***	*0.290*	***<0.001***	*0.201*
S.E.	*80.1*	*198*	*400*	*189*	*100*
PGR					
None	7310	4447	5224	6488	2945
Yes	7429	4352	5462	6832	2993
Pr(>F)	*0.092*	*0.716*	*0.469*	*0.087*	*0.749*
S.E.	*69.1*	*195*	*231*	*119*	*102*
Var x PGR					
AAC Synergy – None	7150	4516	5742 a	6792	2976
AAC Connect – None	7150	4553	5409 ab	6612	2921
CDC Fraser – None	6998	4256	5438 ab	6842	2869
CDC Austenson – None	7582	4545	3058 b	6668	2903
Claymore – None	7657	4152	5689 ab	6772	2984
Oreana – None	7322	4660	6006 a	5244	3017
AAC Synergy – PGR	7427	4315	4663 ab	6531	3166
AAC Connect – PGR	7293	4349	5647 ab	7326	2789
CDC Fraser – PGR	7103	4249	5608 ab	7231	3122
CDC Austenson – PGR	7542	4584	5932 a	7209	2794
Claymore – PGR	7784	3962	5373 ab	7028	3116
Oreana – PGR	7424	4651	5550 ab	5667	2971
Pr(>F)	*0.461*	*0.957*	***0.024***	*0.550*	*0.356*
S.E.	*96.2*	*251*	*565*	*267*	*142*

Table A-4. F-test results and estimated marginal means for the main effects of variety and PGR, and their interaction on protein of malt varieties at individual sites. Means separation is indicated by letters where F-test results were significant at P<0.05. S.E. indicates the standard error.

	Indian Head	Melfort	Outlook	Prince Albert	Scott
Variety			*Protein (%)*		
AAC Synergy	10.5 b	10.3	13.0	11.5	14.8
AAC Connect	10.8 a	10.6	13.1	11.7	15.5
CDC Fraser	10.5 b	10.5	13.1	11.2	14.9
Pr(>F)	***0.003***	*0.348*	*0.534*	*0.242*	*0.159*
S.E.	*0.12*	*0.16*	*0.18*	*0.36*	*0.48*
PGR					
None	10.5	10.2	13.0	11.5	15.1
Yes	10.7	10.7	13.1	11.4	15.0
Pr(>F)	*0.092*	*0.054*	*0.575*	*0.930*	*0.789*
S.E.	*0.11*	*0.16*	*0.17*	*0.38*	*0.47*
Var x PGR					
AAC Synergy – None	10.4	10.0	13.0	11.7	15.0
AAC Connect – None	10.7	10.4	13.1	11.7	15.3
CDC Fraser – None	10.3	10.1	13.1	11.1	15.1
AAC Synergy – PGR	10.6	10.7	13.0	11.3	14.7
AAC Connect – PGR	10.8	10.8	13.1	11.8	15.6
CDC Fraser – PGR	10.6	10.8	13.2	11.2	14.8
Pr(>F)	*0.359*	*0.574*	*0.894*	*0.703*	*0.545*
S.E.	*0.13*	*0.22*	*0.21*	*0.47*	*0.53*

Table A-5. F-test results and estimated marginal means for the main effects of variety and PGR, and their interaction on test weight of malt varieties at individual sites. Means separation is indicated by letters where F-test results were significant at P<0.05. S.E. indicates the standard error.

	Indian Head	Melfort	Outlook	Prince Albert	Scott
Variety	---------- *Test Weight (g 0.5L^{-1})* ----------				
AAC Synergy	325 a	331 a	329 a	330	301 b
AAC Connect	319 b	330 a	326 b	331	302 b
CDC Fraser	317 c	325 b	323 c	328	313 a
Pr(>F)	***<0.001***	***<0.001***	***<0.001***	*0.596*	***<0.001***
S.E.	*1.22*	*0.68*	*0.77*	*2.25*	*3.30*
PGR					
None	320	331 a	330 a	332	302 b
Yes	321	326 b	322 b	327	309 a
Pr(>F)	*0.204*	***0.001***	***<0.001***	*0.102*	***0.001***
S.E.	*1.23*	*0.60*	*0.67*	*1.84*	*3.19*
Var x PGR					
AAC Synergy – None	324	333	332 a	333	296
AAC Connect – None	319	333	332 a	331	301
CDC Fraser – None	317	328	325 b	331	308
AAC Synergy – PGR	326	329	327 b	327	307
AAC Connect – PGR	320	326	320 c	331	303
CDC Fraser – PGR	317	323	320 c	325	317
Pr(>F)	*0.381*	*0.331*	***0.002***	*0.543*	*0.141*
S.E.	*1.33*	*1.02*	*1.02*	*3.18*	*3.60*

Table A-6. F-test results and estimated marginal means for the main effects of variety and PGR, and their interaction on seed size of malt varieties at individual sites. Means separation is indicated by letters where F-test results were significant at P<0.05. S.E. indicates the standard error.

	Indian Head	Melfort	Outlook	Prince Albert	Scott
Variety	---------- *TKW (g 1000 seeds^{-1})* ----------				
AAC Synergy	46.2 a	47.0 ab	43.3 b	50.8	33.3 b
AAC Connect	46.8 a	48.4 a	45.5 a	52.1	34.8 ab
CDC Fraser	45.5 b	46.9 b	43.3 b	51.1	35.6 a
Pr(>F)	***<0.001***	***0.049***	***0.001***	*0.253*	***0.029***
S.E.	*0.21*	*0.57*	*0.37*	*0.55*	*1.29*
PGR					
None	46.8 a	48.4 a	45.6 a	51.4	34.3
Yes	45.7 b	46.5 b	42.5 b	51.2	34.9
Pr(>F)	***<0.001***	***0.049***	***<0.001***	*0.718*	*0.371*
S.E.	*0.19*	*0.52*	*0.30*	*0.45*	*1.25*
Var x PGR					
AAC Synergy – None	46.8	47.8	44.9 b	51.0	33.1
AAC Connect – None	47.6	49.0	47.8 a	51.6	34.6
CDC Fraser – None	45.9	48.3	44.1 bc	51.7	35.2
AAC Synergy – PGR	45.7	46.1	41.8 c	50.6	33.5
AAC Connect – PGR	46.1	47.8	43.1 bc	52.5	35.0
CDC Fraser – PGR	45.2	45.5	42.6 c	50.5	36.0
Pr(>F)	*0.306*	*0.429*	***0.022***	*0.426*	*0.967*
S.E.	*0.27*	*0.69*	*0.52*	*0.77*	*1.40*

Table A-7. F-test results and estimated marginal means for the main effects of variety and PGR, and their interaction on percent plump kernels of malt varieties at individual sites. Means separation is indicated by letters where F-test results were significant at P<0.05. S.E. indicates the standard error.

	Indian Head	Melfort	Outlook	Prince Albert	Scott
Variety			*Plumps (%)*		
AAC Synergy	98.0 a	96.7 a	88.5 b	97.0	66.7 b
AAC Connect	96.8 b	96.6 a	85.9 a	96.2	53.4 c
CDC Fraser	97.4 ab	95.3 b	88.5 b	97.5	76.2 a
Pr(>F)	***0.001***	***0.025***	***0.034***	*0.099*	***<0.001***
S.E.	*0.19*	*0.58*	*0.83*	*0.41*	*4.93*
PGR					
None	97.4	97.7 a	93.0 a	97.3	65.0
Yes	97.4	94.7 b	82.3 b	96.5	65.9
Pr(>F)	*0.952*	***0.024***	***<0.001***	*0.106*	*0.779*
S.E.	*0.16*	*0.61*	*0.72*	*0.34*	*4.69*
Var x PGR					
AAC Synergy – None	98.1	98.1	93.1 a	97.5	64.7
AAC Connect – None	96.8	98.0	93.4 a	96.1	55.7
CDC Fraser – None	97.3	97.1	92.5 a	98.3	74.6
AAC Synergy – PGR	97.9	95.3	84.0 b	96.5	68.6
AAC Connect – PGR	96.9	95.2	78.4 c	96.3	51.2
CDC Fraser – PGR	97.4	93.6	84.5 b	96.7	77.8
Pr(>F)	*0.785*	*0.673*	***0.009***	*0.309*	*0.471*
S.E.	*0.27*	*0.78*	*1.11*	*0.58*	*5.58*

Abstract

15. Abstract/Summary

To demonstrate the responsiveness of barley to plant growth regulators (PGRs), small-plot demonstrations were conducted at Melfort, Indian Head, Prince Albert, Outlook and Scott, SK in 2022. The treatments were arranged in a split-plot design, where PGR was the main-plot and barley variety was the sub-plot. Within barley varieties, 3 malt varieties (AAC Synergy, CDC Fraser and AAC Connect) and 3 feed varieties (CDC Austenson, Oreana and Claymore) were used. The PGR used in the demonstration was Moddus (trinexepac-ethyl) applied at GS 30-32 (early stem elongation) at a rate of 0.42L/ac. Nitrogen was applied based on yield potential of the site where Melfort and Outlook were considered high yield potential and applied 146 kg of N/ha (soil + applied) and Prince Albert, Indian Head, and Scott were considered mid-range yield potential and applied 135 kg N/ha (soil + applied). Data collection in the demonstration consisted of plant density, height, lodging, grain yield, protein, test weight, seed weight and percent plumps. Plant density was significantly affected by variety at two sites, whereas AAC Synergy and Claymore had higher plant densities as compared to AAC Connect at both sites and CDC Fraser at one site. Height was significantly reduced for all varieties across all sites with the application of a PGR, except for the variety Oreana. This may have been due to the fact that Oreana was significantly shorter than all other varieties without a PGR application. Lodging only occurred at Outlook and Indian Head, where lodging was significantly reduced with a PGR application across varieties when sites were analyzed individually. Grain yield was significantly different between varieties at Melfort, Indian Head and Prince Albert, but was significantly increased for CDC Austenson when a PGR was applied at Outlook and when sites were combined. Lastly, when PGR was significant for grain quality, protein was not affected, but test weights, seed weights, and % plumps often declined, but responses varied depending on location.