AGRI-FACTS
Practical Information for Alberta's Agriculture Industry

November 2017 Agdex 100/548-1

Plant Growth Regulators: What Agronomists Need to Know

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.

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

Background

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. 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 from 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 amounts of lodging can be seen where there are insect or disease infections, increased fertilization and higher seeding rates.

PGR performance

PGR performance depends on crop species and cultivar. Some PGRs work better on some crop species than others. For example, in response to chlormequat chloride (Manipulator), wheat is most responsive, barley has an intermediate response and oats are the least responsive.

Additionally, not all cultivars show similar height or lodging responses to PGRs. At present, PGRs are only registered for use on wheat in western Canada.

Cultivar responses

The majority of wheat varieties in western Canada are rated as very good (VG) or good (G) for lodging resistance. However, not all cultivars respond equally well to PGRs, and the initial height or lodging rating of a cultivar is not a reliable indicator of PGR effectiveness.

For example, the response of AAC Brandon, AAC Elie, Stettler and AAC Redwater to four PGR treatments were tested. Despite the "VG" rating and short height, AAC Brandon had poor standability with no PGR application (center left plot), but standability is greatly improved with Manipulator (right) or the dual PGR treatment (left) (Figure 1).

AAC Elie was accurately described by its "G" lodging resistance rating and responded to PGR treatments as expected (Figure 2). Stettler did not require a PGR application despite its "G" rating for lodging resistance (Figure 3).

AAC Redwater had a "G" lodging rating, and it was the tallest of the four cultivars, yet, like Stettler, it did not need a PGR to prevent lodging (Figure 4). These findings are from one location in 2017, and different results may occur in different growing conditions.

Figure 1. AAC Brandon (81 cm, VG) treated with dual PGR – Manipulator + trinexapac-ethyl (left); no PGR (center left), trinexapac-ethyl (center right) and Manipulator (right).

Figure 2. AAC Elie (81 cm, G) treated with no PGR (left); Manipulator (center left), trinexapac-ethyl (center right) and dual PGR – Manipulator + trinexapac-ethyl (right).

Figure 3. Stettler (84 cm, G) treated with no PGR (left); Manipulator (center left), trinexapac-ethyl (center right) and dual PGR – Manipulator + trinexapac-ethyl (right).

Figure 4. AAC Redwater (87 cm, G) treated with no PGR (left); Manipulator (center left), trinexapac-ethyl (center right) and dual PGR – Manipulator + trinexapac-ethyl (right).

Similar results have been shown in research with barley and oat, with not all cultivars requiring or responding to a PGR. Based on this information, growers cannot assume tall cultivars or cultivars with "G" standability ratings need (or will respond to) PGRs.

PGR effects on plant growth

PGRs are applied to the crop foliage. In cereals, they produce ethylene (Ethrel) or inhibit gibberellin biosynthesis (Manipulator and trinexapac-ethyl). 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, the elongation retarding effect can be observed on the tiller.

However, 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.

Both chlormequat-chloride (Manipulator) and ethephon (Ethrel) can increase tiller growth, which may increase or decrease yield. Altered tillering may be attributed to changes in photoassimilate and nutrient availability or PGR-induced changes in plant hormonal patterns. For example, ethylene simulates the breakdown of apical dominance by inhibiting auxin biosynthesis and movement.

Recent research found negligible PGR effects on yield but a significant protein response. The protein content of AC Foremost wheat not receiving a PGR was 12.5 per cent, with Manipulator 12.4 per cent and with trinexapac-ethyl 12.5 per cent.

The significantly lower protein content of Manipulator-treated wheat could be concerning when protein levels are near the minimum requirements. However, when either PGR was used in combination with a foliar fungicide application, protein reductions were avoided.

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 (GS 38 (flag leaf unrolling)), it decreases plant height and increases stem wall thickness but may also 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) was recently registered for use on wheat by Engage Agro. A new product, with the active ingredient trinexapac-ethyl, is in the process of registration by Syngenta.

Crop staging is critical

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

Manipulator is registered for application between the two-leaf stage (Zadoks stage 12) to the flag leaf collar visible stage (Zadoks stage 39). However, Alberta research has found the most effective application time for consistent height reductions is between Zadoks GS 30-32 (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, to the time when the second node is at least 2 cm above node one). Application outside this window may be less effective, but no crop injury has been reported.

Research suggests that ideal staging for trinexapac-ethyl on wheat is similar to Manipulator, at Zadoks GS 30-32 to 37. Additional research is required for both Manipulator and trinexapac-ethyl to identify the appropriate time of application and the option of co-application with fungicides.

Factors limiting PGR use in western Canada

PGRs are most useful in environments with abundant moisture and high levels of fertility. In the high yield potential environments of western Canada, a number of constraints currently limit the adoption of PGR's.

Constraints:

1. Ethrel is a PGR widely used on irrigated acres where lodging is a regular occurrence. However, use is limited because growers must sign a waiver indicating that Bayer (the manufacturer) is not liable for any crop damage that occurs. 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 is a new PGR that came on the market in 2013. It has a much wider window of crop safety. However, there are no established Maximum Residue Limits (MRL) for Manipulator for grain sales into the USA. Due to the absence of an MRL, most Canadian grain buyers will not purchase wheat treated with Manipulator. These trade issues are discouraging Manipulator use in Canada; however, these MRL issues may be resolved in the near future.

3. Trinexapac-ethyl 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. In January 2017, Trinexapac-ethyl was submitted for review by the PMRA as a Category A submission. The timeline for completion of the review and regulatory decision is mid-2019, and it is subject to meeting the evaluation requirements.

Summary

Due to the large yield loss potential of lodging, PGRs use is expected to increase significantly in high yield potential environments of western Canada once marketing issues, PMRA registration and grower experience have been resolved.

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