Alberta Ag Agri-Facts

Revised June 2024; Original Version: September 2018. Agdex 100/548-1

Plant Growth Regulators: What Agronomists Need to Know

Key Takeaways

PGRs are most useful in environments with abundant moisture and high levels of fertility. However, it is critically important to correctly stage PGR applications and not use PGRs under conditions of environmental stress. Small plot research has found that the most effective PGR applications are often associated with extended days to maturity and occasional reductions in test weight and protein. It is also important to remember that PGR applications are not guaranteed to prevent lodging and performance may vary in response to the cultivars and the growing conditions.

To use PGR most effectively:

- Only use PGRs when there is a high probability of lodging
- Avoid using PGR under stressful environmental conditions
- Choose the right PGR product for the crop species, with Moddus® being the best option for barley
- Effective PGR applications require careful crop staging
- Confirm with grain buyers to ensure market access of PGR-treated grains
- Weigh the pros and cons before using PGRs

Background

Plant growth regulators (PGRs) are synthetic compounds that can beneficially modify plant growth and development. These compounds function by altering hormonal activity. In western Canadian cereal crops, PGRs can work to produce shorter stems, reduce lodging, and maintain grain yield.

Lodging is a major production constraint in high-yield environments. Researchers have found that lodging can reduce cereal yields by 7 to 35 per cent. Farmers are looking for agronomic solutions and PGRs can help manage this major concern.

PGRs are not new agri-chemicals. Ethephon (active ingredient in Ethrel®) was discovered in 1965 and is one of the oldest PGRs on the market.

PGRs are used worldwide for several functions:

- improve lodging resistance
- promote fruit ripening
- stimulate flowering in horticultural crops

The use of PGRs is standard practice in western European cereal production. In the UK, they are used on 84 per cent of the winter wheat acres, averaging 1.7 applications per year. The high level of PGR use in the UK can be attributed to the wetter climate and longer growing season where severe lodging occurs every 3 to 4 years with average yield losses of 25 per cent.

Research is ongoing to address many questions about PGRs in Western Canada. It is known that effective PGR applications require careful crop staging, their use is not recommended under stressful environmental conditions, and responses are species and cultivar specific. However, PGRs can be a risk management tool to reduce lodging and yield losses commonly found in intensive management systems.

Lodging

Lodging occurs with moderate to high precipitation and high fertility. Lodging can reduce yields by 7 to 35 per cent with the greatest yield reductions occurring when lodging happens within 20 days after anthesis.

The magnitude of yield loss to lodging depends on several factors:

- cultivar susceptibility to lodging
- growth stage and severity of lodging
- wind and rain events
- early snowfall

Later lodging, during ripening, can increase grain sprouting, increase the need for grain drying, and decrease grade. Harvest delays from lodging can be costly. Increased lodging can be seen where there are insect or disease infections, increased fertilization, and higher seeding rates.

PGR effects on lodging

PGRs are applied to the crop foliage. PGRs change plant physiology by reducing cell elongation, reducing stem length, shortening the uppermost internodes and peduncle, and they may alter stem diameter. Even if tillers are not exposed to the PGR, reduced stem length can be observed on those tillers.

PGRs in western Canada

Two types of PGRs are available in western Canada. The first type are ethylene-releasing agents, such as Ethrel® (active ingredient ethephon). This product is registered for use on wheat, and when applied at the correct growth stage [BBCH 37-45 (flag leaf unrolling)], it decreases plant height and increases stem wall thickness but it may increase tillering.

The second type of PGRs are gibberellin inhibitors. Gibberellin inhibitors reduce stem elongation,

shorten the crop, and reduce lodging. In western Canada, Manipulator™ (active ingredient chlormequat chloride) is registered for treatment of spring, durum and winter wheat, spring and winter barley, and spring and winter oats. It is distributed by Belchim Crop Protection Canada. Moddus® (active ingredient trinexapac-ethyl) is registered to aid in the growth and lodging management of wheat, barley, and oat. It is from Syngenta Canada Inc.

PGR overview

Product name	Manipulator™ 620	Moddus ®	Ethrel ®
Active ingredient	Chlormequat chloride	Trinexapac-ethyl	Ethephon
Cereal crops registered	Spring and winter wheat, durum, barley, oats	Wheat, barley, oats	Spring and winter wheat
Single application Timing Wheat	BBCH 31-32 (one to two node stage). Do not apply later than BBCH 39.	BBCH 30-32 (beginning of stem elongation to 2-node stage) is optimal. Do not apply later than BBCH 39.	BBCH 37-45 (flag leaf just visible to flag leaf sheath swollen). Do not apply after more than 10% of the awns have emerged (BBCH 49).
Split application Timing - Wheat	BBCH 12-30 (2 leaf to beginning of stem elongation) 0.8 L/ha BBCH 31-32 (one to two node stage). No later than BBCH 39. 1.0 L/ha	BBCH 21-24 (start of tillering to 4 tillers) BBCH 37-39 (flag leaf just visible to flag leaf fully unrolled). No later than BBCH 39.	N/A
Single application Timing - Barley	BBCH 30-32 (start of stem elongation to two node stage). Do not apply later than BBCH 39.	BBCH 30-32 (beginning of stem elongation to 2-node stage) is optimal. Do not apply later than BBCH 39.	N/A
Split application Timing - Barley	BBCH 14-32 (4 leaf to two node stage) 1.15 L/ha BBCH 32-39 (two node stage to flag leaf). No later than BBCH 39. 1.15 L/ha	BBCH 21-24 (start of tillering to 4 tillers) BBCH 37-39 (flag leaf just visible to flag leaf fully unrolled). No later than BBCH 39.	N/A
Mode of action	Gibberellin inhibitor	Gibberellin inhibitor	Releases Ethylene
Notes	Potential market access issues when Manipulator is applied to malt, feed and food barley	Most efficient PGR for barley	Correct timing is critical to ensure crop safety

Source: Product labels, accessed June 2024.

Crop staging is critical

Correct application timing is critical for successful results.

Manipulator™ is registered for application between the two-leaf stage (BBCH 12) to the flag leaf collar visible stage (BBCH 39) on wheat. Alberta research has found the most effective single application time for consistent height reductions is the beginning of stem elongation, when the first internode begins to elongate and the top of the inflorescence is at least 1 cm above the tillering node

(BBCH 31), to the time when the second node is at least 2 cm above node one (BBCH 32).

The ideal staging for a single application of Moddus® on wheat and barley is at BBCH 30-32. Like, Manipulator™, Moddus® cannot be applied after BBCH 39 (flag leaf collar visible).

For Ethrel®, apply when most of the tillers are between early flag leaf emergence to swollen-boot stage (BBCH 37-45). DO NOT apply Ethrel after more than 10 per cent of the awns have emerged (BBCH 49). The correct stage of application is critical to ensure crop safety with Ethrel®.

Co-application of fungicides with gibberellin inhibiting PGRs (i.e., Manipulator™ and Moddus®) is not recommended because this is not an ideal time for fungicides. Fungicides applied at BBCH 30-32 have 50% more leaf disease severity, compared with flag leaf fungicide timing. In addition, applying fungicides at the BBCH 30-32 stage did not provide yield or economic benefits, based on Alberta studies with CWRS wheat. Fungicide application at the flag leaf stage (BBCH 39-45) and early flowering (BBCH 61-65) is more effective in managing leaf diseases which can reduce yield potential.

Co-application of herbicides with gibberellin inhibiting PGRs (i.e., Manipulator™ and Moddus®) is also not recommended because BBCH 30-32 is often too late for optimal weed control. The BBCH 30-32 growth stage generally occurs in mid-June, and delaying the herbicide application allows the weeds to be at a much more developed stage, resulting in significant, and unwanted, crop competition.

More resources on PGR timing:

- Video - Growing Smarter: Plant growth regulator staging for wheat and barley

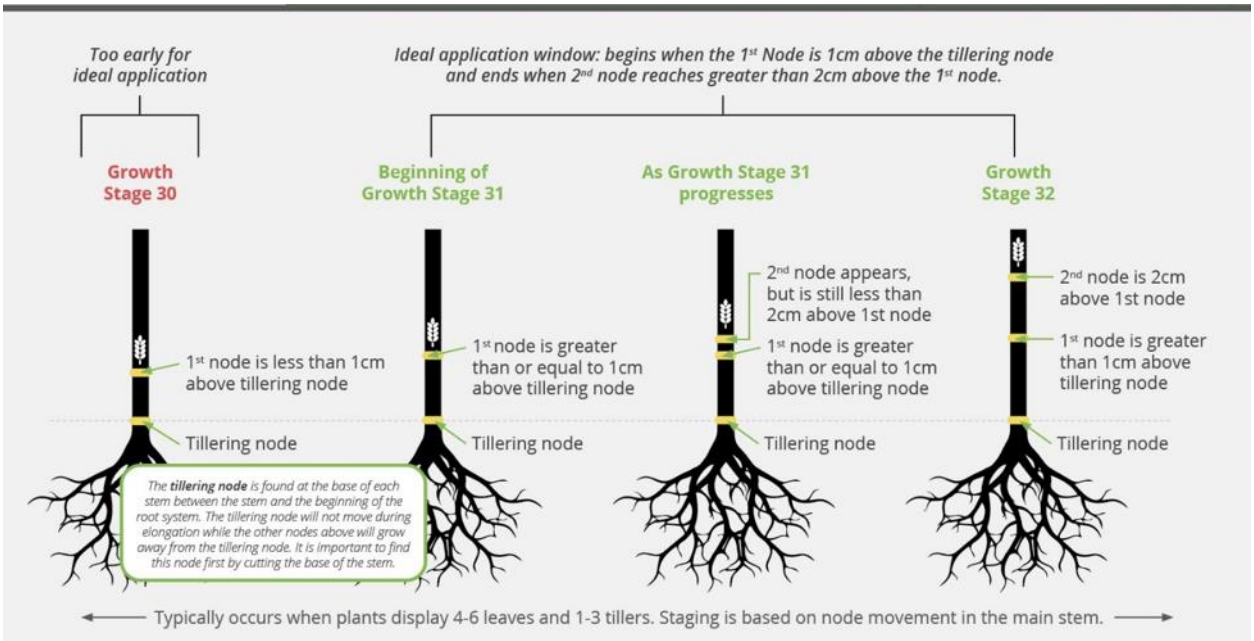


Figure 1. Growth stage 31-32, ideal application timing for Manipulator™ PGR in wheat

PGR risk under stressful environmental conditions

PGRs help manage lodging risk in highly productive environments where agronomic inputs such as high fertility and high seeding rates, target high yields, or where genetic lodging resistance is inadequate. However, this does not mean PGRs are beneficial every year. If environmental conditions are not favourable for lodging (i.e., drought), PGRs should not be used. In these situations, no PGR application may be the best approach.

As stated on product labels, do not use PGRs under any type of stress:

- Due to risk of injury to the crop, avoid overlapping and do not apply Moddus® to crops that are environmentally stressed, such as crops experiencing high temperatures, drought, or frost.
- Manipulator™ 620 should not be applied to crops under stress from waterlogging, drought, or nutrient deficiency.
- As a general guideline, PGR should not be applied if the crop has experienced cold stress (<0 °C) five days before the PGR application.
- PGRs can take 14 to 28 days to fully breakdown within the plant. Avoid applying PGR if heat stress is expected 14 to 28 days after application.

Understanding PGR performance

Plant growth regulators can have inconsistent responses between years, sites, cultivars, and species:

- Alberta research found that 93% of the time, PGRs will cause significant wheat height reductions (between 3 and 13 cm) compared to no PGR application. This means there can be times when there is no crop height reduction with the use of a PGR.

Some PGRs work better on some crop species than others:

- Barley is less responsive to chlormequat chloride. Therefore, products containing trinexapac-ethyl are preferentially used to reduce the risk of lodging in barley.
- A western Canadian study with PGRs on CDC Copeland barley found that Moddus® showed the largest number of lodging reductions.

Cultivars respond to PGRs differently:

- The majority of wheat varieties in western Canada are rated as very good (VG) or good (G) for lodging resistance. However, even with these genetic resistance ratings, they can still lodge under highly productive conditions.
- Not all cultivars respond equally well to PGRs, and the height or lodging rating of a cultivar is not a reliable indicator of PGR effectiveness.
- Of the cultivars tested under western Canadian conditions, AAC Brandon seems to be very responsive to PGR applications. Despite AAC Brandon's good (G) standability rating and short height, AAC Brandon can have poor standability with no PGR application under conditions of high nitrogen fertilizer rates and good moisture, but standability is greatly

improved with Manipulator™.

Inconsistency of results:

- It is important to remember that PGR applications are not guaranteed to prevent lodging. Performance may vary in response to the cultivars and the growing conditions.

Unintended effects of PGR

Plant hormones act in concert, with the levels of one hormone affecting other hormones, so PGRs may have secondary effects, such as delayed senescence, increased resistance to environmental stress, or shifting assimilates to the roots resulting in increased root growth. PGRs can positively or negatively affect yield, but results are inconsistent depending on crop lodging, environmental conditions, crop species, and cultivar.

PGRs are systemic but non-residual, which can result in undesirable side effects such as stem elongation in some varieties and temporary, short-term height reduction. PGRs can also alter tiller growth.

The most effective PGR-induced height reductions and standability improvements are frequently associated with:

- significant increases in crop greenness
- delayed maturity (up to three days)
- decreased thousand kernel weight
- Occasional reductions in test weight by 0.2 to 0.5 kg/ha occurred 15% of the time with PGR applications in small-plot research trials
- Reductions in grain protein content occurred 7% of the time with PGR applications in small-plot research trials. The reduction of grain protein could be concerning when protein levels are near the minimum requirements (i.e., 13.0%). However, when the PGR application was followed by a well-timed foliar fungicide, protein reductions were avoided

Growers must weigh the benefits of PGRs against the chance of extended days to maturity, reduced test weight, and the possibility of reduced protein content when deciding to use a PGR.

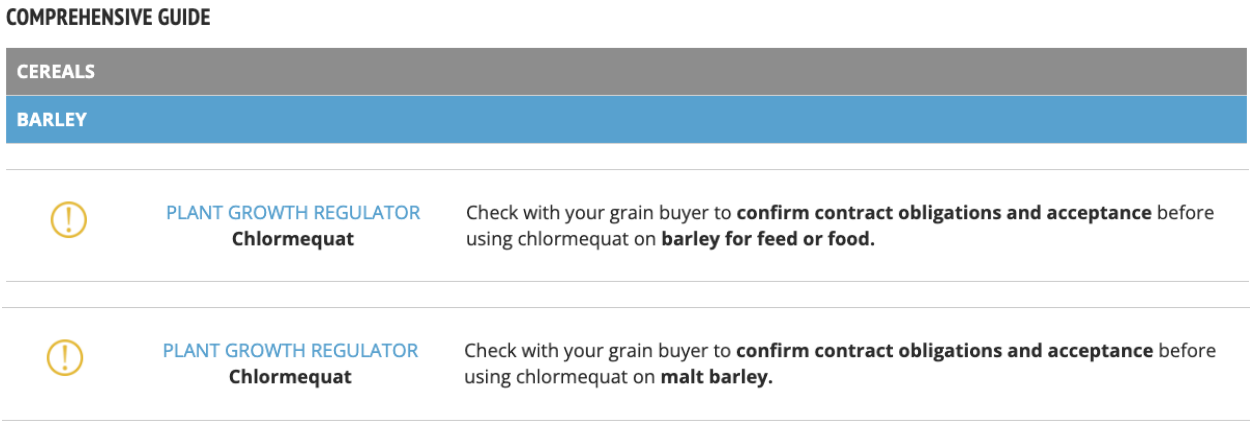
Factors limiting PGR use in western Canada

Constraints:

1. Crop staging for Ethrel® is incredibly particular, and only experienced growers and agronomists should be using this product, as large yield losses can occur with improper application timing. It is a product with great reward but also great risk. Bayer does not

promote the use of this product due to the large risks associated with improper application timing.

2. Manipulator™ has a much wider window of crop safety compared with Ethrel®. However, there are marketing considerations when used on barley. Manipulator™ is marked as "caution" on *Keep It Clean* Product Advisory. Growers are advised to check the Keep it Clean website for product advisory updates. Additionally, farmers should check with their grain buyer to confirm contract obligations and acceptance before using Manipulator™ on food, feed, and malt barley.



3. Moddus® is registered and used in many countries around the world. MRL's are currently established in a number of countries, including the European Union, USA, Japan, and Codex. Moddus® has no market access concerns as of the time of writing this factsheet.

Important Note: Always read and follow the label instructions when applying pesticides or plant growth regulators.

REFERENCES

Asif, M., Strydhorst, S., Strelkov, S.E., Terry, A., Harding, M.W., Feng, J., and Yang, R.C. 2021. Evaluation of disease, yield and economics associated with fungicide timing in Canadian Western Red Spring wheat. Can. J. Plant Sci. 101(5): 680-697. https://doi.org/10.1139/cjps-2020-0318

Bayer CropScience Inc. 2023. Ethrel liquid plant growth regulator label. PMRA Approved: 2023-3125. Bayer CropScience Inc. Available at: https://www.cropscience.bayer.ca/-/media/Bayer-CropScience/Country-Canada-Internet/Products/Ethrel/11580_approved_EN_26July2023_Remediated.ashx

Berry, P., M. Sterling, J. Spink, C. Baker, R. Sylvester- Bradley, S. Mooney, A. Tams and A. Ennos. 2004. Understanding and reducing lodging in cereals. Adv. Agron. 84:217-271.

Clark, R. and Fedak, G. 1977. Effects of chlormequat on plant height, disease development and chemical constituents of cultivars of barley, oats and wheat. Can. J. Plant Sci. 57:31-36.

Fischer, R. and Stapper, M. 1987. Lodging effects on high-yielding crops of irrigated semidwarf wheat. Field Crops Res. 17:245-258.

Garthwaite, D.G. and Thomas, M.R. 2000. "Pesticide Usage Survey". DEFRA Report No. 171. Department for the Environment Food and Rural Affairs, London.

Kelbert, A., Spaner, D., Briggs, K. and King, J. 2004. Screening for lodging resistance in spring wheat breeding programmes. Plant Breeding. 123:349-354.

Morgan, P. W. and Gausman, H.W. 1966. Effects of ethylene on auxin transport. Plant Physiol. 41:45-52.

Peltonen-Sainio, P. Rajala, A., Simmons, S., Caspers, R. and Stuthman, D.D. 2003. Plant growth regulator effects on pre-anthesis main shoot and tiller growth in conventional and dwarf oat. Crop Sci. 43:227-233.

Radmacher, W. 2015. Plant Growth Regulators: Backgrounds and uses in plant production. J. Plant Growth Regul. 34:845-872. DOI 10.1007/s00344-015-9541-6

Rajala, A., and Peltonen-Sainio, P. 2002. Timing applications of growth regulators to alter spring cereal development at high latitudes. Agricultural and Food Science in Finland. 11:233-244.

Strydhorst, S., Bowness, R., Pauly, D., Gill, K.S., Oatway, L., Yang, R-C., Hall, L., and Perrott, L. 2017. Advanced agronomic practices in wheat, barley and pea to maximize yield and harvestability. Project final report 2014F041R.

Syngenta Canada Inc. 2023. Moddus® label. Available at: https://assets.syngenta.ca/pdf/ca/labels/Moddus_33930_en_pamphlet.pdf?_gl=1*y2ozk9*_up*MQ..&gclid=CjwKCAjwg8qzBhAoEiwAWagLrCQzpVAdatrRgBXHcCjhVeKxuI7OLmeew4DagUBEhWaBFsUxkly3GRoCVewQAvD_BwE.

Taminco US Inc. 2020. Manipulator™ 620 label. Taminco US Inc. Available at: https://manipulatorpgr.belchimcanada.com/wp-content/uploads/2023/06/Label-English.pdf

Tidemann, B.D., O'Donovon, J.T., Izydorczyk, M., Turkington, T.K., Oatway, L., Beres, B., Mohr, R., May, W.E., Harker, N.K., Johnson, E.N., and deGooijer, H. 2020. Effects of plant growth regulator applications on malting barley in western Canada. Can. J. Plant Sci. 100(6): 653-665. https://doi.org/10.1139/cjps-2019-0200

Tripathi, S.C., Sayre, K.D., Kaul, J.N. and Narang, R.S. 2003. Growth and morphology of spring wheat (*Triticum aestivum L.*) culms and their association with lodging: effects of genotypes, N levels and ethephon. Field Crops Research. 84:271-290.

United States Environmental Protection Agency. 1995. Reregistration Eligibility Decision. Facts. Ethephon. EPA- 738-F-95-004.

Wiersma, J.J., Dai, J. and Durgan, B.R., 2011. Optimum timing and rate of trinexapac-ethyl to reduce lodging in spring wheat. Agronomy Journal. 103:864-870.

Woodward, E.J. and Marshall, C. 1988. Effects of plant growth regulators and nutrient supply on tiller bud outgrowth in barley (*Hordeum distichum L.*) Annals of Botany. 61:347-354.

Original factsheet prepared by

Dr. Sheri Strydhorst, Alberta Agriculture and Forestry

Dr. Linda Hall, University of Alberta

Laurel Perrott, Lakeland College

Factsheet update by

Dr. Sheri Strydhorst, Sheri's Ag Consulting Inc.

Ruoxi Xia, Alberta Grains