An introduction to Plant Growth Regulators
MRL Update

• We expect the establishment of the chlormequat chloride tolerance in the USA by mid-May 2018. Chlormequat chloride is the active ingredient in Manipulator.

• Engage Agro will be asking customers for forecasts in anticipation of the establishment of the MRL in the USA. We will also be providing Manipulator training sessions to agronomists, growers and retailers to ensure label compliance.

• In the event the tolerance is not established in time for application, Engage Agro will not release additional product to the distribution channel.

• Always check with your buyer before applying any crop protection product.
Agenda

• Introduction – What are PGR’s?
• Understanding Plant Hormones
• PGR’s in Cereal Production
• How PGR’s work in Cereal crops
• PGR’s For Canada
  – Manipulator Introduction
• Wheat Growth Stages (GS/30-32)
• Manipulator application guidelines
• Discussion / Q&A
What are PGR’s?

- “plant growth regulators affect the balance of plant hormones in treated plants”
  

- PGR’s benefit crop production by modifying the balance of plant hormones

http://www.flowerbulbs.cornell.edu/forcing/lily_cultivars/Fangio.htm
Understanding Plant Hormones

What are Plant Hormones?

- Signaling molecules that regulate plant growth and development
- They are NOT nutrients, but naturally occurring chemicals that promote and influence the growth, development and differentiation of cells and tissues in plants

![Ethylene molecule](https://example.com/ethylene.png)

![Plant structures](https://example.com/plant_structures.png)
Understanding Plant Hormones

- Five “Classical” Plant Hormones
  - Auxins
  - Cytokinins
  - Gibberellins  \(\text{Stimulate plant growth}\)
  - Abscisic Acid
  - Ethylene \(\text{Inhibit plant growth}\)

Abscisic Acid is the hormone which stimulates the closure of stomata.
Understanding Plant Hormones

- Ethylene
  - Gaseous compound
  - Stimulates senescence
  - Stimulates release of dormancy
  - “Triple response” – stunting of growth, twisting of plants, abnormal thickening of stems
  - Stimulates fruit ripening
Understanding Plant Hormones

- **Gibberellins**
  - Synthesized in *young* tissues of the *shoot* and developing seed
  - Stimulates stem *elongation* through cell division and elongation
  - Gibberellins production is highest during *periods of rapid growth*. 
PGR’s in Cereal Production

Why PGR’s -> Reduced Lodging

- PGRs are used on cereals to prevent lodging by helping plants develop shorter, thicker, stronger stems.

- PGR’s are sprayed on the crop in the same way as a herbicide or fungicide.
PGR’s in Cereal Production

Why PGR’s -> Reduced Lodging

- Effects of lodging →
  - Yield loss
    - Reduction of photosynthetic capabilities of the plant
    - Interference with the transport of nutrients and moisture from the soil
  - Uneven maturity
  - Loss of grain quality
  - Ease of harvesting

- Factors that cause Lodging in cereal crops →
  - Cultivar susceptibility
  - Weather
  - Crop Management
    - Fertility
    - Seeding rates

“Lodging is reported to be the most limiting factor in attaining high yields from increased nitrogen fertilization”
(2008 Alberta Agriculture and Rural Development Lodging of Cereal Crops)
How PGR’s work in Cereal crops

• Cereals plant growth regulators fall into two main groups related to their mode of action.

  • Ethylene releasing compounds
    • 2-chloroethyl phosphonic acid - ethephon
    • Ethephon is slightly acidic but when absorbed into the more neutral cells/cytoplasm ethephon breaks down into ethylene – inhibiting stem elongation
    • eg: Ethrel/Cerone

  • Inhibitors of gibberellin biosynthesis
    • anti-gibberellins

• In Canada a PGR which claims to reduce lodging must be registered with the PMRA, **efficacy testing must be done** prior to registration to prove the PGR works.
  • PGR’s which claim to increase growth are regulated by the CFIA, the same as fertility products
How PGR’s work in Cereal crops

- Ethylene releasing compounds

- Essentially add the hormone ethylene onto the plant

- Reduce height and thicken stems when applied within a narrow application window
  - *may harm the plant when applied outside of their application window

- Excellent results to reduce “neck snapping”
Anti-gibberellin compounds

Gibberellin biosynthesis

Chlormequat: Manipulator, Cycocel etc...

Triazoles: used in OSR/canola in the UK

Trinexapac-ethyl: Moddus, Palisade
Prohexadione-Ca: Apogee, Canopy

Newest group of growth retardants: no commercial products available

How PGR’s work in Cereal crops

- **Anti-Gibberellin Products**
  - reduce gibberellin production which reduces plant height and thickens stems
  - significantly reduces the risk of lodging and yield loss in cereal grains

- **Trinexapac-ethyl & Prohexadione Ca**
  - Trinexapac-ethyl & Prohexadione Ca reduce gibberellic acid (GA) production **late** in the biosynthesis of GA, and has a **short** residual activity. Trinexapac ethyl is often tank mixed with Chlormequat because they are complimentary.

- **Chlormequat**
  - Chlormequat reduces gibberellic acid (GA) production **early** in the biosynthesis of GA, and has a **long** residual activity. Since its introduction for use in 1965, Chlormequat Chloride has become the standard for lodging control in cereals.
## PGR’s in the UK

### Plant Growth Regulator Use in the UK

<table>
<thead>
<tr>
<th>Crop</th>
<th>% receiving PGR</th>
<th>Apps/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>winter wheat</td>
<td>89</td>
<td>1.7</td>
</tr>
<tr>
<td>winter barley</td>
<td>77</td>
<td>1.4</td>
</tr>
<tr>
<td>winter oats</td>
<td>78</td>
<td>1.4</td>
</tr>
</tbody>
</table>

75% of PGR applications contain chlormequat

2006 - Department for the Environment Food and Rural Affairs, London
## Comparison of standard PGR’s used in Europe

<table>
<thead>
<tr>
<th>Anti-gibberellin PGR’s</th>
<th>Unformulated Chlormequat</th>
<th>Trinexapac ethyl &amp; Prohexadione CA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mode of action</strong></td>
<td>Inhibits <em>early</em> stages of gibberellin biosynthesis</td>
<td>Inhibits <em>late</em> stages of gibberellin biosynthesis</td>
</tr>
<tr>
<td><strong>Minimum temperature</strong></td>
<td>8 ° C</td>
<td>10 ° C</td>
</tr>
<tr>
<td><strong>On set of action</strong></td>
<td>Slow</td>
<td>Fast</td>
</tr>
<tr>
<td><strong>Residual activity</strong></td>
<td>Long</td>
<td>short</td>
</tr>
<tr>
<td><strong>Application widow</strong></td>
<td>GS 23-31 (2-6 leaf stage)</td>
<td>GS 30-32 (5-6 leaf stage)</td>
</tr>
</tbody>
</table>

Source: Wilhelm Rademacher - Control of Lodging in Intense European Cereal Production

<table>
<thead>
<tr>
<th>Ethylene releasing compounds</th>
<th>Ethephon</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mode of action</strong></td>
<td>Releases ethylene $\rightarrow$ which can cause stunting of growth, and abnormal thickening of stems</td>
</tr>
<tr>
<td><strong>Minimum temperature</strong></td>
<td>15 ° C</td>
</tr>
<tr>
<td><strong>Application widow</strong></td>
<td>GS 37-45 (early flag to swollen-boot stage)</td>
</tr>
</tbody>
</table>

Source: Cerone® product label
Comparison of standard PGR’s used in Europe

• Chlormequat is the standard product used in Europe across most cereal crops

• Trinexapac ethyl, Prohexadione CA and Ethephon are used in specific situations depending on growing conditions.

  – Example:
  • Trinexapac ethyl is a strong barley PGR but with a narrow window of application
  • Growers will use Trinexapac ethyl on their barley and Chlormequat on their wheat because of wider application flexibility
Why is there so much interest in PGR’s now?

• In PGR’s with older formulations, application timing is very critical.
  • If they aren’t applied at the right time, results are not beneficial;
  • In Canadian growing conditions, this window can be as short as a few days.

• PGR’s with older formulations require temperatures to be above 8° C, or they won’t work
  • This is part of the reason we haven’t seen much PGR use in Canadian cereal production
Formulation:

- Chlormequat chloride (620 g/L) + Low temperature activators + Safeners
- Suspension concentrate (SC)
- Systemic

Key Features:

- Performance not affected by temperature
  - Designed to work as low as 1°C
  - Safening system

- Wide window of application
  - GS 12-39 (2-3 leaf stage to flag)

- Excellent tank mix compatibility
The dark green area was the section treated with MANIPULATOR™

Dark green means it has a higher yield potential
PGR application timing on wheat
Manipulator Application Timing

1. **Optimum timing** (~ 5 to 6 leaf) – Growth Stage 30 - 32:
   - Excellent results compared to untreated.

2. **Flag leaf** Growth Stage 39
   - Very good results compared to untreated.

3. **Herbicide Timing** (3 to 4 leaf, 1 tiller) – Growth Stage 21 - 29:
   - Good results compared to untreated.

   - **If you want to avoid a separate pass →**

     - Tank mixing with a flag leaf fungicide shows better PGR efficacy than herbicide timing

     - We do not recommend applying a flag leaf fungicide at GS 30-32, as data shows that early fungicide applications are not as effective
Staging GS- 30

5 -6 leaf, 1-2 tillers
Staging GS 30-32

Pull a sample which represents the average growth stage of the field. The wheat in this picture is at GS 30.
Staging GS 30-32

Identify the main stem.
This stem is usually the largest with the thickest stem. This plant is in GS 30.
Remove the tillers.
Staging GS 30-32

Cut the roots off at the base of the plant, then make a lateral cut from the base of the stem.
Identify the head. If the head is more than 1 cm above the ground, and the first node is not visible, the plant is in GS 30.

Note ➔ this wheat plant is entering GS 30.
Staging GS 30-32

If the head is 1 cm above the first visible node, the plant is in GS 31.
If the head is 1 cm above the second node, the plant is in GS 32.
Manipulator Trial Results - 2014

Small Plot Trial: NARF - Melfort, SK

- Untreated
- GS21 Herbicide timing
- GS31 5-6 leaf stage
- GS39 Flag Leaf stage

Bar chart showing height (cm) and yield (bu/ac) for different stages.

Legend:
- Height (cm)
- Yield (bu/ac)
Manipulator Trial Results - 2013

Spring Wheat Trial: IHARF - Indian Head, SK

Height and Yield at 3 different fertility rates and 2 different timings
Manipulator Trial Results - 2014

Spring Wheat Trial: IHARF - Indian Head, SK

Height, Yield and Protein at 3 different fertility rates and 3 different PGR timings
Manipulator Trial Results - 2015

Spring Wheat Trial: IHARF - Indian Head, SK

Height, Yield and Protein at 3 different fertility rates and 3 different PGR timings
Manipulator internodes

Stage: Awns just visible (GS 49) - 17 days after application

Manipulator

untreated

1st node location

2nd internode length
Application Guidelines

• Timing
  – GS 12 – 39
  – 5-6 leaf stage (GS 30 – 31) is ideal

• Rate
  – 1.8L/ha
  – 0.7 L/ac

• Pack size
  – 2 x 10L case
  – 14 ac/jug

• Formulation
  – SC
  – Shake jug before using

• Water volume
  – 100 L/HA or 10 gal/ac

• Rain fast
  – 2 hours in good growing conditions
Wheat Varieties & PGR’s

• Different varieties react differently to applied plant growth regulators.
  – reduction in height and lodging in CPS varieties, in the absence of lodging in the untreated section we do not see a yield benefit.
  – In hard red spring and durum varieties a yield increase was realized even in the absence of lodging

• Smart Phone APP Developed to assist in PGR use.
  – Download it now on the app store!
Manipulator Trial Results - 2014

Note the differences in results with between varieties and classes

14 ac treated plots vs untreated

Yield Difference (bu/ac)
Height Difference (inches)
Fertility across all treatments: 140-38-19-19
Seeding rate: 35 seeds/ft²
Site was hit with hail mid-July resulting in estimated yield losses of 10%
Fertility across all treatments: 140-38-19-19
Seeding rate: 35 seeds/ft²
Site was hit with hail mid-July resulting in estimated yield losses of 10%

Grain yield (bu/ac)

<table>
<thead>
<tr>
<th></th>
<th>CDC Plentiful</th>
<th>CDC Utmost VB</th>
<th>AC Carberry</th>
<th>AC Strongfield</th>
<th>AC Transcend</th>
<th>Elgin ND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>46.36 f</td>
<td>62.9 c</td>
<td>57.53 e</td>
<td>58.92 de</td>
<td>58.87 de</td>
<td>68.84 b</td>
</tr>
<tr>
<td>Manipulator</td>
<td>58.23 e</td>
<td>71.05 b</td>
<td>62.34 cd</td>
<td>67.5 b</td>
<td>68.36 b</td>
<td>78.96 a</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Difference (bu/ac)</th>
<th>% difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDC Plentiful</td>
<td>11.87</td>
<td>22.7</td>
</tr>
<tr>
<td>CDC Utmost VB</td>
<td>8.15</td>
<td>12.2</td>
</tr>
<tr>
<td>AC Carberry</td>
<td>4.81</td>
<td>8.0</td>
</tr>
<tr>
<td>AC Strongfield</td>
<td>8.58</td>
<td>13.6</td>
</tr>
<tr>
<td>AC Transcend</td>
<td>9.50</td>
<td>14.9</td>
</tr>
<tr>
<td>Elgin ND</td>
<td>10.12</td>
<td>13.7</td>
</tr>
</tbody>
</table>

NOTE ➡ the results are significant
Manipulator Trial Results - 2017
Spring Wheat Trial: IHARF - Indian Head, SK

Fertility across all treatments: 140-38-19-19

Seeding rate: 35 seeds/ft²

Site received 5.78 inches of rain throughout the growing season.

<table>
<thead>
<tr>
<th></th>
<th>CDC Plentiful</th>
<th>AAC Jatharia VB</th>
<th>AAC Brandon</th>
<th>CDC Landmark VB</th>
<th>AAC Spitfire</th>
<th>AC Transcend</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Height (cm)</strong></td>
<td>Untreated</td>
<td>Manipulator</td>
<td>Difference</td>
<td>% difference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CDC Plentiful</td>
<td>80.1 cde</td>
<td>74.5 gh</td>
<td>5.6</td>
<td>7.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AAC Jatharia VB</td>
<td>88.9 a</td>
<td>80.8 cd</td>
<td>8.1</td>
<td>9.1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AAC Brandon</td>
<td>77.0 efg</td>
<td>73.6 h</td>
<td>3.4</td>
<td>4.4%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CDC Landmark VB</td>
<td>78.2 def</td>
<td>73.0 h</td>
<td>5.2</td>
<td>6.6%</td>
<td></td>
<td></td>
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<tr>
<td>AAC Spitfire</td>
<td>84.0 b</td>
<td>75.5 fgh</td>
<td>8.5</td>
<td>10.1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC Transcend</td>
<td>87.4 a</td>
<td>81.9 bc</td>
<td>5.5</td>
<td>6.3%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Seeding rate: 35 seeds/ft²

Site received 5.78 inches of rain throughout the growing season.
Spring Wheat Trial: IHARF - Indian Head, SK

Grain Yield (bu/ac)

Fertility across all treatments: 140-38-19-19
Seeding rate: 35 seeds/ft²
Site received 5.78 inches of rain throughout the growing season.

<table>
<thead>
<tr>
<th>Varietal Group</th>
<th>Untreated</th>
<th>Manipulator</th>
<th>Difference</th>
<th>% difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDC Plentiful</td>
<td>58.82d</td>
<td>65.66c</td>
<td>6.8</td>
<td>11.6%</td>
</tr>
<tr>
<td>AAC Jatharia VB</td>
<td>64.92c</td>
<td>70.10b</td>
<td>5.2</td>
<td>8.0%</td>
</tr>
<tr>
<td>AAC Brandon</td>
<td>72.23b</td>
<td>77.93a</td>
<td>5.7</td>
<td>7.9%</td>
</tr>
<tr>
<td>CDC Landmark VB</td>
<td>65.71c</td>
<td>70.62a</td>
<td>4.9</td>
<td>7.5%</td>
</tr>
<tr>
<td>AAC Spitfire</td>
<td>70.97b</td>
<td>79.20a</td>
<td>8.2</td>
<td>11.6%</td>
</tr>
<tr>
<td>AC Transcend</td>
<td>69.82b</td>
<td>77.73a</td>
<td>7.9</td>
<td>11.3%</td>
</tr>
</tbody>
</table>

NOTE ➔ the results are significant (2017 was a dry year)
Manipulator Height Trends
Summary field data 2011 - 2014

**CWRS**

<table>
<thead>
<tr>
<th>Height Reduction</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>5% +</td>
<td>95%</td>
</tr>
<tr>
<td>10% +</td>
<td>83%</td>
</tr>
<tr>
<td>15%+</td>
<td>53%</td>
</tr>
<tr>
<td>20%+</td>
<td>20%</td>
</tr>
</tbody>
</table>

*35 trials

**CPS**

<table>
<thead>
<tr>
<th>Height Reduction</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>5% +</td>
<td>100%</td>
</tr>
<tr>
<td>10% +</td>
<td>67%</td>
</tr>
<tr>
<td>15%+</td>
<td>33%</td>
</tr>
<tr>
<td>20%+</td>
<td>8%</td>
</tr>
</tbody>
</table>

*12 trials
Manipulator Yield Trends
Summary field data 2011 - 2014

**CWRS**

<table>
<thead>
<tr>
<th>Yield Increase</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>5% +</td>
<td>85%</td>
</tr>
<tr>
<td>7.5%+</td>
<td>63%</td>
</tr>
<tr>
<td>10%+</td>
<td>55%</td>
</tr>
</tbody>
</table>

*35 trials

**CPS**

<table>
<thead>
<tr>
<th>Yield Increase</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>5% +</td>
<td>33%</td>
</tr>
<tr>
<td>7.5%+</td>
<td>25%</td>
</tr>
<tr>
<td>10%+</td>
<td>8%</td>
</tr>
</tbody>
</table>

*12 trials
## Manipulator Trial Results

### Combine productivity

<table>
<thead>
<tr>
<th>Location</th>
<th>Variety</th>
<th>Height (cm)</th>
<th>Yield (bu/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossfield</td>
<td>Harvest</td>
<td>103.9 a</td>
<td>110.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>81.3 b</td>
<td>117.70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22.0% Reduction</td>
<td>7.0% Increase</td>
</tr>
</tbody>
</table>

Maps provided by Craig Shand
Manipulator

Field Observations: 2011 - 2017

- Trials are showing yield results even with no lodging
- Trials at flag leaf timing have significant results
- In the absence of height reduction, treated crop still prevented lodging – thicker stems
- After 7 years and over 100 trials:
  - Results are very consistent in intensively managed fields
Summary

• Manipulator →
  – Has a unique formulation
  – Has a wide application widow
  – Works in colder temperatures
  – Research results are showing excellent results.
Shorter – Stronger – Better

• Thank you!
• Please call 1-866-613-3336 if you have any questions
  • www.engageagro.com
## Links to 3rd Party 2015 Research on Manipulator

<table>
<thead>
<tr>
<th>Organization</th>
<th>Research Focus</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Central Research Foundation (Yorkton)</td>
<td>Impact of Manipulator on wheat with differing lodging resistance at high rates of N fertility</td>
<td><a href="http://www.ecrf.ca">www.ecrf.ca</a></td>
</tr>
<tr>
<td></td>
<td>Impact of Manipulator timing and N fertility on wheat lodging and yield</td>
<td></td>
</tr>
<tr>
<td>Indian Head Agricultural Research Foundation (Indian Head)</td>
<td>Optimal Nitrogen rates for wheat with and without Plant Growth Regulators.</td>
<td><a href="http://iharf.ca">http://iharf.ca</a></td>
</tr>
<tr>
<td>Irrigation Crop Diversification Corporation (Outlook)</td>
<td>Demonstration of Plant Growth Regulator Application on irrigated wheat production</td>
<td><a href="http://irrigationsaskatchewan.com/icdc">http://irrigationsaskatchewan.com/icdc</a></td>
</tr>
<tr>
<td>Northeast Agriculture Research Foundation (Melfort)</td>
<td>Optimal Nitrogen Rate with Plant Growth Regulators and Fungicides for Spring Wheat</td>
<td><a href="http://neag.ca/">http://neag.ca/</a></td>
</tr>
<tr>
<td>Wheatland Conservation Area Inc. (Swift Current)</td>
<td>Plant Growth Regulators and N Rates in Durum Wheat</td>
<td><a href="http://wheatlandconservation.ca/home.html">http://wheatlandconservation.ca/home.html</a></td>
</tr>
</tbody>
</table>
References


**MANIPULATOR** is a registered trademark of Engage Agro Corporation

Always read and follow label directions.
NDVI picture of field shown →

- The dark green area was the section treated with MANIPULATOR™
- Dark green means it has a higher yield potential