Introduction to Plant Growth Regulators for Use in Grass Seed Crops

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What is a Plant Growth Regulator?

- **Plant growth regulators** (PGRs) are organic compounds, other than nutrients, that when applied affect processes such as growth and development.

- Plant growth and development processes are mediated by **hormones**. These processes can be successfully manipulated by application of the appropriate PGR.

- PGRs are active at low concentrations but have pronounced effects akin to hormones. PGRs may affect growth, development or both processes.

**Chemical Structures**

1. Chlormequat chloride (CCC, Cycocel)
   - Chemical formula: \( \text{Cl}^{-} - \text{CH}_{2} - \text{CH}_{2} - \text{N} - \text{CH}_{3} \)
   - Description: Promotes rapid growth and development.

2. Ethephon (Cerone, Ethrel, Finish)
   - Chemical formula: \( \text{Cl}^{-} - \text{CH} - \text{CH} - \text{P} - \text{OH} \)
   - Description: Used for floral induction and hastening maturity.
PGRs may be naturally occurring compounds, synthetic analogs of hormones, or inhibitors of hormone biosynthesis.

PGRs are classified into groups by activity, function, or mode of action.

Some herbicides and fungicides may have PGR properties.

### Classification of Plant Growth Regulators

<table>
<thead>
<tr>
<th>PGR Class</th>
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<tbody>
<tr>
<td>Gibberellins (GA) and synthetic analogs</td>
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<tr>
<td>Cytokinins and synthetic analogs</td>
</tr>
<tr>
<td>Auxins and synthetic analogs</td>
</tr>
<tr>
<td>Ethylene</td>
</tr>
<tr>
<td>Ethylene biosynthesis inhibitors</td>
</tr>
<tr>
<td>Onium compounds</td>
</tr>
<tr>
<td>Triazoles</td>
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<tr>
<td>Acylcyclohexanediones</td>
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</tbody>
</table>

![GA3](Image)
PGRs for Lodging Control in Grass Seed Crops

- Stem elongation results from activity of the intercalary meristem. Each internode elongates independently and is promoted by the hormone \( \text{GA}_1 \).
- When the tiller cannot support the weight of the inflorescence, the tiller lodges or falls to the ground.
- Lodging restricts pollination and reduces fertilization. Seed filling is reduced due to self-shading of the lodged crop.
- Seed number is reduced by lodging.
GA Biosynthesis Pathway

Geranylgeranyl diphosphate

CDP synthase

Copalyl diphosphate

ent-kaurene synthase

ent-kaurene

ent-kaurenoic acid

GA_{12} aldehyde synthase

GA_{12} aldehyde

3β-hydroxylase

GA_{20}

GA_{1}

GA_{8}

GA Biosynthesis Inhibitors

Chlormequat chloride, Mepiquat chloride

Oniums

Paclobutrazol, Uniconazole

Triazoles

Trinexapac-ethyl, Prohexadione-calcium

Acylcyclohexanediones

Dichloro-methano 16,17 dihydro GA_{5} (DMDGA_{5})

Modified GAs
PGRs for Lodging Control in Grass Seed Crops

- PGR use in grass seed crops is not a new phenomenon and the most widely researched and used of the early PGRs was paclobutrazol, a triazole that affects ent-kaurene in the GA biosynthesis pathway.
- Seed yield was increased and lodging reduced by paclobutrazol.
- While this PGR worked well in some species such as the fine fescues, inconsistent results and occasional soil persistence problems eventually ended the use in other important grass seed crops.
Acylcyclohexanedione PGRs

- Trinexapac-ethyl (TE) and prohexadione-calcium (PC) plant PGRs are inhibitors of the 3-β hydroxylation of GA$_{20}$ to GA$_1$. GA$_1$ promotes stem elongation, GA$_5$ promotes flowering, GA$_{29}$ is inactive.
- The PGRs are structurally similar to 2-oxoglutaric acid, a cofactor in the hydroxylation reaction.
While TE and PC shorten stems and reduce lodging, seed yield may be increased even with low incidence of lodging.

TE and PC increase the efficiency of carbon partitioning to seed.

**Acylcyclohexanedione effects**
- Increased floret number
- Increased seed set
- Increased seed number
- Increased seed yield
- Increased harvest index
- Mixed effects on seed weight
- Decreased stem length
- Decreased lodging
Acylcyclohexanedione PGRs

- The efficacy of TE and PC applications is influenced by rate, seasonal timing, environment, nitrogen management, residue management, etc.

TE effects on perennial ryegrass seed production in 9 years of trials (Chastain et al., 2013).

<table>
<thead>
<tr>
<th>TE rate (g ai/ha)</th>
<th>Seed yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1462 a</td>
</tr>
<tr>
<td>200</td>
<td>1831 b</td>
</tr>
<tr>
<td>400</td>
<td>2090 c</td>
</tr>
<tr>
<td>600</td>
<td>2303 c</td>
</tr>
</tbody>
</table>
Acylcyclohexanedione PGRs

- The seasonal timing of TE and PC is important for optimal seed yield.

TE effects on perennial ryegrass seed production in 9 years of trials (Chastain et al., 2013).

<table>
<thead>
<tr>
<th>TE timing (BBCH scale)</th>
<th>Seed yield (kg/ha)</th>
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</thead>
<tbody>
<tr>
<td>29</td>
<td>1770 b</td>
</tr>
<tr>
<td>32</td>
<td>1981 c</td>
</tr>
<tr>
<td>37</td>
<td>1814 bc</td>
</tr>
<tr>
<td>51</td>
<td>1958 c</td>
</tr>
<tr>
<td>59</td>
<td>1518 a</td>
</tr>
</tbody>
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Interaction of PGRs and Residue Management

TE and residue management (Burn or Flail) effects on cumulative creeping red fescue seed yield over a 4-year period (Zapiola et al., 2006).

<table>
<thead>
<tr>
<th>TE rate (g ai/ha)</th>
<th>Timing</th>
<th>Burn</th>
<th>Flail</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>4245 a</td>
<td>3035 a</td>
</tr>
<tr>
<td>400</td>
<td>Fall</td>
<td>4301 a</td>
<td>3058 a</td>
</tr>
<tr>
<td>400</td>
<td>Spring</td>
<td>5855 b</td>
<td>3862 b</td>
</tr>
</tbody>
</table>

Interaction of PGRs and Residue Management
Interaction of PGRs and Nitrogen

TE and N effects on perennial ryegrass seed production (Chastain et al., 2013)

180 kg N/ha

0 kg N/ha

Graph showing the interaction of PGRs and nitrogen on seed yield. The graph includes data from 2010, 2011, and 2012, with seed yields in kg/ha for different nitrogen rates (0, 180 kg/ha). A linear regression equation is also shown: 

\[ y = 189.31x - 34.838 \]

\[ R^2 = 0.9946 \]
The Future?

GA analogs

- This new group of PGRs are not yet used in commercial agriculture and include versions that inhibit stem elongation and promote flowering at the same time.
- Dichloro-methano 16,17-dihydro GA$_5$ (DMDGA$_5$) has shown good potential for growth retardation in turfgrasses.
- 16,17-dihydro GA$_5$ and 16,17-dihydro GA$_5$–13 acetate (DiHGA$_5$ acetate) are experimental modified GAs that reduce stem elongation.
- The next generation of PGRs will likely be even more effective and possibly economical than those presently available.