Plant Growth Regulators for Fine Turf: Cool-Season

GCSAA Seminar, Tuesday February 7, 2017: 1 to 5 pm

Erik Ervin, Ph.D., Virginia Tech
Bill Kreuser, Ph.D., University of Nebraska-Lincoln
Adam Van Dyke, M.S., Professional Turf Solutions

Introductions

- Ervin
- Kreuser
- Van Dyke
- Audience

Today’s Road Map

- PGR Overview and Secondary Effects, Ervin, Kreuser
- Modeling PGR performance with GDDs, Kreuser
- Poa:
  - Control: Ervin, Askew
  - Seedhead suppression: Van Dyke

What is a Plant Growth Regulator?

- A natural or synthetic compound that regulates (inhibits or promotes) plant growth and development
- Made within plants (hormones) or taken up by plants from exogenous sources (soil microbes or human-applied)
- PGR classification system
  - Type I and II (Watschke, 1985)
  - Class A to D (Watschke, 1995)
  - Class A to F (Ervin, 2007)

PGR Classification

Class A) late-step GA inhibitors: TE (1993), foliar
  Prohexadione-Ca (Anuew, 2015)
Class B) early-step GA inhibitors: flurprimidol, pac (1983)
  root
Class C) cell-division inhibitors: mefluidide (1980)
  foliar
Class D) herbicides: glyphosate, etc.
Class E) hormones: ethephon (1999), GA, BA, foliar
Class F) naturally-occurring PGRs: kelp, humics…

Class A Compounds

- Late Inhibition of Gibberellic Acid
  - Final Step in Pathway
- Foliar Absorption
  - Rapid Uptake (15 to 60 Minutes)
  - Effective in Wide Range of Spray Volumes
  - Liquid and Dry Formulations
- Safest PGR
  - Widespread Usage
  - Very safe on C3 Grasses
- 50% Yield Suppression Typical

Common Products

- Trinexapac-Ethyl
- Primo Maxx
- Governor
- Prohexadione-Ca
- Anuew
Class B Compounds

- Early Inhibition of Gibberellic Acid
  - Can disrupt other pathways
- Root Absorption
  - Irrigate in with ¼ inch
- More Phytotoxic
  - Slight Discoloration, Poa annua
  - Widespread usage
- 50% Yield Suppression Typical

Common Products

<table>
<thead>
<tr>
<th>Product</th>
<th>Formulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flurprimidol</td>
<td>Cutless</td>
</tr>
<tr>
<td>Paclobutrazol</td>
<td>TGR</td>
</tr>
<tr>
<td>Paclobutrazol</td>
<td>Trimit</td>
</tr>
</tbody>
</table>

Positive Secondary-Effects

Morphology & Physiology

<table>
<thead>
<tr>
<th>Species</th>
<th>Tillers per 4 inch plug</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primo</td>
<td>No Primo</td>
</tr>
<tr>
<td>Perennial ryegrass</td>
<td>341 203</td>
</tr>
<tr>
<td>Kentucky bluegrass</td>
<td>266 233</td>
</tr>
<tr>
<td>Zoysia</td>
<td>338 301</td>
</tr>
</tbody>
</table>

Primo increases Tiller Density


Class B's also increase tiller density of C3 & C4 turfgrasses
**Primo: Rooting increase for C3?**

Colorado (Ervin)  
PR: no effect  
KBG: no effect

Auburn (Walker, Guertal)  
CB: no effect  
Iowa State (Christians)  
CB: no effect

Virginia Tech (Schmidt, Zhang)  
CB: no effect  
Kansas State (Fry, Marcum)  
PR: no effect  
TF: no effect

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**Root restriction on Tifeagle due to Pac**

*0.25 lb ai = 16 oz/A*

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**Class A & B PGRs: Physiological Effects**

- Photosynthesis, carbohydrates, cytokinins
- Water Use & Drought
- Shade Response
- Disease impacts
- Heat & Cold
- Wear Tolerance / Divot recovery / Ball Roll
Photosynthesis and carbohydrate dynamics

- Photosynthesis is key energy generating process
- Does GA inhibition and restricted shoot elongation have any effect on photosynthesis?
- With less carbohydrates fueling shoot elongation, is energy conserved?
- Consequences for turf health/quality?

**Cutless & Embark temporarily reduce PS**

<table>
<thead>
<tr>
<th>PGR</th>
<th>4 DAT</th>
<th>8 DAT</th>
<th>16 DAT</th>
<th>32 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>34.7 a</td>
<td>7.1 a</td>
<td>12.0 a</td>
<td>14.8 a</td>
</tr>
<tr>
<td>Embark</td>
<td>15.4 b</td>
<td>3.2 b</td>
<td>11.1 a</td>
<td>13.6 a</td>
</tr>
<tr>
<td>Cutless</td>
<td>18.0 b</td>
<td>3.9 b</td>
<td>4.8 b</td>
<td>17.7 a</td>
</tr>
</tbody>
</table>

Han and Fermanian (HortSci, 1998) also reported 15-30% TNC increases at 2- and 4-wk after TE treatment

**Total nonstructural carbohydrates (TNC) as influenced by trinexapac ethyl in bermudagrass**

Gaussoin & Branham, Michigan State, 1997

**Total nonstructural carbohydrates (TNC) as influenced by trinexapac ethyl in bentgrass**


**Available carbohydrates increased with sequential apps**

Photosynthesis: leaf area basis, KBG

Beasley & Branham, Crop Science, 2007

No PS change for TE; slight decrease early on for Pac, then an increase

Cutless & Embark temporarily reduce PS

Beasley & Branham, Crop Science, 2007

No change to slight increase in Photochemical Efficiency due to Primo

**Primo & ET**
- ET reduced on Primo-treated KBG: 5 out of 34 weeks = 5% decrease in ET (1.10”/wk vs. 1.05”/wk)
- Marcum (KSU) reported Primo reduced Tall fescue ET by 11% over 6 weeks
- King (Australia) reported Primo reduced KBG/TF mix ET by 20% over 4 weeks

**Primo and drought/salt stress**
- Jiang & Fry (1998) reported Primo-treated PR resisted wilting and maintained higher quality during GH & field dry-down trials
- Baldwin, Lui, McCarty (2006) reported bi-weekly Primo apps improved salt tolerance (12-26 dS/m) and gave 25% greater root mass of Champion & Tifeagle

**Paclobutrazol, ET, and Drought**
- Marcum & Jiang (1997) reported no effect of Pac on tall fescue ET over 6 weeks
- Koski (1997) reported no difference due to Pac in wilting resistance or drought recovery of creeping bentgrass
- Jiang & Fry (1998) reported no soil moisture depletion differences due to Pac on PR in GH and field dry-down trials

**Shade signals altered growth**
- Increase in far-red wavelengths of light signal:
  - GA production which stimulates stem and leaf cell elongation at the expense of tillering

<table>
<thead>
<tr>
<th>Seedling ht (cm)</th>
<th>GA1-level</th>
</tr>
</thead>
<tbody>
<tr>
<td>full sun</td>
<td>6</td>
</tr>
<tr>
<td>50% sun</td>
<td>10</td>
</tr>
<tr>
<td>10% sun</td>
<td>18</td>
</tr>
</tbody>
</table>

**Primo and Shade**
- Sequential Primo use a definite Best Management Practice on Shaded Golf Course Surfaces
  - ↓ GA
  - ↓ leaf elongation
  - ↑ carbs
  - Maintain density longer

**Meyer Zoysia shoot growth response to shade & Primo**
- Works on C3 and C4 grasses

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Gawronska et al., 1996, Plant Cell Phys 36(7):1361

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Gawronska et al., 1996, Plant Cell Phys 36(7):1361
Primo increases *Zoysia matrella* shade tolerance.

**Diamond Zoysia: October 17, 2008 – 147 DAI**

90% Shade

90% Shade
Trinexapac-ethyl

Atkinson, McCarty, Lui @ Clemson: Primo at 1.5 oz/A/wk

**80% Shaded Bent/Poa Fairway**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>End Quality 1-9 scale</th>
<th>Root Strength kg force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>3.1 b</td>
<td>8.5 b</td>
</tr>
<tr>
<td>Primo</td>
<td>5.5 a</td>
<td>16.3 a</td>
</tr>
<tr>
<td>Banner</td>
<td>5.3 a</td>
<td>11.3 ab</td>
</tr>
<tr>
<td>CPR</td>
<td>3.0 b</td>
<td>8.0 b</td>
</tr>
</tbody>
</table>
90% shaded KBG, effects of Cutless

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Quality</th>
<th>Verdue</th>
<th>Root wt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>4.5</td>
<td>0.325</td>
<td>0.18</td>
</tr>
<tr>
<td>Cutless 0.5 lb/A</td>
<td>6.2</td>
<td>0.538</td>
<td>0.15</td>
</tr>
<tr>
<td>Cutless 1.0 lb/A</td>
<td>4.7*</td>
<td>0.655</td>
<td></td>
</tr>
</tbody>
</table>

*High rate caused phyto

Shade and Class A & B PGRs

- This is a sound physiological approach to improving C3 and C4 shade tolerance
- Get on a program and stay on it, along with:
  - Reduced N fertilization
  - Reduced irrigation amounts
  - Slightly raised mowing height
- Primo safer than Cutless or Trimmit

Class A & B PGR Effects on Disease

- Class A & B PGRs are structurally similar to DMI fungicides, so have mild disease control activity
- They also reduce growth which may allow contact & systemic fungicides to stay in & on the plant longer, prolonging control
- Once disease is present, some have shown that PGRs may slow recovery from the disease

Interaction of N & PGRs on Dollar Spot

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate oz/M</th>
<th>Dollar Spot Low N</th>
<th>Dollar Spot High N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>0</td>
<td>75 (infection centers)</td>
<td>24</td>
</tr>
<tr>
<td>Cutless</td>
<td>0.37</td>
<td>29</td>
<td>13</td>
</tr>
<tr>
<td>Trimmit</td>
<td>0.37</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>Primo</td>
<td>0.53</td>
<td>51</td>
<td>23</td>
</tr>
</tbody>
</table>

From: Branham & Calhoun

Dollar Spot Incidence on Penncross at 0.5 lb N/M/month and treated monthly at label rates

Zhang & Schmidt. 2000. JASHS. 125: 47
Burpee, Georgia studies on DS and Rhizoc

- Time after spraying to see 5% Dollar Spot in Bent
  - Daconil alone: 25 days
  - Daconil + Primo: 26 days
  - Daconil + Cutless: 29 days
  - Daconil + Trimmit: 29 days

- Rhizoctonia brown patch on bentgrass
  - Cutless and Primo: no effect
  - Trimmit: reduced disease from 1 to 3 weeks after treatment in 1 of 2 years.

Disease Summary

- Any control appears to be disease-specific
  - No research info other than DS & Rhizoc

- They can help with DS suppression and slightly lengthen fungicide activity

- No evidence of an increase in disease due to Class A & B PGRs

- Primo is weak on DS

Class A & B PGRs and Abiotic Stress Tolerance

- Good data indicating Primo improves heat and drought tolerance of bentgrass

- Effect on cold hardiness is less clear

- Class B use on heat, drought, or cold stressed grasses appears to be more risky due to sterol inhibition

McCann & Huang, Rutgers, 2008: Bent response to Drought & Primo

<table>
<thead>
<tr>
<th>Treatment</th>
<th>5 days Dry-down</th>
<th>12 days</th>
<th>19 days</th>
<th>26 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>0.80</td>
<td>0.62</td>
<td>0.49</td>
<td>0.18</td>
</tr>
<tr>
<td>Primo 5 apps</td>
<td>0.80</td>
<td>0.79</td>
<td>0.77</td>
<td>0.52</td>
</tr>
</tbody>
</table>

Day 12 Soil Moisture:
- Primo = 8.3%
- Check = 3.8%

Primo effects (3 apps) on heat (95 F) & drought-stressed (dry-down) creeping bentgrass


Primo (3 apps) effects on heat (95 F) & drought-stressed (dry-down) creeping bentgrass

Chlorophyll content

Carbohydrate content

Leaf zeatin riboside (ZR) content as influenced by trinexapac ethyl in creeping bentgrass

Repeated Primo apps resulted in an increase in leaf tissue cytokinin content

Zhang & Schmidt, Virginia Tech, 2000: Bent response to 6 wk drought (-0.5 MPa)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>SOD antioxidant</th>
<th>Photochemical Efficiency</th>
<th>Root wt mg/pot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primo 0.125 oz/mo</td>
<td>22.9 a</td>
<td>0.50 a</td>
<td>20 b</td>
</tr>
<tr>
<td>Banner 0.75 oz/mo</td>
<td>19.1 b</td>
<td>0.44 a</td>
<td>62 a</td>
</tr>
<tr>
<td>Check</td>
<td>14.8 c</td>
<td>0.36 b</td>
<td>27 b</td>
</tr>
</tbody>
</table>

Pre-survey: Are you concerned that repeated PGR use reduces divot recovery or wear tolerance?

YES: 35%
NO: 65%

PGRs and Divot Recovery: Calhoun, MSU

<table>
<thead>
<tr>
<th>PGR</th>
<th>Days to 90% Divot Closure, Bentgrass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>34</td>
</tr>
<tr>
<td>Cutless 16 oz/A</td>
<td>32</td>
</tr>
<tr>
<td>Trimmit 16 oz/A</td>
<td>34</td>
</tr>
<tr>
<td>Primo 22 oz/A</td>
<td>32</td>
</tr>
</tbody>
</table>

Effects of Plant Growth Regulators on ‘Penncross’ Lateral Divot Recovery into June Cup Cuttings

Yelverton, NC State

Sequential TE apps result in more leaf cytokinins
= more tillering
= delay of senescence or stay-green effect
PGRs and Ball Roll Distance

- Golfer perception of green speed study, Nikolai et al., Mich State

1. "Golfers cannot detect differences in green speed of 6 inches or less"
2. "While the majority can detect differences in speed of up to a foot, as speed increases, their ability to detect 1-foot differences diminishes."

PGRs and Ball Roll Distance, Michigan State

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate &amp; Interval</th>
<th>Av. Deviation from Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primo</td>
<td>0.1; 7-d</td>
<td>+8.9&quot;</td>
</tr>
<tr>
<td>Primo</td>
<td>0.15; 14-d</td>
<td>+2.1&quot;</td>
</tr>
<tr>
<td>Primo</td>
<td>0.25; 21-d</td>
<td>+3.5&quot;</td>
</tr>
<tr>
<td>Trimmit</td>
<td>0.18; 14-d</td>
<td>+10.7&quot;</td>
</tr>
<tr>
<td>Trimmit</td>
<td>0.18; 21-d</td>
<td>+10&quot;</td>
</tr>
</tbody>
</table>

Av. of 77 measurements over 2006 season; Penn A4 at 0.125"

PGRs and Ball Roll Distance at 28 d after app

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Oz/M per 28 d</th>
<th>June 11</th>
<th>Aug 6</th>
<th>Oct 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td></td>
<td>8’ 8”</td>
<td>8’ 10”</td>
<td>8’ 7”</td>
</tr>
<tr>
<td>Trimmit</td>
<td>0.18</td>
<td>8’ 6”</td>
<td>8’ 7”</td>
<td>9’ 1”</td>
</tr>
<tr>
<td>Trimmit</td>
<td>0.37</td>
<td>8’ 1”</td>
<td>8’ 3”</td>
<td>8’ 11”</td>
</tr>
<tr>
<td>Trimmit</td>
<td>0.73</td>
<td>8’</td>
<td>8’ 3”</td>
<td>8’ 10”</td>
</tr>
<tr>
<td>Primo</td>
<td>0.12</td>
<td>8’ 5”</td>
<td>8’ 7”</td>
<td>8’ 8”</td>
</tr>
</tbody>
</table>

Problem: close to or during rebound phase
Fagerness et al., NCState, 2000 on Penncross

Studied PGR's Effect on Ball Roll

- Research Questions & Objectives
  1. When are putting greens fastest?
  2. How Do PGRs affect ball roll distance
     1. Within a day?
     2. Over the course of 10 days?
  3. Does Clipping Yield influence Ball Roll Distance?

Details of the Experiment

- Bent/Poa Putting Green
- Treatments
  - Primo (0.125 oz/M @ 200GDD)
  - Trimmit & Cutless (0.25 oz/M @ 300GDD)
- Measured
  - Clipping Yield Daily
  - Ball Roll After Mowing, After Rolling, Afternoon

Kreuser & Rossi, Cornell research
When Are Putting Greens Fastest?

- After Mow
- After Roll
- Afternoon

Average Ball Roll Distance

Days After Civitas Application

Ball Roll Declined From Morning to Afternoon

Kreuser & Rossi, Cornell research

When Are Putting Greens Fastest?

- After Mow
- After Roll
- Afternoon

Average Ball Roll Distance

Days After Civitas Application

Ball Roll Declined as Quality Declined 9 and 10 DAT

Too Much of a Good Thing ….

Kreuser & Rossi, Cornell research

Primo increased ball roll a little

Golfers Can’t Perceive Increase Less Than 6 Inches

Control Primo

Average Ball Roll Distance

Days After Civitas Application

Kreuser & Rossi, Cornell research

Trimmit and Cutless increased ball roll after rolling but not sustained into Afternoon

After Mow After Roll Afternoon

Kreuser & Rossi, Cornell research

Ball roll Not related to clipping yield

Average ball roll distance

Yield

Kreuser & Rossi, Cornell research

Ball Roll Summary.....

- Ball roll greatest 4 to 5 days after daily rolling
- As quality declined, ball roll declines
- PGRs had a small benefit on ball roll distance
- Ball roll not directly related to clipping yield
- Management Strategies:
  - Grow healthy turfgrass
  - Roll once daily prior to an event
  - Use PGRs to increase plant health despite variable effect on ball roll
Growing Degree Day Models Predict PGR Performance

Bill Kreuser, Ph.D.
@UNLTurf
http://turf.unl.edu

The Biggest Challenge with PGRs

It’s Hard to Know if They Are Working

Soil nitrogen mineralization confounds PGR performance

• Absolute clipping yield vs relative yield
• Greatest in warm and moist soils

Real World Mineralization Example

2015 PGA Championship

• Prior to PGA – Dry, warm, little nitrogen fertilizer
• Friday before – 0.75” rain and warm weather during tournament
• Rapid turf growth during week of the tournament

Labels Can Be Imprecise – Good and Bad

Example: 2008 PGR Label

Rate can be legally increased 100%

It can be re-applied as often as desired

Today’s (full) Road Map

• PGR Misconceptions
• Modeling PGR Performance
  – Cool-season putting greens
  – Warm-season putting greens (cutting edge results)
  – Cool-season fairways and athletic fields (new)
• Challenges predicting the amount of suppression/rebound
• GreenKeeper Demonstration
PGR Metabolism Increases with Temp

• Decreased Efficacy During Summer
  – Lickfelt et al. (2005)
  – Beasley and Branham (2007)

• TE Metabolism Directly Related to Air Temperature (Beasley and Branham, 2005)
  – 6.4 Day Half Life at 18°C (64°F)
  – 3.1 Day Half Life at 30°C (86°F)

**Doubling temperature (°C) roughly doubled PGR breakdown (metabolism)**

Goals for a PGR program

• Sustain growth suppression for the season
  – Plant health, green speed, nutrient requirements

• Avoid too much growth suppression
  – Poor recovery, phytotoxicity

• Avoid extra applications
  – Wastes time and product (money)

Growing Degree Day Models in Turf

• Environmental models to predict pest emergence or plant growth stage
  – Seedheads
  – Insects
  – Early-season dollar spot

• Cold-blooded organisms
Growing degree days (GDD) factors in air temp

- Can these heat unit models (GDDs) predict the difference in PGR response in summer?

- Calculating GDD

<table>
<thead>
<tr>
<th>Date</th>
<th>High (F)</th>
<th>Low (F)</th>
<th>Average (F)</th>
<th>Average (C)</th>
<th>GDD (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/1/16</td>
<td>75</td>
<td>50</td>
<td>63</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>5/2/16</td>
<td>72</td>
<td>47</td>
<td>60</td>
<td>15</td>
<td>32</td>
</tr>
<tr>
<td>5/3/16</td>
<td>85</td>
<td>65</td>
<td>75</td>
<td>24</td>
<td>56</td>
</tr>
<tr>
<td>5/4/16</td>
<td>93</td>
<td>72</td>
<td>83</td>
<td>28</td>
<td>84</td>
</tr>
</tbody>
</table>

Tools out there (GreenKeeperApp.com)

Creating PGR GDD Models

**Horrible Job**

1) Apply PGRs to turf
2) Collect a ton of clippings
   40,000+ samples
3) Fit the relative clipping yield to weather data
4) Estimate re-application intervals from models

**Proof of Concept:** Primo Maxx on creeping bentgrass greens 2008-2010

**Primo Maxx:** Four Week Applications

**Primo Maxx:** 800 GDD Re-applications

**Primo Maxx:** 400 GDD Re-applications

Growth rates vs GDD after application

- Primo Maxx Re-Applied Once GDD = 800 GDD Model Then Reset to Zero
- Primo Maxx Re-Applied Once GDD = 400GDD Model Then Reset to Zero

**230 GDD**
Primo Maxx: 200 GDD Re-applications

200 GDD is a good conservative goal

<table>
<thead>
<tr>
<th>High/Low Temp (F)</th>
<th>Daily GDD (C)</th>
<th>Days to 200 GDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>50/70</td>
<td>15.5</td>
<td>15 days</td>
</tr>
<tr>
<td>60/80</td>
<td>21.1</td>
<td>9 days</td>
</tr>
<tr>
<td>70/90</td>
<td>26.7</td>
<td>7 days</td>
</tr>
</tbody>
</table>

University of Minnesota research supports 200 GDD interval

Tested lower Primo Maxx Rates
- 0.13, 0.094, 0.063, 0.031 fl oz/M

- 200 GDD re-application interval still required at lower rates
  - Suggest 200 “safe” interval
- Lowest rates provided less clipping yield suppression

Re-applying a PGR when only half has been broken down leads to PGR accumulation

Example: Apply Primo at 1, 2, 3 Half-lives (5 oz/A)

For Primo Maxx = 1 half-life is ~100GDD

Application rate had minimal impact on duration of suppression of Primo

Over-regulation growth possible if apps are sooner than half the “ideal” interval

Applying Primo Maxx at 100 GDD increased growth suppression

Primo Maxx is applied sooner than it is breaking down
Anuew PGR on the block

A.I.: Prohexadione-Ca
PGR Class: Class A – Late GA Inhibitor
Uptake: Foliar
Formulation: Extruded granule (dry product)
Rate Range: 1.8 to 29.1 oz/acre (0.04 to 0.67 oz/M)
1.8 to 7.25 oz/acre – Cool-season greens
7.25 to 14.5 oz/acre – Warm-season greens

Prohexadione-Ca performance on greens

Model Period: 840
Amplitude: 35%
Ideal interval: 280 GDD

Anuew re-applied at 300 GDD

- Conservative interval is 250 GDD
- Visual quality improved similar to Primo Maxx

Prohexadione-Ca (Anuew) lasts slightly longer than trinexapac-ethyl

Goal: Develop GDD models for all PGRs

Questions:
- Can root absorbed Class B PGRs be modeled?
- Do Class B PGRs have a strong rebound?
- Can mixing PGRs improve control?

Objective:
Create GDD models for Class B PGRs

2014 Paclobutrazol in Nebraska

11 oz/A (0.25 oz/M)
L-93

Amplitude: 45%***
Period: 890***
Adj R²: 0.74
Ideal Interval: 300 GDD
Paclo. GDD impacts annual bluegrass

325-350 GDD (Base 0°C) Maintains Bent Suppression Hurts Poa Annua

Low rate vs high rate Trimmit 2SC

5.5 oz/A (0.13 oz/M) 16 oz/A (0.38 oz/M)

31% Suppression 53% Growth Suppression
270 GDD Interval 310 GDD Interval

Low rate vs high rate Cutless 50W

2.0 oz/A (0.05 oz/M) 8.0 oz/A (0.18 oz/M)

20% Suppression 32% Suppression
200 GDD Interval 270 GDD Interval

Low rate vs high rate Legacy

4.8 oz/A (0.11 oz/M) 9.6 oz/A (0.22 oz/M)

25% Suppression 41% Growth Suppression
270 GDD Interval 300 GDD Interval

Low rate vs high rate Musketter

12 oz/A (0.27 oz/M) 22 oz/A (0.51 oz/M)

28% Suppression 45% Growth Suppression
290 GDD Interval 290 GDD Interval

Rebound phase doesn’t always occur

Texas heat may have reduced the rebound
Future Research

Texas Tech
Putting Green Research
Comparing PGR Performance

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>Common Name</th>
<th>Growth Suppression</th>
<th>Duration of Effect</th>
<th>Ideal GDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trinexapac-ethyl</td>
<td>Primo Maxx</td>
<td>20%</td>
<td>800 GDD</td>
<td>280 GDD</td>
</tr>
<tr>
<td>Paclobutrazol</td>
<td>Trimmit</td>
<td>30-50%*</td>
<td>850-950 GDD*</td>
<td>280-310 GDD*</td>
</tr>
<tr>
<td>Flurprimidol</td>
<td>Cutless</td>
<td>20-30%*</td>
<td>600-800 GDD*</td>
<td>210-270 GDD*</td>
</tr>
<tr>
<td>Anuew</td>
<td>Prohexadione- Ca</td>
<td>25%</td>
<td>840 GDD</td>
<td>280 GDD</td>
</tr>
<tr>
<td>Flurprimidol + Trinexapac-ethyl</td>
<td>Legacy</td>
<td>20-35%*</td>
<td>810-910 GDD*</td>
<td>270-300 GDD*</td>
</tr>
<tr>
<td>Flurprimidol + Paclobutrazol + Trinexapac-ethyl</td>
<td>Musketeer</td>
<td>25-40%*</td>
<td>880 GDD</td>
<td>290</td>
</tr>
</tbody>
</table>

* Range from low to high application rate

Collaborative PGR Research

- Not many great bermudagrass sites in Neb.
- Models successfully developed in NC, TN, MS, and AL in 2016 and 2017

Primo Maxx Performance on UD

Warm season GDD Models Use a Base Temperature of 10C (not)

GDD Models Looking Promising

- Both rates suppressed clipping yield by 80-90%
- Peak suppression occurred 100 GDD after application
- Intervals around 200 GDD (similar to cool-season but different base temperature)
- Differences in rebound at different times of the year

Anuew Performance on Champion

8 oz/Acre Rate

16 oz/Acre Rate
Primo and Anuew Performance on UD

• Intervals are very similar to those of cool-season turf
  – Need to use a base temperature of 10°C vs 0°C
• Substantial amounts of growth suppression possible
  – Increased green speed
  – Increased disease
  – Weekly, low-rate, applications can lead to over-regulation

Today’s Road Map

• PGR Misconceptions
• Modeling PGR Performance
  – Cool-season putting greens
  – Warm-season putting greens (cutting edge results)
  – Cool-season fairways and athletic fields (new)
• Challenges predicting the amount of suppression/rebound
• GreenKeeper Demonstration

Bentgrass Fairways

Wide Range of Rates

<table>
<thead>
<tr>
<th>Product</th>
<th>Rate (oz/A)</th>
<th>Liquid/dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
<td>na</td>
</tr>
<tr>
<td>Anuew</td>
<td>7</td>
<td>Dry</td>
</tr>
<tr>
<td>Anuew</td>
<td>15</td>
<td>Dry</td>
</tr>
<tr>
<td>Cutless MEC</td>
<td>25</td>
<td>Liquid</td>
</tr>
<tr>
<td>Cutless MEC</td>
<td>49</td>
<td>Liquid</td>
</tr>
<tr>
<td>Legacy</td>
<td>10</td>
<td>Liquid</td>
</tr>
<tr>
<td>Legacy</td>
<td>20</td>
<td>Liquid</td>
</tr>
<tr>
<td>Muskeeter</td>
<td>18</td>
<td>Liquid</td>
</tr>
<tr>
<td>Muskeeter</td>
<td>30</td>
<td>Liquid</td>
</tr>
<tr>
<td>Primo Maxx</td>
<td>11</td>
<td>Liquid</td>
</tr>
<tr>
<td>Primo Maxx</td>
<td>33</td>
<td>Liquid</td>
</tr>
<tr>
<td>Trimmit 2SC</td>
<td>16</td>
<td>Liquid</td>
</tr>
<tr>
<td>Trimmit 2SC</td>
<td>32</td>
<td>Liquid</td>
</tr>
</tbody>
</table>

Low rate vs high rate Anuew

• Low rate: 7.0 oz/A (0.05 oz/M)
  • 60% Suppression
  • 350 GDD Interval
• High rate: 15.0 oz/A (0.18 oz/M)
  • 75% Suppression
  • 380 GDD Interval

Low rate vs high rate Primo Maxx

• Low rate: 11 oz/A (0.11 oz/M)
  • 55% Suppression
  • 350 GDD Interval
• High rate: 33 oz/A (0.22 oz/M)
  • 80% Growth Suppression
  • 380 GDD Interval
Low rate vs high rate Trimmit 2SC

16 oz/A (0.13 oz/M)  
32 oz/A (0.38 oz/M)

70% Suppression  
480 GDD Interval

80% Growth Suppression  
600 GDD Interval

Phytotoxicity is worse at peak suppression

- PGRs with more growth suppression have more phytotoxicity
- High application rates increase suppression and phytotoxicity
- Lack of phytotoxicity tells you something about the amount of growth suppression

More growth suppression = more phyto

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>Common Name</th>
<th>Growth Suppression</th>
<th>Ideal GDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trinexapac-ethyl</td>
<td>Primo Maxx</td>
<td>55-80%</td>
<td>350-380</td>
</tr>
<tr>
<td>Paclobutrazol</td>
<td>Trimmitt</td>
<td>70-80%</td>
<td>480-640</td>
</tr>
<tr>
<td>Flurprimidol</td>
<td>Cutless</td>
<td>30-40%</td>
<td>380-410</td>
</tr>
<tr>
<td>Anuew</td>
<td>Prohexadione-Ca</td>
<td>60-75%</td>
<td>350-380</td>
</tr>
<tr>
<td>Flurprimidol + Trinexapac-ethyl</td>
<td>Legacy</td>
<td>40-70%</td>
<td>320-390</td>
</tr>
<tr>
<td>Flurprimidol + Paclobutrazol + Trinexapac-ethyl</td>
<td>Musketeer</td>
<td>55-70%</td>
<td>350-400</td>
</tr>
</tbody>
</table>

Over-regulation growth possible if apps are sooner than half the “ideal” interval

Over-regulation is common

- Misapplications less serious than most fear (rare)
- Summer re-application intervals during cold weather (seasonal)
- Overspray of fairways, collars, rough when treating greens (extremely common)

POTENTIAL CAUSE AND RECOVERY FROM GOLF COLLAR DECLINE
Golf Collar Decline History

- Collar decline is a widespread issue across the golf industry
- Causes: Mower turns, soils, slower growing turf, PGRs?
  - Hypothesis: Collars and warm-season turf have longer intervals and more suppression than cool-season greens. Greens applications lead to excessive amounts of growth suppression.

Example of PGR Collar Decline

PGRs Applied at Green Rates/Intervals on a Creeping Bentgrass Fairway
- Primo Maxx – 5.5 fl oz/M @ 200 GDD
- Trimmit 2SC – 8.0 fl oz/M @ 260 GDD
These intervals typically suppression bent greens by 20 and 35%, respectively.

One week later, phytotoxicity is becoming more apparent

Suppression 70-90%

Six weeks of greens PGR rates and intervals causes severe phytotoxicity on collars

Suppression 80-95%

Recovery from PGR Over-regulation

2 Days After Recovery Treatments
Recovery from PGR Over-regulation

Too Much of a Good Thing Possible

Recovery Treatments

<table>
<thead>
<tr>
<th>Product/Treatment</th>
<th>Rate (HOC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RyzUp (low-label) - Gibberellin</td>
<td>0.3 oz/A</td>
</tr>
<tr>
<td>RyzUp (mid-label) - Gibberellin</td>
<td>0.6 oz/A</td>
</tr>
<tr>
<td>Seaweed Extract (SWE)</td>
<td>3 oz/1000 ft²</td>
</tr>
<tr>
<td>SWE + GA (low)</td>
<td>0.3 oz/A + 3 oz/1000 ft²</td>
</tr>
<tr>
<td>SWE + GA (med)</td>
<td>0.6 oz/A + 3 oz/1000 ft²</td>
</tr>
<tr>
<td>Iron sulfate</td>
<td>1 oz product/1000 ft²</td>
</tr>
<tr>
<td>Nitrogen fertilizer (2x)</td>
<td>Extra 0.2 lbs N/1000 ft²</td>
</tr>
<tr>
<td>Nitrogen fertilizer (3x)</td>
<td>Extra 0.4 lbs N/1000 ft²</td>
</tr>
<tr>
<td>Lowered Mowing Height</td>
<td>0.300&quot;</td>
</tr>
<tr>
<td>Non-treated control</td>
<td>Nothing applied</td>
</tr>
</tbody>
</table>

Gibberellin helps over-regulation but caused severe etiolation on non-treated

Second application led to collapse of control and Primo treated; Trimmit OK

Increased nitrogen fertilizer and lowered mowing heights seemed to help. Seaweed extracts and iron didn't help.

Research still on-going
GreenKeeperApp.com – It’s Free!
Essential Turf Management App

Current Functionality
- Sprayer Math & Mixing Instructions
- Automatically Track PGR GDD
- Crowdsourcing Pest Reports
- Product and Weather Logs
- Add Multiple Users
- Twitter Integration

www.GreenKeeperApp.com

Current Homepage

Making a new application in GreenKeeper

Define the area, sprayer, and excess square footage
New in 2017: Define area or number of tanks

Pick the Products for the Application
Define the:
- Application Rate
- Units of Measure
- Reapplication interval
  - Days
  - GDD (PGRs)
- Pests
  - Curative
  - Preventative
- Notes about the product
  - EPA Reg #
  - Batch #
  - Etc.
Total product required and mixing instructions provided real time

Push “Finalize Mix” when complete

Easy PDF printouts for assistants of spray tech to reduce math errors

Grant employees access and save paper

The new applications appear on the homepage

GreenKeeper use is growing

- 3,800 emails addressed and 2,800 courses
- 42,000 products tracked with GreenKeeper
- Adding many new features this winter

GreenKeeper can help plan timing and even rates in the future

- Latest research
  - Use an equation to calculated how much PGR to apply at set intervals
  - GreenKeeper will display the amount to apply
  - Limit the risk of over-suppression

Take Home Points

- Calendar-based PGR applications are not efficient (too much or too little control)
- GDD models predict how long PGRs last
  - Depends on PGR, species, mowing height, etc
- Rate impacts the amount of control
  - Same caveats as above
- Over-regulation or suppression is real
  - Potential for products to help; more research needed
- Greenkeeper can help keep track of everything
Ervin, Superintendent example use of GDD approach

Country Club Of VA, Richmond, example
• Troy Fink, CGCS, James River Course
• A4, USGA greens, <1% Poa
• 150 GDD spray trigger: May-Sept
• 1.75 lb N/M from 20 Apr to 15 Sept
• 4.3 lb N total

Country Club Of VA, Richmond, example
• Apr 20, 1st Primo application
• 5.5 oz/A or 0.125 oz/M all season
• Until June 17, apps needed based on 150 GDD trigger every 7 to 12 days
• After June 17, GDD spray trigger < 7 days, so added in Cutless at 10 oz/A to maintain weekly sprays until 14-Aug, then back to Primo-only until Oct 3
• Average GDD interval between apps: 160

Country Club Of VA, Richmond, example
Troy Fink quote:
“Regulation was the best I’ve ever had. Clippings would barely cover the bottom of the bucket to a 1-inch depth. If weather interfered with proper 150 GDD timing, an increase in clippings was always seen, but re-applying at next application would bring everything back to normal.”

Poa section

Outline
1. Control/Suppression with data from Dr. A.J. Powell (Univ KY) and Dr. Shawn Askew (VT)
2. Paclobutrazol + FeSO4 data from Ervin (VT)
3. Seedhead suppression data from Adam Van Dyke

Poa Populations x Time

5% Poa
10% Poa
20% Poa
How do PGR’s Affect Poa Populations?

University Club of Kentucky
Sand-based Green/PGR control of Poa study
AJ Powell, University of Kentucky

Collected April 2007, sequential treatments applied whole 2006 season
8 applications

<table>
<thead>
<tr>
<th>PGR Treatment</th>
<th>April 2007 Cover Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>19%</td>
</tr>
<tr>
<td>Cutless 50W 8 oz/A (8x)</td>
<td>9%</td>
</tr>
<tr>
<td>Trimmit 2SC 16 fl oz/A (8x)</td>
<td>5%</td>
</tr>
<tr>
<td>Primo MAXX 1EC 11 fl oz/A (8x)</td>
<td>23%</td>
</tr>
</tbody>
</table>
Poa damage and control

- Use high rates of Trimmit or Cutless in Spring & Fall
- Go off in summer or go to Primo or stay on low rates of Trimmit or Cutless
- Use best judgment based on experience and state-specific advice

Objective (Askew, VT research)

- To evaluate post patent formulations of paclobutrazol and trinexapac ethyl compared to proprietary products for Poa annua suppression and creeping bentgrass putting green quality

- Both of these plant growth regulators are available from multiple sources following recent patent expiration
- In the current economic climate turf managers are more likely to consider post-patent products for cost savings

Locations

- Spotswood Country Club
- Draper Valley Country Club
Treatment Programs

<table>
<thead>
<tr>
<th>Trt</th>
<th>Spring (2X)</th>
<th>Summer (3X)</th>
<th>Fall (3X)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Trimmit (16 oz/A)</td>
<td>Trimmit (8 oz/A) + Primo Maxx (0.125 oz/M)</td>
<td>Trimmit (16 oz/A)</td>
</tr>
<tr>
<td>2</td>
<td>Tide Paclo (16 oz/A)</td>
<td>Tide Paclo (8 oz/A) + T-nex (0.125 oz/M)</td>
<td>Tide Paclo (16 oz/A)</td>
</tr>
<tr>
<td>3</td>
<td>Trimmit (8 oz/A)</td>
<td>Trimmit (4 oz/A) + Primo Maxx (0.125 oz/M)</td>
<td>Trimmit (8 oz/A)</td>
</tr>
<tr>
<td>4</td>
<td>Tide Paclo (8 oz/A)</td>
<td>Tide Paclo (4 oz/A) + T-nex (0.125 oz/M)</td>
<td>Tide Paclo (8 oz/A)</td>
</tr>
<tr>
<td>5</td>
<td>Cutless (0.5 lb/A)</td>
<td>Cutless (0.25 lb/A) + Primo Maxx (0.125 oz/M)</td>
<td>Cutless (0.5 lb/A)</td>
</tr>
<tr>
<td>6</td>
<td>Nontreated</td>
<td>Nontreated</td>
<td>Nontreated</td>
</tr>
</tbody>
</table>

Effect of Two Paclobutrazol Products on Poa annua Cover Over Time on Two Virginia, USA Golf Putting Greens in 2010-2011
**Summary (Askew trial)**

- From mid-summer through fall annual bluegrass cover was significantly influenced by paclobutrazol rate
- All treatment programs reduced annual bluegrass cover compared to the nontreated control
- Significant creeping bentgrass injury was not observed at either site

---

**Annual bluegrass control on putting greens with paclobutrazol and Fe-sulfate**

Erik Ervin, Professor  
Turfgrass Culture & Physiology  
Virginia Tech  
Nate Reams, M.S.

---

**The idea came from a visit to Ireland**

- Favor bents and fescues over Poa by
  - Frequent high rates of FeSO$_4$, N as ammonium-sulfate, no P, no K, no lime, higher mowing, but frequent rolling, sanding, seeding, low disturbance

---

**Background: Influential consultants, Jim Arthur: Practical Greenkeeping**

“Sulphate of iron, the greenkeepers friend, acidifies soil, blackens moss, hardens soft turf, scorches and kills weeds, inhibits earthworms, and acts as an effective mild fungicide.”

“Natural products, extracted from seaweed, have a useful if not dramatic effect in stimulating root growth...In support of their use one must remember that greenkeepers more than a century ago were aware of the benefits of seaweed...greens were smothered in rotted seaweed for a week, then removed and stacked with sand to make topdressing.”

---

**Our experiment @ Virginia Tech: 11-13**

- Modified sand green, >25 yrs old
- 50% Penneagle/L93, 50% Poa
- Mowed 5x/wk at 0.125”
- No P or K applied, N applied at 0.10 lb/M with NH$_4$SO$_4$ every 2 wks, 16 times = 1.6 lbs N/yr
- Diseases controlled with chlorothalonil & strobil
- Irrigate to field capacity at sign of wilt
- Standard coring & topdressing
Treatments

Main plots
1. No Fe-sulfate
2. 0.25 lb Fe-sulfate/M (~4 oz)
3. 0.50 lb Fe-sulfate/M (~8 oz)
4. 1.0 lb Fe-sulfate/M (~16 oz)

Iron rates are split by:
1. Untreated
2. SWE, 4 oz/M
3. Trimmit 2SC (pac) @ 22 oz/A Sp/Fa; 11 oz Su

Initial conditions and practices

- 45 to 65% Poa in plots
- Soil sampled at 1-inch and 4-inch depths
  pH1 = 6.22; P = 29 ppm (sufficient); K = 28 ppm (low)

Plots in March

Plots in October

Close-up of high Fe/pac plot

Poa collapse in high Fe plot, Aug
Percent Poa over Time: May 2011-13

Dollar spot and Moss, Sept.
infection centers or colony centers, golf tee count

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Dollar spot</th>
<th>Moss</th>
</tr>
</thead>
<tbody>
<tr>
<td>0Fe, Pac</td>
<td>28</td>
<td>34</td>
</tr>
<tr>
<td>0Fe, SWE</td>
<td>45</td>
<td>6</td>
</tr>
<tr>
<td>0Fe, Ck</td>
<td>89</td>
<td>8</td>
</tr>
<tr>
<td>4Fe, Pac</td>
<td>21</td>
<td>33</td>
</tr>
<tr>
<td>4Fe, SWE</td>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>4Fe, Ck</td>
<td>55</td>
<td>9</td>
</tr>
<tr>
<td>8Fe, Pac</td>
<td>7</td>
<td>19</td>
</tr>
<tr>
<td>8Fe, SWE</td>
<td>34</td>
<td>1</td>
</tr>
<tr>
<td>8Fe, Ck</td>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td>16Fe, Pac</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>16Fe, SWE</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>16Fe, Ck</td>
<td>15</td>
<td>1</td>
</tr>
</tbody>
</table>

Conclusions

- Aggressive use of Pac (22 oz/A Sp/Fa; 11 oz Su) reduces Poa (to 3%), but with quality losses, moss invasion
- 8 oz (or 0.5 lb/M) Fe-sulfate masks the quality loss, reduces Poa moderately (to <30%), keeps dollar spot, moss out
- Rootzone acidification does not appear to be the mechanism of Poa control; need to look at
  - Leaf desiccation or direct Fe-toxicity to Poa?
  - Temporary thatch acidification?

High Fe rates reduced Dollar Spot

Soil test data, 1-inch depth after 3 yrs

<table>
<thead>
<tr>
<th>Treatment</th>
<th>pH</th>
<th>P, ppm</th>
<th>K, ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Fe</td>
<td>5.96</td>
<td>4.5</td>
<td>14.5</td>
</tr>
<tr>
<td>4 Fe</td>
<td>6.03</td>
<td>4.0</td>
<td>13</td>
</tr>
<tr>
<td>8 Fe</td>
<td>6.09</td>
<td>4.3</td>
<td>12.8</td>
</tr>
<tr>
<td>16 Fe</td>
<td>5.95</td>
<td>4.5</td>
<td>11.3</td>
</tr>
</tbody>
</table>

Initial values: 6.22 29 28
Nov 2010

Potable water used for irrigation; pH = 7.6

Winter Applications of PGRs for Annual Bluegrass Seedhead Suppression

Adam Van Dyke
Professional Turfgrass Solutions
Roadmap

1. Background on annual bluegrass biology
2. Review PGR products used for controlling seedheads
3. The backstory
4. Introduce this new concept and share some research
5. Discuss

Acknowledgements

➢ No endorsement, or lack of endorsement, is intended for products or companies mentioned, or not mentioned – whether written or spoken. Inclusion is merely for informational purposes.
➢ Thank you to the RMEGI (Rocky Mountain GCSA chapter) the Intermountain GCSA and all the superintendents that have been instrumental in this journey

Complexity of “Poa”

Annual bluegrass

Annual-types (Poa annua L. var. annua “wild types”)

Intermediate-types (Poa annua L. var. reptans “cultured types”)

Perennial-types (Poa annua L. var. reptans “cultured types”)

AKA biotypes

Why the complexity?

➢ Parents: Poa infirma & Poa supina
  • Both diploids
  • 2 sets of chromosomes (14 total)
➢ Annual bluegrass is a tetraploid
  • $2n \times 4x = 28$ chromosomes
  • Greater genetic diversity
  • 5–20 different biotypes on a single green?
  • Can self pollinate in as short as 1 hour
  • Viable seed can ripen on panicles severed from the plant on the same day pollination occurs

Biotypes

➢ Each type reacts differently to stimuli
  • Environmental
  • Cultural
  • Herbicides (specifically PGRs)
➢ Different morphological features
  • Color, habit, density, texture, flowering
  • Annual-types
    • Continual flowering with pulses
    • 44 to 149 days from germination to flower
  • Perennial-types
    • More seasonal flowering

A few different biotypes
PGRs for seedhead control

Mefluidide (Embark)
- Arguably better seedhead suppressor
- More potential for injury
- Absorbed by leaves
- Slows cell division by interfering with mitosis
- Two forms: Embark 2S and T&O
- Currently not being manufactured

Ethephon (Proxy and many others)
- Suppression more variable
- Less potential for injury
- Crown rising issues in hot temperatures???
- Absorbed by leaves
- Increases ethylene and enhances release in plants, which delays or inhibits flowering
- Current label rate for Proxy is 5oz/1000
  - 5oz fb 5oz maybe fb another 5oz at 2-4wk intervals
  - Spring programs for greens typically include Primo Maxx at 5oz/A or 0.125oz/1000

Timing seedhead sprays

- Triggers have been as simple as an arbitrary calendar date or more complex
- Some use phenological indicators such as forsythia, daffodil, dogwood, others
- Some watch for seedheads in higher heights of cut, then look for bud swell on lower height turf
- Many have adopted growing degree day models which are more consistent and use base 22F, 32F, 50F to accumulate heat units
- All still give erratic control. Why?

Why care about flowering?
AKA seedhead production

Playability
- It looks bad (poor aesthetics)
- Lowers playing quality by disrupting surface uniformity (ball roll)

Physiology
- Requires a lot of stored energy
- Diverts that energy (carbs) away from leaves and roots
- Weakens plant so more susceptible to secondary issues
  - Traffic and cultivation tolerance
  - Drought/Heat/Shade stress
  - Disease/Insects/Weed pressure
  - Summer survival (especially annual biotypes)
Check out the November 2017 issue of GCM

The “early” application concept

- Developed by Dr. Shawn Askew at Virginia Tech many years ago
- Ethephon applied PRIOR TO the normal spring timing program in transition zone
- What about northern regions with snow???
- Brought this concept to regions with distinct winter-to-spring seasons (with snow cover) and coined them “winter” timings
  - Pre-snow cover (November or December)
  - Post-snow melt (February/March/April)

February 2013

February 2014

February 2015

RMGCSA-sponsored research 2014–15

- 70:30 Poa:Bent green in Salt Lake City, UT
  - Mtn. View GC
  - 1970s
  - Push-up style
  - No history of PGRs
RMGCSA-sponsored research 2014-15 treatments

- Pre-snow
  - Ethephon 5oz/1000 in 2 Gal water/1000
  - Embark TO 10oz/A = 0.2oz/1000
  - Embark 2S 1oz/A = 0.02oz/1000
- Post-snow
  - Ethephon 5oz/1000
  - Embark TO 10oz/A
  - Embark 2S 1oz/A
- Combination of Pre- & Post-snow timings
  - First assessment of Proxy+Embark
  - Spring program check

Details

- Pre-snow timing November 18, 2014
- Post-snow timing February 12, 2015
- Normal spring DD-based program
  - Initiated 350 DD<sub>32°F</sub> (Base 32°F)
  - 5oz Proxy + 0.125oz Primo/1000 sq. ft.
  - 1st spray March 17, 2015
  - Hollow-tine aerification March 30 (+2wks)
  - 2nd spray April 13, 2015 (+2wk – apps 4wks apart)
- Remember…winter timings also received the spring program!
May 11, 2015
FLOWERS!!!

Turf quality

<table>
<thead>
<tr>
<th>Product</th>
<th>March</th>
<th>May</th>
<th>June</th>
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<tr>
<td>Ethephon 2SL</td>
<td>5.3 a</td>
<td>6.7 a</td>
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<tr>
<td>Ethephon 2SL Pre-snow</td>
<td>4.9 ab</td>
<td>6.3 ab</td>
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<td>Ethephon 2SL Post-snow</td>
<td>4.6 ab</td>
<td>6.7 a</td>
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<tr>
<td>Ethephon 2SL Pre &amp; Post-snow</td>
<td>5.0 ab</td>
<td>6.3 ab</td>
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<td>Embark TO Pre-snow</td>
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<tr>
<td>Spring program</td>
<td>4.0 c</td>
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<td>5.7 abc</td>
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<td>Embark 2S Pre &amp; Post-snow</td>
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<tr>
<td>Untreated</td>
<td>4.0 c</td>
<td>5.0 d</td>
<td>5.0 c</td>
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IGCSA-sponsored research 2015–16

- 60:40 Bent:Poa green in SLC, UT
  - River Oaks GC
  - 1980s
  - Sand-based style
  - Frequent history of PGRs in spring
- Proxy 5oz/1000
  - in 2 Gal/1000
  - Pre-snow Nov. 17th
  - Post-snow Feb. 19th
- fb spring program
  - Two Apps
  - March 11th & April 12th
  - Proxy+Primo
May 9th thru 16th...topdressing

- Effective integrated approach for seedhead control...

Product testing and agronomic solutions since 2008

RMGCSA-sponsored research 2016–17

- 80:20 Poa:Bent green in Denver, CO
  - Murphy Creek GC
  - Late 1990’s
  - Sand rootzone
  - Frequent history of PGRs throughout year

RMGCSA-sponsored research 2016–17 treatments

- Pre–snow
  - Proxy 5oz/1000 in 2 Gal water/1000
  - Mixed with either Interface+Mirage or Instrata
- Post–snow
  - Proxy 5oz/1000
  - Mixed with either Mirage or Banner
- Combination of Pre– & Post–snow timings
- Spring check program
  - Proxy+Primo March 10, April 5, April 20

Pre–snow timing
Nov. 30, 2016
Post-snow timing
Feb. 20, 2017

Seedheads peak May 23, 2017

Proxy and snow mold fungicide mixtures

- Pre-snow Instrata + Proxy fb spring program
- Pre-snow Instrata + Proxy fb post-snow Banner + Proxy fb spring program
- Pre-snow Interface + Proxy fb spring program
- Pre-snow Interface + Proxy fb spring program
- Winter Syngenta fungicides only fb spring program
- Winter Syngenta fungicides only fb untreated in spring

% annual bluegrass seedhead suppression (% of untreated in spring)

Inclusion of plant-health products

- Inducer compounds
- Phosphites/Phosphonates
  - Fiata (others)/Signature (Fosetyl-Al)
- SAR induction: Salicylic acid signaling pathway
- Mineral oil (synthetic isoparaffin)
  - CIVITAS TURF DEFENSE Ready-2-Mix
- ISR activation: Jasmonic and Ethylene pathways

SAR inducer products

- Proxy S0l Spring
- Proxy S0l Pre-snow & Spring
- Proxy S0l + Signature 60 Plus 4oz Spring
- Proxy S0l + Chipco Signature 60 Spring
- Proxy S0l + Chipco Signature 60 Pre-snow & Spring
- Proxy S0l + FilaCide 6oz Spring
- Proxy S0l + FilaCide 6oz Pre-snow & Spring
- Proxy S0l + Primo 0.125oz Spring
- Proxy S0l + Primo 0.125oz Pre-snow & Spring

Spring program

- Proxy Pre-snow
- Proxy + Primo Pre-snow
- Proxy + Signature Pre-snow

Product testing and agronomic solutions since 2008
Proxy + CIVITAS mixtures

- Spring program: 42%
- Proxy 5oz Pre-snow: 71%
- Proxy 5oz Post-snow: 74%
- Proxy 5oz Pre/Post-snow: 86%
- Proxy 5oz + CIVITAS 16oz Pre-snow: 71%
- Proxy 5oz + CIVITAS 16oz Post-snow: 86%

Winter ethephon concept applies to fairways as well

- Pre-snow Musketeer + Proxy
- Pre-snow Musketeer
- Post-snow Musketeer
- Post-snow Musketeer + Proxy

Proxy with Musketeer and Cutless programs on greens (post-snow)

- Post-snow Musketeer + Proxy
- Post-snow Musketeer
- Post-snow Musketeer + Cutless

Fairway seedhead control with Proxy & single apps of Musketeer

- Spring + Proxy: 54%
- Pre-snow Musketeer 50oz + Spring program: 61%
- Pre-snow Proxy 5oz + Musketeer 30oz + Spring program: 63%
- Post-snow Musketeer 50oz + Spring program: 57%
- Post-snow Proxy 5oz + Musketeer 30oz + Spring program: 64%

"providing product testing and agronomic solutions since 2008"
Untreated
Post-Proxy fb Proxy+Musk fb Musk
Post-Proxy fb Proxy+Cut fb Cut

Spring Proxy+Primo

Winter ethephon applications improve seedhead suppression of annual bluegrass in spring
No serious phyto has occurred in early spring from these winter applications
- Quality and color have been enhanced in some instances
- Crown rising, or scalping injury, has not been observed in ~20 trials
- Ethephon mixtures with other PGRs have had variable results
- Beware of label use max of 30 oz/yr
- So much more to learn

Thanks for your attention
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