Oats seeding rate funders report- 2025

Project title: Different oat varieties, PGRs, seeding rates and their interactions on lodging and shattering.

Non-technical summary

This study explored how plant growth regulators (PGRs) and seeding rates interact to influence oat performance across varying environments in Western Canada. This report presents preliminary findings based on field trials conducted over two growing seasons, supported by a controlled greenhouse study to better understand crop responses under drought conditions.

Results indicate that environmental conditions, particularly moisture before and after PGR application, are the primary drivers of crop response. Field data indicate that under dry conditions before application (<10 mm rainfall in the 10 days before application), both CCC and TE applied at BBCH 31/32 effectively reduced plant height, with TE generally showing greater efficacy. Under moist pre-application conditions, early application was less effective, whereas TE applied at BBCH 37 resulted in greater and more consistent height reduction, independent of prior moisture conditions. In addition, later application (BBCH 37), particularly with TE, was associated with improved yield performance compared with earlier application timing and CCC application.

Increasing the seeding rate generally had limited benefits. While it increased plant density, it often reduced the number of productive tillers, probably due to competition between plants and did not consistently improve yield. This suggests that using recommended seeding rates is more effective than increasing plant density.

The study also found no interaction between PGRs and seeding rates, implying their effects were largely independent. Overall, environmental conditions were the most important factor affecting growth, with PGR effects depending on timing, variety, and environmental conditions.

Background

Lodging, environmental stress, and crop management practices are major constraints to oat production in the Canadian Prairies, where yield and standability are strongly influenced by interactions among variety, seeding rate, nitrogen management, and weather conditions (Wu and Ma 2016; Mangin et al. 2022; Wu et al. 2022; Studhalter et al. 2023). Although breeding has produced cultivars with improved lodging resistance, lodging remains a complex trait affected by crop architecture and environment, particularly under high fertility or dense stands (Nakhforoosh et al. 2020; Alexander et al. 2025). Plant growth regulators (PGRs), such as trinexapac-ethyl (TE) and chlormequat chloride (CCC), reduce stem elongation by inhibiting gibberellin biosynthesis and have been used to improve standability and harvestability in cereals (Rademacher 2000, 2016; Wiersma et al. 2011; Leśniowska-Nowak et al. 2017; Castro-Camba et al. 2022). However, most prairie research on PGRs has focused on wheat and barley, leaving limited oat-specific information on varietal responses, optimal application timing, or interactions with agronomic practices such as seeding rates. Environmental stresses, particularly drought and heat, further complicate management decisions by reducing plant growth, biomass, and yield potential (Zhao et al. 2021; Neupane et al. 2025), and drought frequency and severity in the Prairies are expected to increase with climate variability (Bonsal et al. 2020; Mapfumo et al. 2023; Mardian et al. 2024). Despite evidence that PGRs can be effective at both early and later growth stages (Rajala and Peltonen-Sainio 2002; Wiersma et al. 2011), their performance under varying moisture conditions and seeding densities remains poorly quantified. Therefore, integrated evaluation of PGR × variety × seeding rate × environment interactions is needed to identify management strategies that reduce lodging, optimize agronomic performance, and improve oat production stability in prairie systems.

Objectives:

1) To identify the PGR-oat variety pairs that lead to significant plant height reduction and subsequent lodging under different environments.
2) To assess the effects of two PGRs (TE and CCC) on other agronomic parameters in different oat varieties.
3) To assess the effects of increased seeding rate on agronomic parameters in different oat varieties.
4) To evaluate the interaction of PGRs with seeding rates on agronomic parameters and shattering in different oat varieties
5) To evaluate the effects of plant growth regulators on oat agronomic parameters under drought conditions
6) To carry out a morphological assessment of palea and lemma in different oat varieties and relate these structures to shattering under normal and drought conditions.

Research design and methodology

Field Experiments: Research objectives 1−4

Field trials were conducted at four western Canadian sites, including St. Albert Research Station (2024–2025), The Breton Plots, University of Alberta-Breton (2025), Gateway Research Organization Westlock, Alberta (2024–2025), and Codette, Saskatchewan (2024–2025), representing seven site-years.

Treatments consisted of four oat varieties with contrasting plant architecture: AC Morgan and CDC Arborg (tall varieties), and CS Camden and Summit (short varieties); two seeding rates, 300 plants m^{-2} (recommended) and 400 plants m^{-2} (increased); and three PGR treatments, CCC, TE, and a no PGR control. The experiment was arranged in a split-spilt plot with PGR treatments assigned to main plots, seeding rates to subplots, and varieties randomized within sub-subplots with four replications. Each site consisted of 96 plots, with individual plot sizes of at least 2 m × 7 m. Plant growth regulators were applied at BBCH growth stages 31/32 following recommended guidelines. A separate trial was conducted to evaluate PGR application at a later (BBCH 37) timing. In this add-on trial, AC Morgan was seeded at 300 plants $m^{-2,}$ and only CCC was applied. Nutrient applications (NPKS) were based on site-specific soil tests and target yield goals.

Data collected included plant density (2–3 weeks after seeding), plant height at flowering, days to flowering and maturity, and number of productive tillers. Lodging was assessed on a 0–9 scale. At maturity, grain yield (adjusted to 13.5% moisture), thousand kernel weight (TKW), test weight (TW), and grain protein concentration were measured. Shattering was assessed at harvest using a 0–100% scale.

Greenhouse Experiment: Research Objective 5

A controlled greenhouse experiment was conducted at the University of Alberta Plant Growth Facility from August 2024 to May 2025. Field soil classified as Black Chernozem was collected, sieved to remove debris, and mixed with sand at 1:2 (v/v) ratio. Soil fertility was adjusted to achieve a target oat yield of 8070 kg ha^{-1}. The experiment followed a factorial design with 30 treatments and 10 replications, conducted over two experimental cycles. Treatments consisted of two oat varieties (AC Morgan and CS Camden), three watering regimes, and five PGR treatments. Watering regimes were designed to simulate optimal and drought conditions: i) 80% field capacity (FC); ii) 80−40% FC: seeding occurred at 80% FC, soil allowed to dry down to 40% FC and maintained at this level until harvest (modelled drought of 2021); and iii) 50−40% FC: seeding occurred at 50% FC and trial maintained at 40% FC until harvest (modelled drought of 1988). Plant growth regulator treatments included TE and CCC applied at BBCH 31/32 & 37, and an untreated control. Measurements included plant injury (assessed visually following PGR application for 15 d), SPAD readings, stem diameter, plant height, tiller number, days to flowering and maturity, above-ground biomass, seed yield, and harvest index.

Statistical Analysis

Data were assessed for normality using Q-Q plots, histograms, and the Shapiro–Wilk test before analysis. All analyses were conducted using linear mixed-effects models. To address objective 1, plant height and lodging data were analyzed to evaluate the effect of PGRs, variety, and their interactions across environments. Site-year, PGR, variety, and their interactions were treated as fixed effects, while replication nested within site-year was included as random effects. For objective 2, the effects of PGR treatments (CCC and TE) on agronomic parameters (including yield, TKW, and TW) were analyzed within each variety. Site-year, PGR, variety, and their interactions were treated as fixed factors, with replication as a random effect. To address objective 3, the effect of seeding rate on agronomic parameters was evaluated within each variety using site-year, seeding rate, variety as fixed effects and replication as a random effect. For objective 4, interactions between PGR and seeding rates on agronomic traits and shattering were analyzed with site-year, PGR, seeding rate, variety and their interactions as fixed effects, with replication as a random effect. To address objective 5, greenhouse data were analyzed using a linear mixed-effect model with variety, watering regime, PGR treatment, and their interactions as fixed effects, and replication nested within experiment cycle as a random effect. Where significant effects were detected, treatment means were separated using Tukey's Honest Significant Difference (HSD) test at $\alpha = 0.05$. All statistical analyses were performed in RStudio (Version 4.1.1), and figures were generated using RStudio (Version 4.1.1) and OriginLab 2025.

Results and discussions

Characterization of sites

Site conditions were characterized based on the rainfall received 10 days before and 7 days after PGR application. Dry conditions were defined by low pre-application rainfall (<15 mm), while moist conditions were defined by >15 mm of precipitation.

For the BBCH 31/32 PGR application stage, dry pre-application conditions were observed at Westlock-2024 (6.8 mm); Westlock-2025 (4.0 mm), Codette-2025 (3.7 mm) and St. Albert-2024 (8.6 mm); St. Albtert-2025 (3.8 mm) (Table 1). In contrast, moist conditions were recorded in the Breton-2025 (16 mm), and Codette-2024 (62.9 mm) (Table 1).

Dry post-application conditions were observed at Codette-2025 (13.0 mm), St. Albert-2024 (8.4 mm), and Breton-2025 (5.2 mm), whereas moist conditions occurred at Westlock-2024 (15.2 mm), Westlock-2025 (84.0 mm), St. Albert-2025 (59.4 mm), and Codette-2024 (38.6 mm) (Table 1).

For the BBCH 37 application timing, dry pre-application conditions were observed at St. Albert-2024 (7.8 mm), whereas moist conditions were recorded in Codette-2024 (54.4 mm), Breton-2025 (17.2 mm), and St. Albert-2025 (17.8 mm) (Table 2).

Dry post-application conditions were observed at St. Albert-2024 (0.0 mm), St. Albert-2025 (8.0 mm), whereas moist conditions occurred at Breton-2025 (21.1 mm) and Codette-2024 (18.0 mm) (Table 1).

PGR × variety effects on plant height as affected by environmental conditions [Objective 1]

In sites with dry pre-application conditions, both CCC and TE significantly reduced plant height; although TE tended to have a greater effect, the difference between PGRs was not significant (Fig. 1). In contrast, no significant reduction in plant height was observed under moist pre-application conditions. Oat varietal responses differed, with AC Morgan showing a strong and significant reduction (12% relative to control) in plant height and CDC Arborg the least response (7%) to TE application. No lodging incidence was observed at any of the sites assessed.

For the BBCH 37 application timing, regardless of pre-PGR application moisture conditions (i.e. moist or dry), both CCC and TE significantly reduced plant height compared to the no-PGR control, with no significant differences between PGRs (Fig. 2).

At Codette-2024 and Breton-2025, the application of both CCC and TE at BBCH 37 tended to result in greater plant height reduction than at BBCH 31/32 (Fig. 2). These two sites experienced moist conditions pre-PGR application at both BBCH 31/32 and BBCH 37 (Table 1, 2). In contrast, under dry pre-PGR application conditions (St. Albert-2024), application at BBCH 31/32 resulted in a greater and significant reduction in plant height than at BBCH 37. Greater plant height reduction occurred at BBCH 37 under moist conditions for both PGRs, whereas under dry conditions, earlier application (BBCH 31/32) was more effective. This indicates that PGR efficacy depends on plant physiological status and moisture availability at the time of application. Overall, these results show that PGR application in oats should be guided by pre-application soil moisture conditions. Under dry conditions (<10 mm rainfall 10 d before application), PGRs (CCC or TE) can be applied at BBCH 31/32 to effectively reduce plant height, with TE tending to be more effective. However, under moist conditions, early application may be less effective, and application of either CCC or TE at BBCH 37 is recommended to achieve greater height reduction.

PGR × variety effects on other agronomic parameters as affected by environmental conditions [Objective 2]

Application of TE significantly increased the number of productive tillers per plant in AC Summit and CDC Arborg at St. Albert-2024 (Fig. 3). Although St. Albert experienced dry pre- and post application conditions, similar conditions in Codette-2025 did not result in increased productive tiller numbers, indicating that the response may be site-specific and likely influenced by other environmental or management factors. Test weight of CDC Arborg was significantly reduced with TE application at Codette-2025 (Fig. 4). These results indicate that the PGR effect on TKW was generally minimal.

The effect of PGRs on oat yield varied across site-years and varieties and was influenced by post-application moisture conditions. At Codette-2025, CCC reduced CS Camden and CDC Arborg yields (Fig. 5). Similarly, at St. Albert-2024, CCC reduced the yields of all the oat varieties grown, while TE reduced AC Summit and CS Camden yields. However, CCC tended to have a greater negative effect than TE at this site. Both Codette-2025 and St. Albert-2024 sites were characterized by dry pre- and post application conditions (Table 1), indicating that limited soil moisture conditions may have exacerbated crop stress and increased susceptibility to PGR-induced injury, particularly with CCC. In a separate study, CCC was associated with greater crop injury in oats than TE (*Supplementary data Figure S17*). In contrast, at Breton-2025, both CCC and TE increased the yields of all oat varieties, with significantly increased yields observed in AC Summit and CS Camden. Although dry conditions were experienced following PGR application at this site, yield was not adversely affected, likely due to adequate moisture conditions before application. These results indicate that yield responses to PGR application are strongly influenced by moisture conditions surrounding application time. The mechanism responsible for the yield increase under favourable soil moisture conditions needs to be clarified in future studies.

The TKW responses to PGR application varied across site-years and varieties, with reductions mainly observed under dry post-PGR application conditions (Fig. 6). At St. Albert-2024, CCC reduced TKW in AC Summit, CS Camden, and CDC Arborg, while TE also reduced TKW in CS Camden. Similarly, at Breton-2025, CCC reduced TKW in AC Summit, CS Camden, and AC Morgan, with a significant reduction observed in AC Morgan. At Codette-2024, both CCC and TE significantly reduced TKW in CS Camden, even though this site experienced moist post-PGR application conditions (Fig. 6). Across site-years, CS Camden consistently exhibited reductions in TKW with both PGRs, indicating greater sensitivity to PGR application for this trait compared to the other oat varieties assessed. The observed declines in TKW under dry conditions suggest that limited post-application moisture may have constrained grain filling, thereby exacerbate PGR-induced stress and reduce assimilate availability to developing kernels.

Application of PGR at a later timing (BBCH 37) resulted in significantly higher yield than at BBCH 31/32 at Codette-2024, where moist soil conditions prevailed before and after PGR application at both growth stages (*Supplementary data Figures S6-S9*). Similarly, under comparable moisture conditions at Breton-2025, TE application resulted in higher yield for AC Morgan. A significant reduction in TKW was observed with PGR application at BBCH 37 compared to BBCH 31/32. These results indicate that under adequate soil moisture conditions, later PGR application (BBCH 37) and the use of TE may enhance yield performance relative to earlier application timing and CCC application.

Agronomic responses of oat varieties to increased seeding rate [Objective 3]

Regardless of variety, increasing seeding rates resulted in a significant increase in plant density at all sites (Fig. 7). Overall, the highest plant densities were observed at Codette-2025, while the lowest were recorded at Westlock-2024. At the recommended seeding rate (300 plants m^{-2}), varietal differences were not explicit, except at Codette-2024 and Codette-2025, where CS Camden and CDC Arborg had higher plant densities compared to the other varieties, respectively. These results indicate that plant density is mainly influenced by seeding rate and environmental conditions, while varietal differences in establishment are generally small and clear under specific site conditions.

Overall, the number of productive tillers per plant was highest at St. Albert-2024, and the lowest at Westlock-2024 (Fig. 8). The effect of increasing seeding rate on productive tiller number varied across sites. AC Morgan maintained its number of productive tillers per plant (1−1.5) at increased compared to the recommended seeding rates in five out of the seven site-years, with significant reduction at the other two site-years (Fig. 8). In contrast, the other oat varieties showed reductions in productive tiller numbers in most environments. The reduction in productive tillers at higher seeding rates likely reflects increased intraspecific competition among plants. Overall, these results indicate that the number of productive tillers is influenced by environmental conditions, with AC Morgan showing greater stability across sites compared with other oat varieties.

Test weight, grain yield, and TKW were primarily influenced by environment (*Supplementary data Figures S10-S12*). Test weight was highest at Westlock-2025 and the lowest at St. Albert-2024, with minimal response to increasing seeding rate, except for a slight increase in CDC Arborg at Codette-2025. Across most site-years, AC Summit consistently exhibited higher TKW than other oat varieties. Grain yield exceeded 8,000 kg ha^{-1} at St. Albert-2025, Breton-2025, and Codette-2025, whereas yields at other sites were substantially lower. Overall, yield was unresponsive to increased seeding rate, except for AC Morgan at Breton-2025. Similarly, TKW was highest at Westlock-2025 and lowest at St. Albert-2024, with limited response to seeding rate; however, CDC Arborg and AC Morgan showed slight reductions in TKW at higher seeding rates.

Overall, these results indicate that environmental conditions are the primary drivers of oat establishment, tillering, and yield, while increasing seeding rate beyond the recommended rate provides limited agronomic benefit and may reduce productive tillering due to increased intraspecific competition. Varietal differences were generally small and site-specific, although AC Morgan showed greater stability in tillering and AC Summit consistently achieved higher test weight. Therefore, optimizing seeding rate within recommended ranges, rather than increasing it, is a more effective management strategy under the conditions of this study.

PGR × seeding rate effects on oat agronomic traits and shattering [Objective 4]

Analysis of variance (ANOVA) revealed the interaction effect of PGR × seeding rate was not significant on any of the agronomic traits measured (*Supplementary data Table S5*), indicating that the effects of PGR application were consistent across seeding rates. Therefore, agronomic responses observed under objective 3 were generally consistent in this section; however, a few notable yield responses are highlighted below.

No shattering was observed in any of the oat varieties across all environments and treatment combinations. However, yield responses to PGRs at different seeding rates varied among site-years when interpreted in the context of moisture conditions before and after PGR application. At St. Albert-2024, characterized by wet conditions both before and after PGR application (Table 1), yield reductions were observed in CS Camden at higher seeding rates following both CCC and TE application (Fig. 9). In contrast, at Codette-2025, where conditions were dry before- and moist following PGR application, CCC application increased AC Summit yields, meanwhile AC Morgan had reduced yields with TE application. At Breton-2025, which experienced moist conditions before and dry conditions following PGR application, CCC reduced yields at higher seeding rates in AC Summit and CS Camden but increased AC Morgan yields, while TE increased AC Summit yields. These results indicated that for CS Camden and AC Summit, yield reductions were more likely at higher seeding rates when moisture stress occurred post PGR application, irrespective of pre-application conditions. In contrast, under moist post-application conditions, AC Summit showed potential for yield increases following PGR application. For AC Morgan, pre-application moisture conditions appeared to be critical in determining yield responses. Dry conditions before application were associated with yield reductions at higher seeding rates following PGR application, even when moisture improved afterward, whereas moist pre-application conditions resulted in yield increases at higher seeding rates, despite drier conditions post application.

Overall, decisions on PGR application and increasing seeding rates should incorporate short-term moisture conditions before and after application to optimize yield outcomes. The greatest risk occurs at high seeding rates under post-application drought, whereas the greatest benefit is achieved when adequate moisture supports crop recovery. Variety-specific responses should also be considered when selecting management strategies. (*Supplementary Data Figures S13-S16 for other agronomic parameters*)

Plant growth regulator effects on oat agronomic traits under drought conditions (Obj 5).

Under controlled greenhouse conditions, the interaction of oat variety, watering regime, and PGR timing significantly affected plant height and stem diameter (< 0.01; Supplementary data Table S6). Without PGRs application, AC Morgan was consistently taller and had thicker stems than CS Camden across moisture regimes. Under fully watered conditions, later CCC application (BBCH 37) significantly reduced the height of AC Morgan and CS Camden, while stem diameter responses were genotype-dependent: PGR treatments reduced stem thickness in AC Morgan except TE (BBCH 31/32), whereas CS Camden stem diameter remained mostly unchanged (Fig. 10A-B).

Drought amplified PGR effects: under 80–40% field capacity, i.e., modelled drought of 2021, all PGRs reduced the height in both oat varieties, with CCC (37) and TE (31/32) increasing the stem diameter of AC Morgan, while that of CS Camden was unaffected. Under 50–40% field capacity, i.e., modeled 1988 drought, further height reductions were observed but were less pronounced. Stem diameter responses differed between the two oat varieties. In CS Camden, TE (31/32, 37) increased stem diameter, whereas CCC (31/32) was only effective. In contrast, no significant effects of PGRs treatment on stem diameter were observed in AC Morgan. This result indicates that genetic background and stress intensity may modify PGR outcomes in oats.

Days to flowering showed a significant variety × watering regime × PGR timing interaction ($P < 0.001$). Under fully watered conditions, PGRs delayed flowering in CS Camden, but AC Morgan was unaffected. In contrast, the 80–40% field capacity drought conditions accelerated flowering in both varieties (Fig. 10C). Days to maturity were largely unaffected except for AC Morgan under fully watered conditions with CCC (37) application, where delayed maturity was observed (Fig. 10D).

Tillering, biomass, yield, and harvest index were primarily determined by variety and drought. PGR treatments had minimal effects on tiller number, productive tillers, biomass, or seed yield per plant (Fig. 11A-C), although CCC and TE, particularly at specific timings, slightly increased stem diameter under stress, potentially enhancing lodging resistance. Overall, drought was the dominant factor influencing performance, while PGR effects were conditional on oat varieties, timing, and environmental conditions. (Details in manuscript)

Preliminary conclusion

Across both field and greenhouse studies, environmental conditions and oat varietal differences were the primary factors influencing oat performance, while the effects of PGRs and seeding rate were generally limited and inconsistent. In the field, PGR (CCC and TE) effectively reduced plant height, with responses varying by variety, PGR application timing, and moisture conditions around application timing. The most consistent reductions were observed at BBCH 37, particularly in AC Morgan, indicating greater potential for lodging management at later application stages. However, PGRs had minimal impact on key agronomic traits such as yield, test weight, and TKW, suggesting that their role is primarily structural rather than productivity-enhancing.

Varietal differences played a dominant role in determining agronomic performance, with CDC Arborg and AC Morgan consistently producing higher yields, while AC Summit showed superior test weight. Increased seeding rates reduced productive tillers across most oat varieties and did not improve yield or grain quality, indicating that higher seeding rates are not economically beneficial under the conditions of this study. Similarly, the interaction between PGRs and seeding rate did not result in additional agronomic advantages.

Greenhouse results further demonstrated that PGR responses are strongly influenced by oat varieties, application timing, and moisture conditions, with drought acting as the dominant stress factor that leads to further height reduction. While PGRs influenced plant height and stem characteristics under controlled conditions, their effects on yield-related traits remained minimal.

Overall, these findings suggest that variety selection and environmental conditions are the key drivers of oat performance. PGRs should be used strategically for lodging control rather than yield improvement. Application of TE at BBCH 37 is recommended, particularly for taller and lodging-prone varieties such as AC Morgan. Increasing seeding rates beyond the recommended rates is not advisable, as it does not improve yield/quality and may reduce tillering efficiency.

Benefits to the Industry

The findings of this study offer practical benefits to the oat production industry by providing strategies to reduce lodging and improve crop stability. Lodging not only decreases harvest efficiency but can also cause significant yield losses. By identifying effective PGR treatments, optimal seeding rates, and suitable variety choices, growers can produce more uniform, sturdier crops that are easier to manage and harvest. These improvements in crop structure reduce the risk of mechanical damage during harvest and ensure higher quality grain, which is particularly important for processing industries such as oat milling and food production. Additionally, the ability to tailor PGR use to specific oat varieties and environmental conditions allows producers to adopt precise management approaches, making oat cultivation more resilient under both well-watered and drought-prone conditions.

Economic Impact

Economically, implementing these strategies can enhance profitability for farmers and the broader industry. Reduced lodging and improved crop uniformity translate directly into higher marketable yields and lower losses, while optimized PGR application and seeding rates can lower input costs by minimizing unnecessary input application. Over time, these practices can increase the return on investment per hectare, particularly in regions prone to variable rainfall or extreme weather. Furthermore, improved grain quality and yield stability strengthen the competitiveness of domestic oats in both local and export markets, supporting long-term industry growth and sustainability. By integrating these findings, the oat sector can achieve more efficient, productive, and economically viable production systems.

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List of Tables and Figures

Table 1. Site characterization of pre- and post-PGR application environmental conditions at growth stage BBCH31-32

Site Year	PGR Application date	10 d pre-PGR Rainfall (mm)	10 d pre-PGR Max Temp ^{O}C	7 d post-PGR Rainfall (mm)	7 d post-PGR Max Temp ^{O}C
Westlock2024	June, 25	6.8	19	15.2	22
Westlock2025	June, 10	4.0	20	84.0	19
Codette2025	June, 11	0.2	22	13.0	22
St. Albert2024	June, 24	8.6	20	8.4	21
St. Albert2025	June 10	3.8	22	59.4	20
Breton2025	June, 2	16.5	24	5.2	22
Codette2024	June, 18	62.9	19	38.6	22

Sites receiving <15 mm of rainfall before or after PGR application were classified as dry, whereas those receiving >15 mm were classified as wet.

Table 2. Site characterization of pre- and post-PGR application environmental conditions at growth stage BBCH 37

Site Year	PGR Application date	10 d pre-PGR Rainfall (mm)	10 d pre-PGR Max Temp ^{O}C	7 d post-PGR Rainfall (mm)	7 d post-PGR Max Temp ^{O}C
Codette2024[a]	June, 25	54.4	20.6	18.0	22.7
St. Albert2024[b]	July, 5	7.8	21.7	0.0	28.9
Breton2025[a]	June, 30	17.2	22.0	21.1	22.4
St. Albert2025[a]	June, 26	17.8	20.0	8.0	24.4

Sites receiving <15 mm of rainfall before or after PGR application were classified as dry, whereas those receiving >15 mm were classified as wet.

Field study figures:

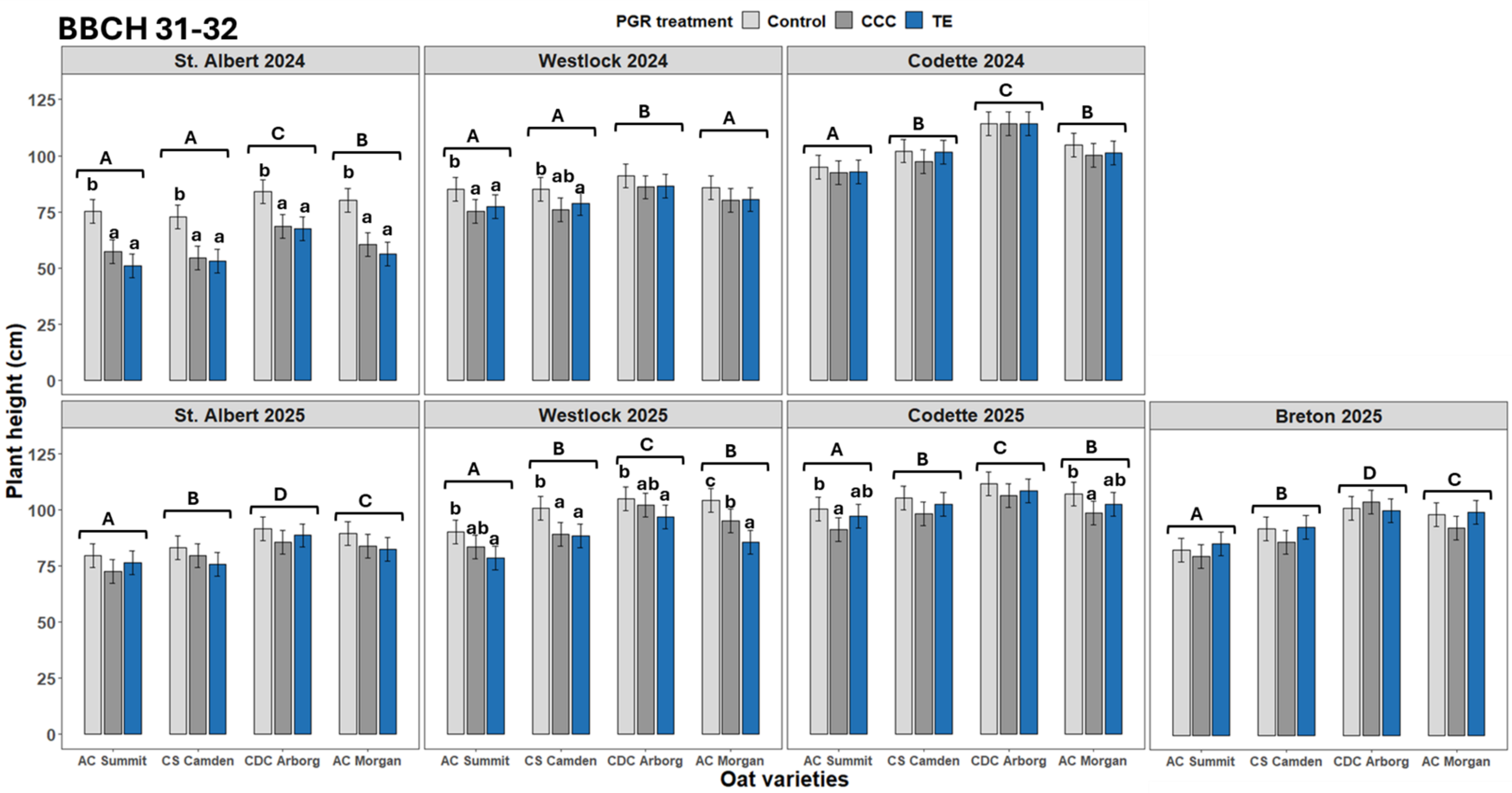

Fig. 1. PGR treatments × oat variety × site-year interaction effects on plant height. PGRS were applied at BBCH 31/32 [bars and error bars represent the mean and standard error, respectively; TE: trinexapac-ethyl, CCC: chlormequat chloride; Oat varieties: AC Summit, CS Camden, CDC Arborg, and AC Morgan. Different lowercase letters indicate significant differences among PGR treatments; different uppercase letters indicate differences among oat varieties at $P < 0.05$].

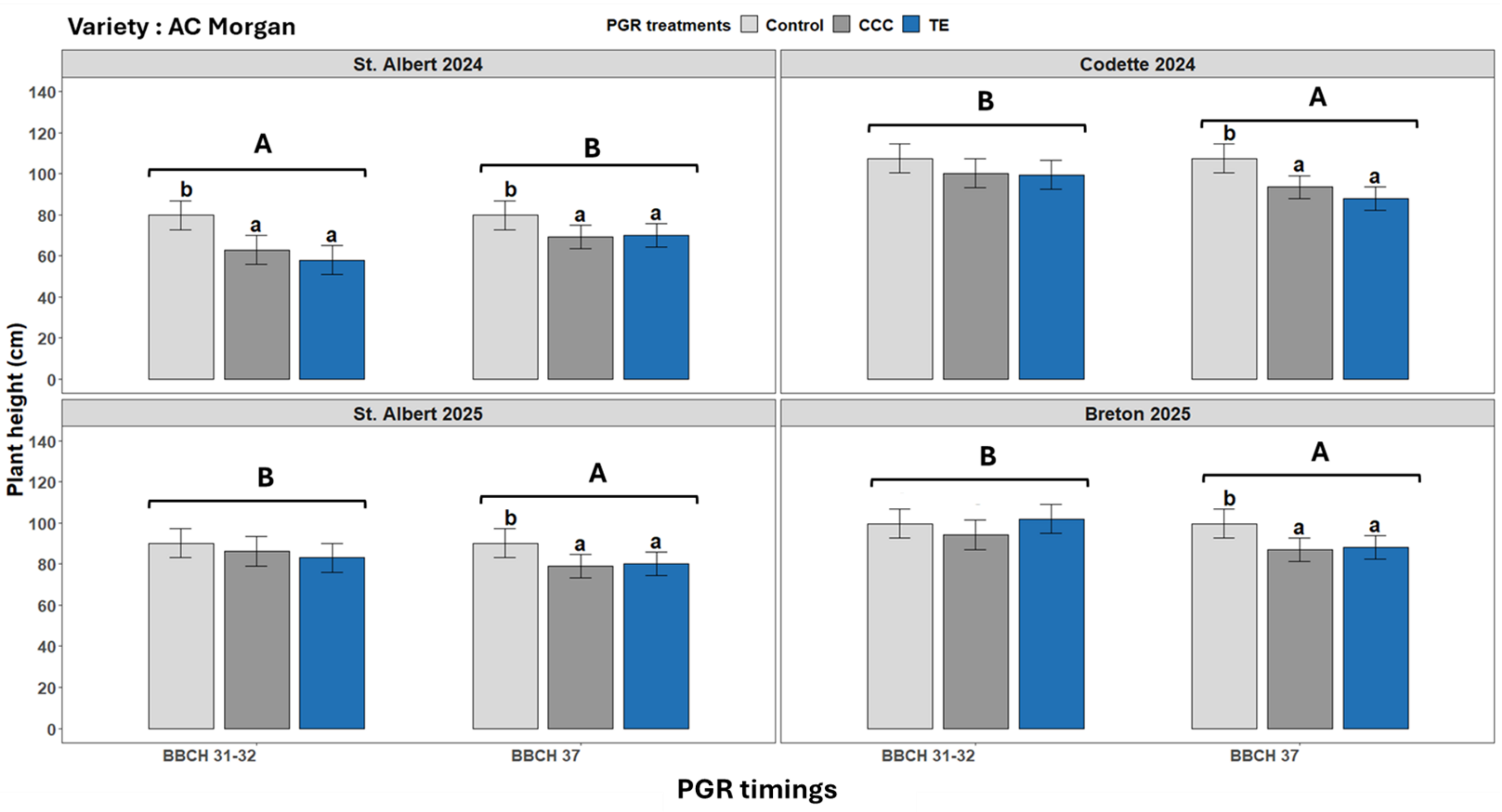

Fig. 2. PGR treatments × timing × site year interaction effects on plant height in the oat variety AC Morgan at BBCH 31/32 and BBCH 37 [bars and error bars represent the mean and standard error, respectively; TE: trinexapac-ethyl, CCC: chlormequat chloride. Significance: Different lowercase letters indicate significant difference among PGR treatments, and different uppercase letters indicate significance between timings at *P*< 0.05].

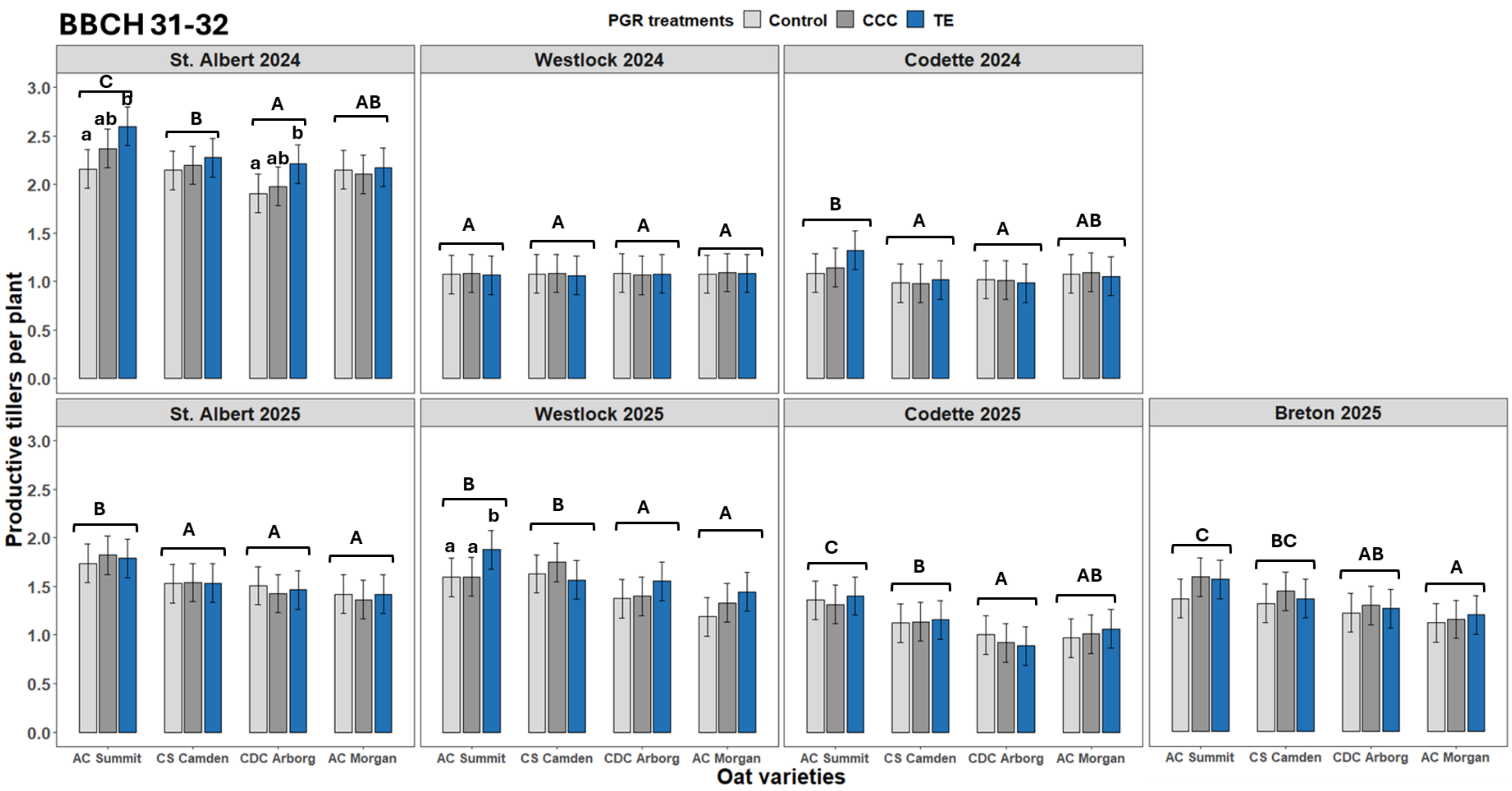

Fig. 3. PGR treatments × oat variety × site year interaction effects on productive tillers per plant in four different oat varieties at BBCH 31-32 [bars and error bars represent the mean and standard error, respectively; TE: trinexapac-ethyl, CCC: chlormequat chloride; Oat varieties: AC Summit, CS Camden, CDC Arborg, and AC Morgan. Different lowercase letters indicate significant difference among PGR treatments; different uppercase letters indicate differences among oat varieties at $P < 0.05$].

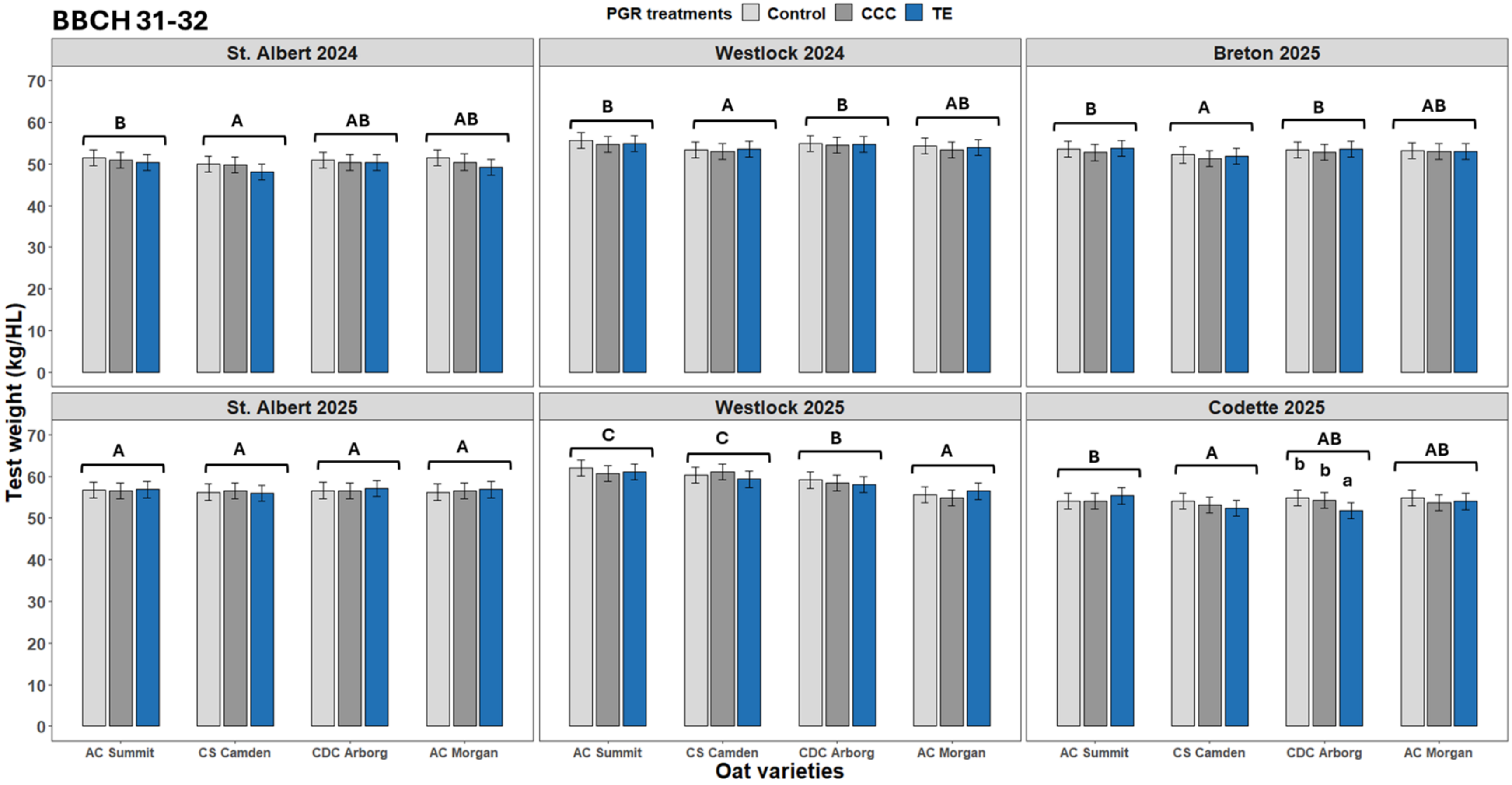

Fig. 4. PGR treatments × oat variety × site year interaction effects on test weight in four different oat varieties at BBCH 31-32 [bars and error bars represent the mean and standard error, respectively; TE: trinexapac-ethyl, CCC: chlormequat chloride; Oat varieties: AC Summit, CS Camden, CDC Arborg, and AC Morgan; Different lowercase letters indicate significant difference among PGR treatments, different uppercase letters indicate differences among oat varieties at $P < 0.05$].

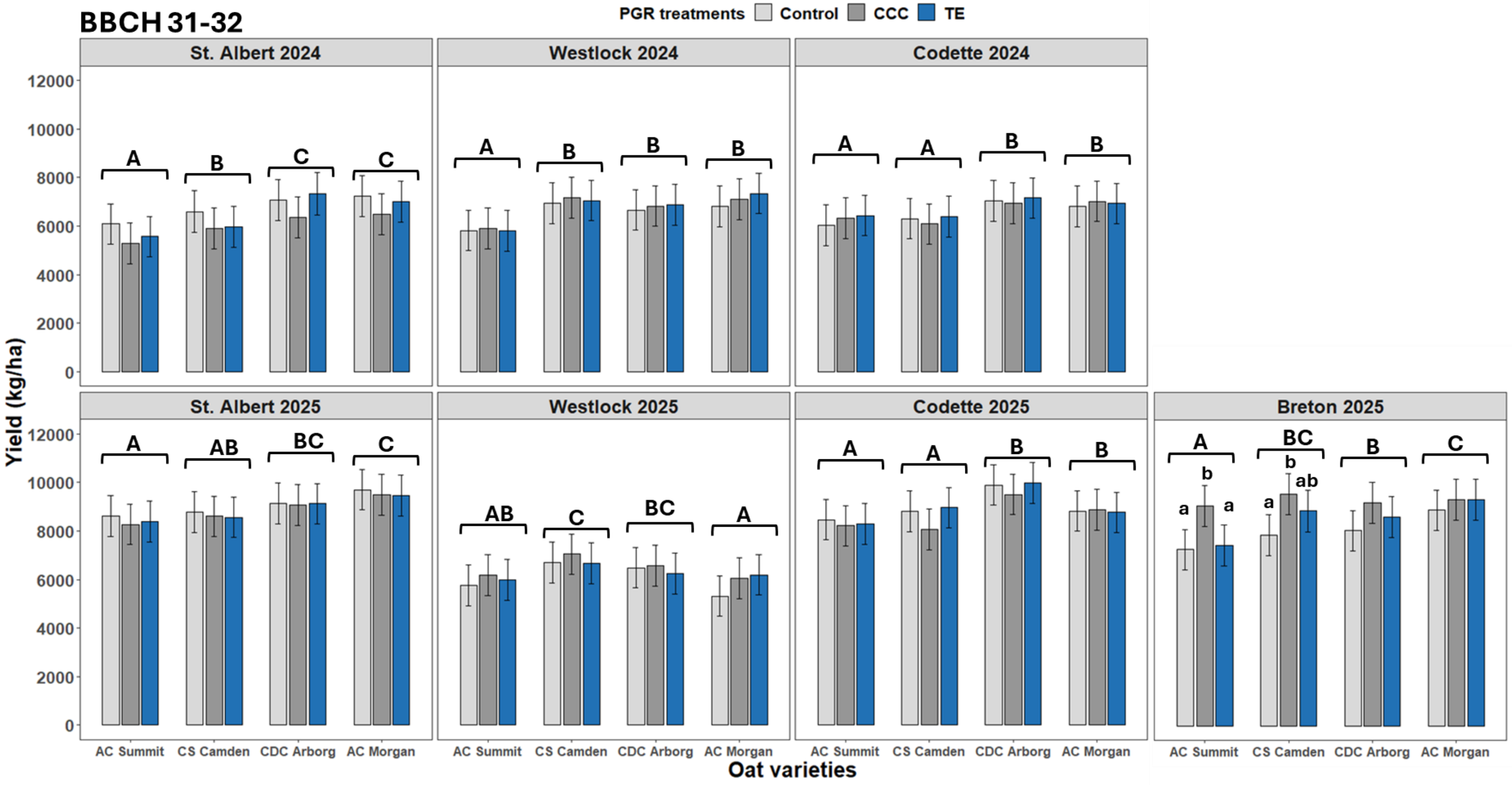

Fig. 5. PGR treatments × oat variety × site year interaction effects on yield in four different oat varieties at BBCH 31/32 [bars and error bars represent the mean and standard error, respectively; TE: trinexapac-ethyl, CCC: chlormequat chloride; Oat varieties: AC Summit, CS Camden, CDC Arborg, and AC Morgan; Different lowercase letters indicate significant difference among PGR treatments, different uppercase letters indicate differences among oat varieties at *P*< 0.05].

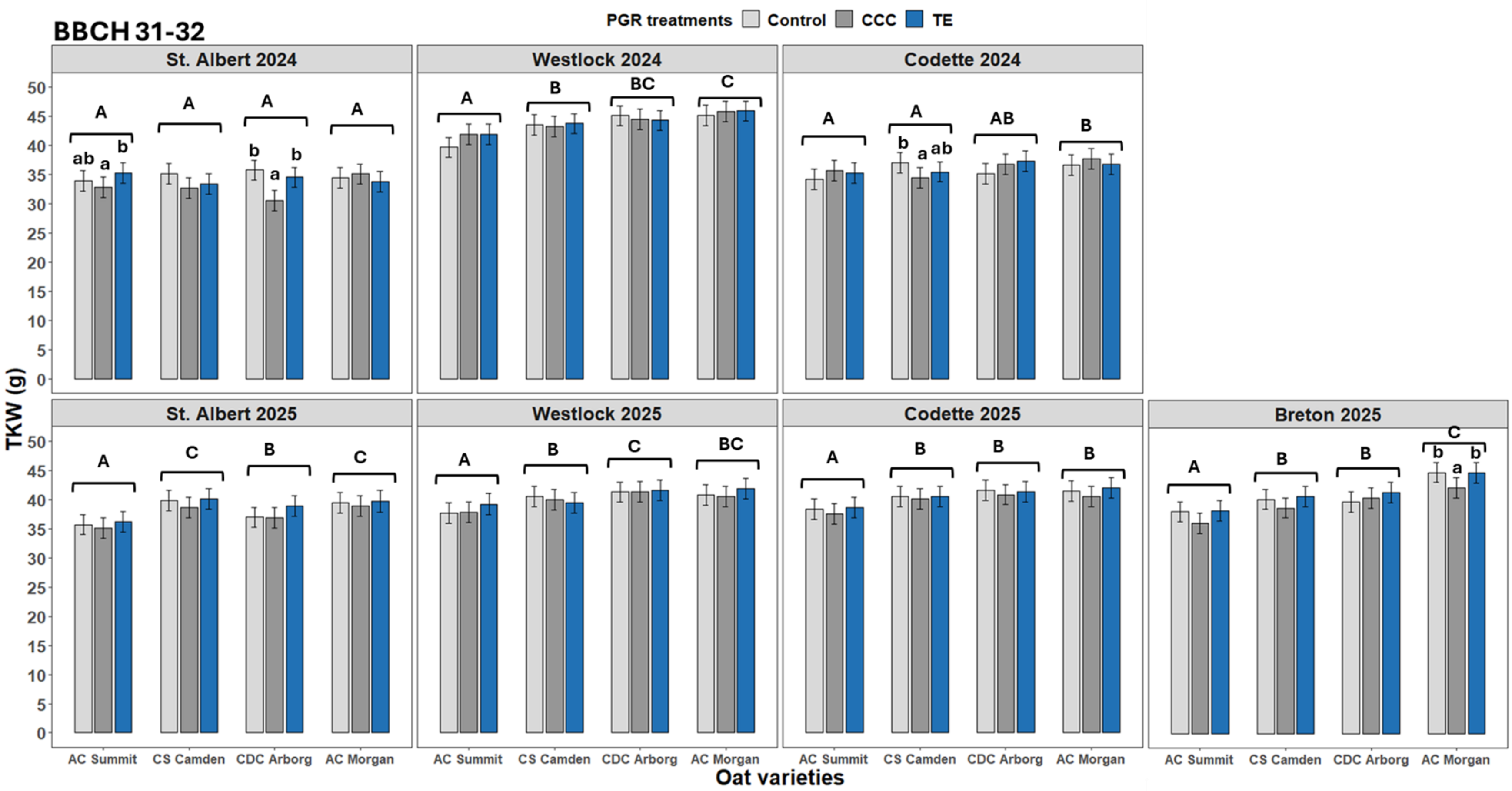

Fig. 6. PGR treatments × oat variety × site year interaction effects on thousand kernel weight (TKW) in four different oat varieties at BBCH 31/32 [bars and error bars represent the mean and standard error, respectively; TE: trinexapac-ethyl, CCC: chlormequat chloride; Oat varieties: AC Summit, CS Camden, CDC Arborg, and AC Morgan. Different lowercase letters indicate significant difference among PGR; different uppercase letters indicate differences among oat varieties at $P < 0.05$].

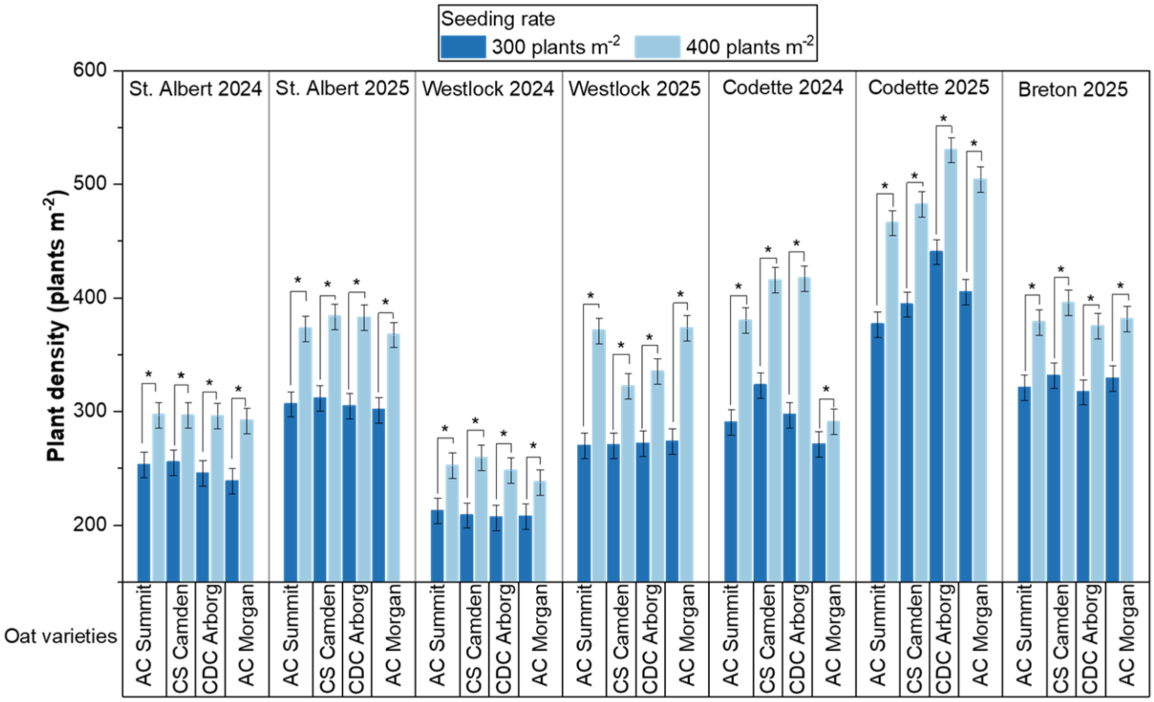

Fig. 7. Seeding rate × oat variety × site-year interaction effects on plant density in four different oat varieties at BBCH 31/32 [bars and error bars represent the mean and standard error, respectively; Oat varieties: AC Summit, CS Camden, CDC Arborg, and AC Morgan. '*' indicates significant differences between seeding rates for each variety at *P*< 0.05].

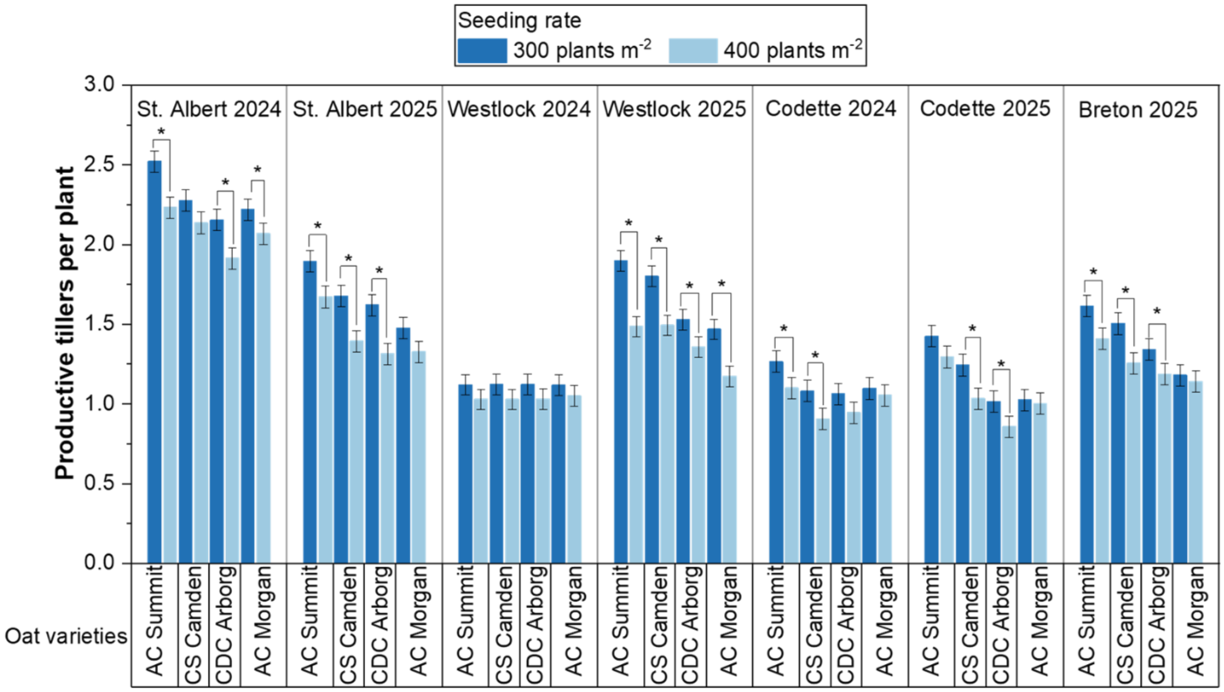

Fig. 8. Seeding rate × oat variety × site year interaction effects on productive tillers per plant in four different oat varieties at BBCH 31/32 [bars and error bars represent the mean and standard error, respectively; Oat varieties: AC Summit, CS Camden, CDC Arborg, and AC Morgan. '*' indicates significant differences between seeding rates for each variety at *P*< 0.05].

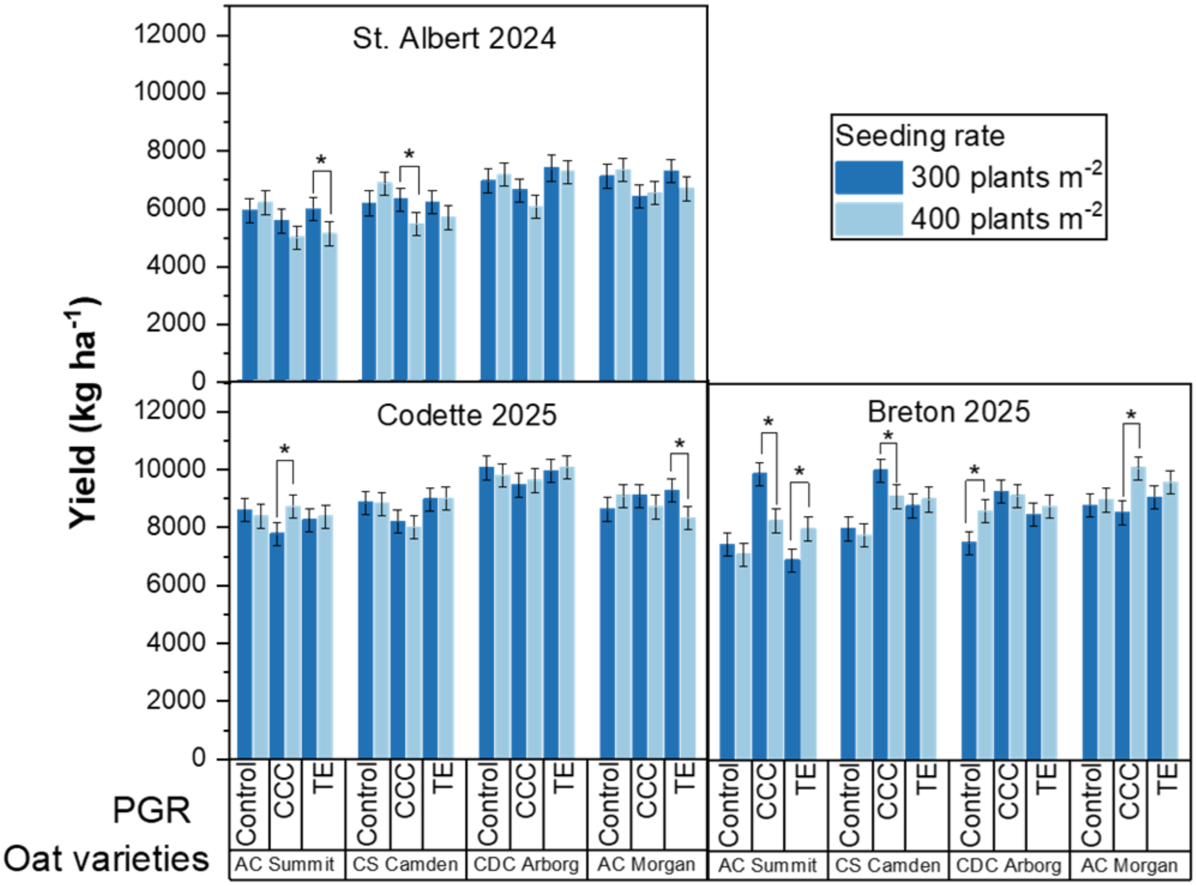

Fig. 9. Seeding rate× PGR × oat variety × site year interaction effects on yield in four different oat varieties at BBCH 31/32 [bars and error bars represent the mean and standard error, respectively; TE: trinexapac-ethyl, CCC: chlormequat chloride; Oat varieties: AC Summit, CS Camden, CDC Arborg, and AC Morgan.‘*’ indicate significant differences between seeding rates at *P*< 0.05].

Greenhouse study figures

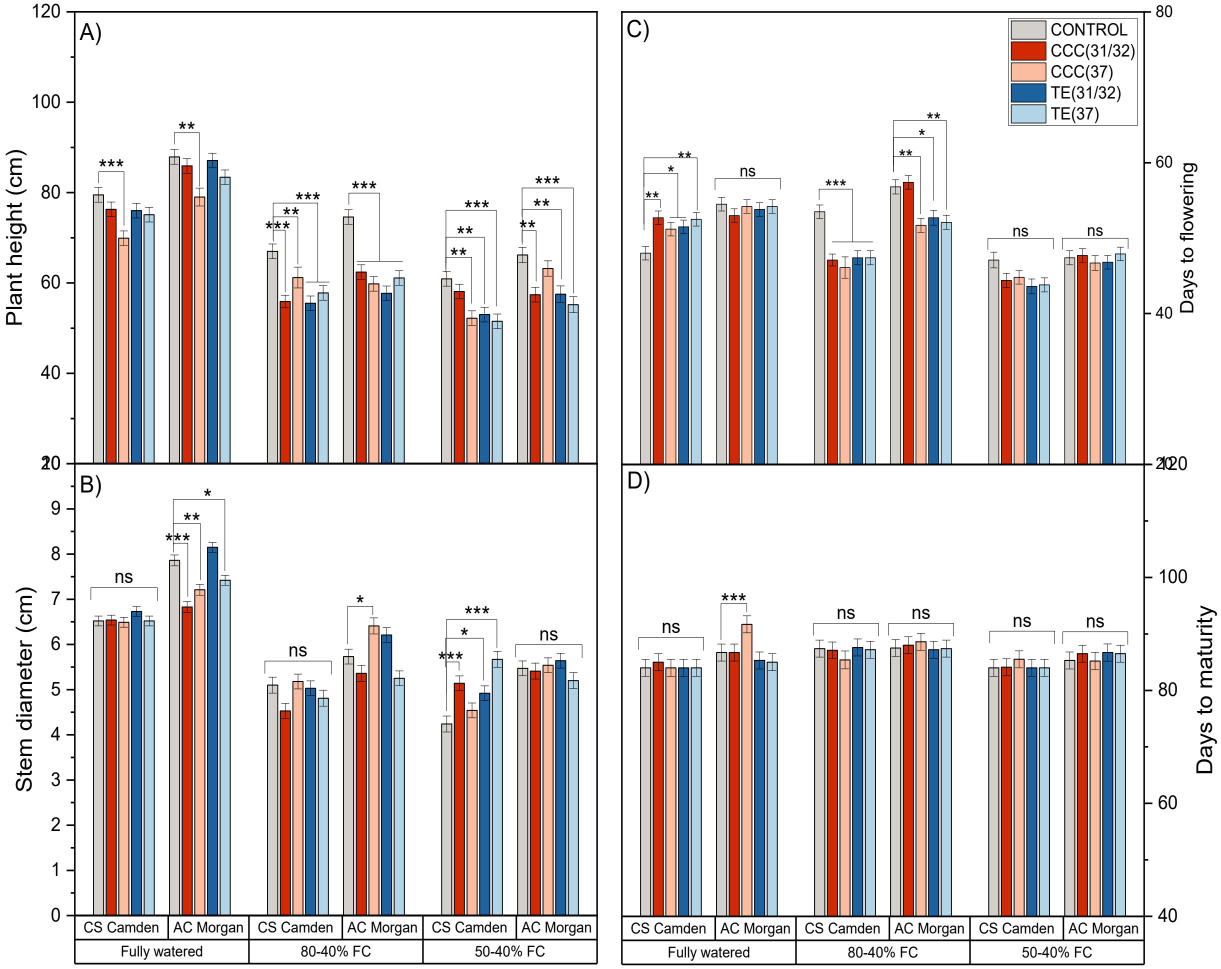

Fig. 10. The oat variety × watering regime × PGR timing interaction effects on (A) Plant height, (B) Stem diameter, (C) Days to flowering and (D) Days to maturity in two contrasting oat varieties [bars and error bars represent the mean and standard error, respectively; PGR: plant growth regulator; FC: Field capacity; Oat varieties: CS Camden, AC Morgan; Significance: ns: not significant, *, **, *** indicate P< 0.05, P< 0.01, P<0.001 respectively].

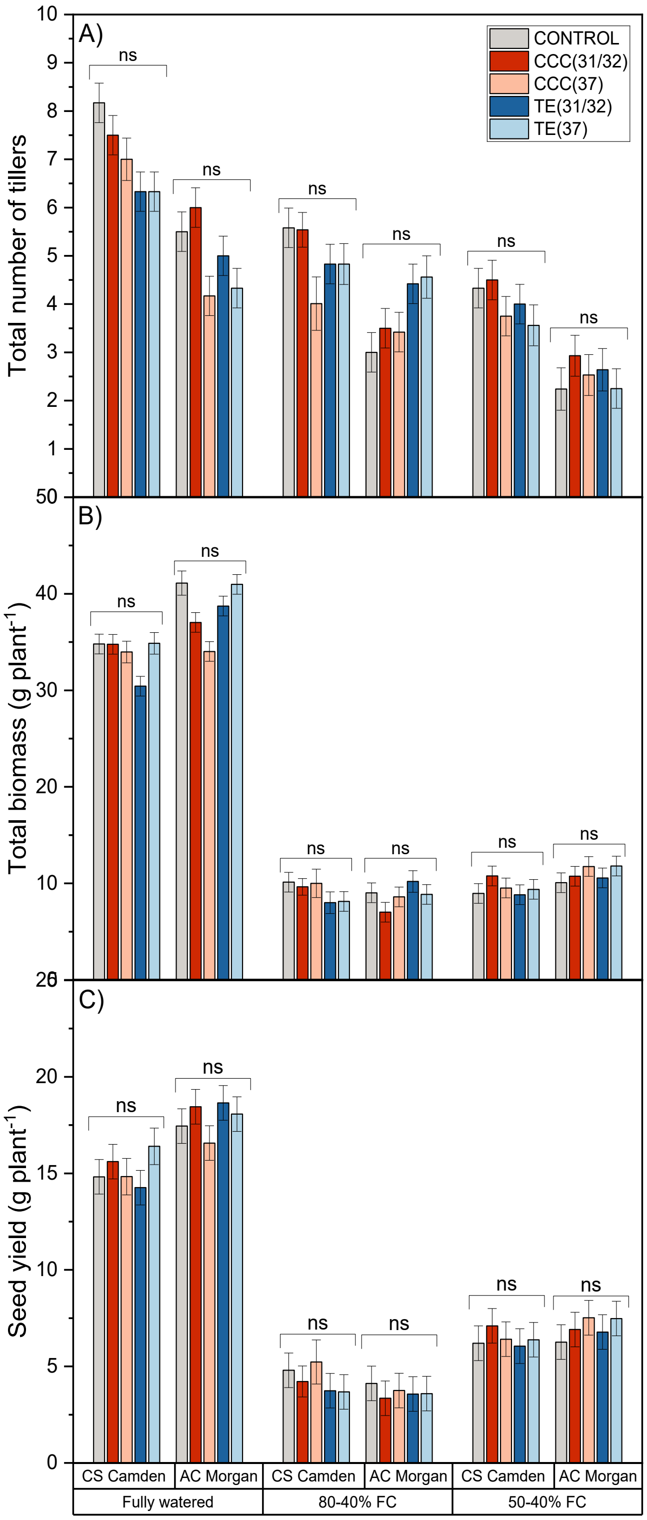

Fig. 11. The oat variety × watering regime × PGR timing interaction effects on (A) Total number of tillers, (B) Total biomass, and (C) Yield/plant in two contrasting oat varieties [bars and error bars represent the mean and standard error, respectively; PGR: plant growth regulator; FC: Field capacity; Oat varieties: CS Camden, AC Morgan; Significance: ns: not significant].