Plant Growth Regulators for Fine Turf: Cool-Season

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

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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	
Flurprimidol	Cutless
Paclobutrazol	TGR
Paclobutrazol	Trimmit

BREAK, 10 MINUTES

ERIK ERVIN TRANSITION

Positive Secondary-Effects

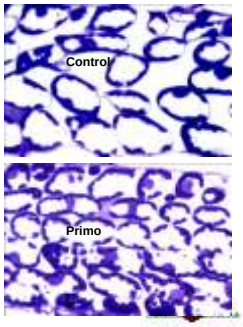
Morphology & Physiology

TE increases cell density and chlorophyll

Table 1: Effects of trinexapac-ethyl (TE) (0.25 kg ha^{-1} (a.i.)) on mesophyll cells and chlorophyll concentration of Kentucky bluegrass.

Observation	Control	Treated	P	cv (%)
Mesophyll cells (cell/ml)				
No./mm^2	550	750	0.003	22.4
Length (μm)	55	45	0.001	11.5
Width (μm)	32	30	0.160	11.7
Chlorophyll content (mg g^{-1} FW)				
2 WAT - a	2.71	2.94	0.170	13.0
b	1.31	1.61	0.001	11.3
Total	4.02	4.55	0.034	8.4
4 WAT - a	2.78	2.85	0.010	3.3
b	0.62	1.00	0.033	53.3
Total	5.39	5.74	0.110	13.3

Ervin and Koski. 1998. HortSci. 33(7):1200-1202.

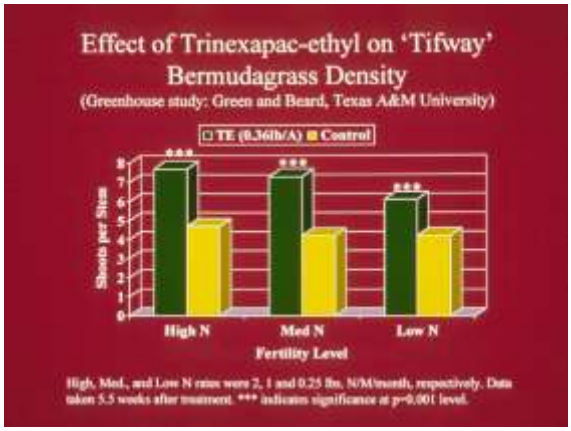


Primo increases Tiller Density

Ervin, HortSci. 1998; Crop Sci. 2001; HortSci, 2001

Species	Tillers per 4 inch plug: Primo	Tillers per 4 inch plug: No Primo
Perennial ryegrass	341	203
Kentucky bluegrass	266	233
Zoysia	338	301

Class B's also increase tiller density of C3 & C4 turfgrasses



Primo: Rooting increase for C3?

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

BUT see unpublished pictures from Yelverton, NC-State

Auburn (Walker, Guertal)
CB: no effect

Virginia Tech (Schmidt, Zhang)
CB: no effect

Iowa State (Christians)
CB: no effect

Kansas State (Fry, Marcum)
PR: no effect
TF: no effect

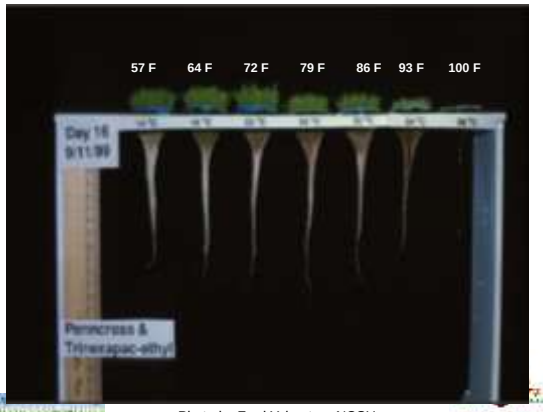


Photo by Fred Yelverton, NCSU

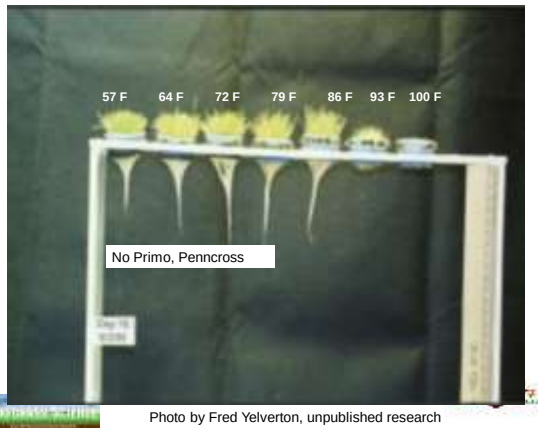
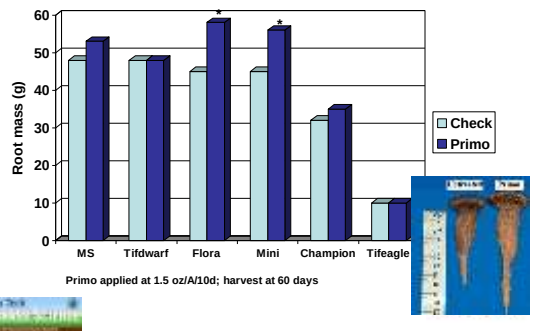


Photo by Fred Yelverton, unpublished research

Primo effects on ultradwarf bermuda rooting

McCullough et al., 2005, Clemson, Greenhouse study



Primo applied at 1.5 oz/A/10d; harvest at 60 days

Root restriction on Tifeagle due to Pac

0.25 lb ai = 16 oz/A

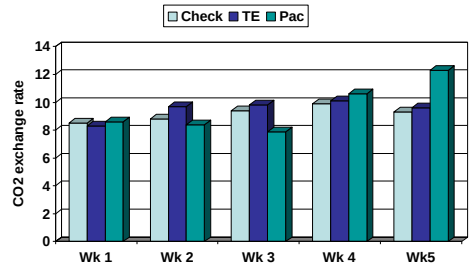
Class A & B PGRs: Physiological Effects

- **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?

Photosynthesis: leaf area basis, KBG



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

Beasley & Branham, Crop Science, 2007

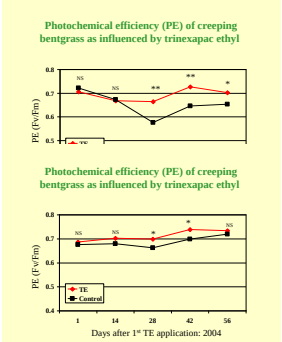
Cutless & Embark temporarily reduce PS

PGR	4 DAT	8 DAT	16 DAT	32 DAT
Check	34.7 a	7.1 a	12.0 a	14.8 a
Embark	15.4 b	3.2 b	11.1 a	13.6 a
Cutless	18.0 b	3.9 b	4.8 b	17.7 a

----------Carbon Dioxide Exchange Rates----------

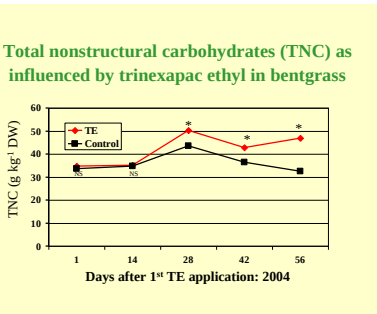
Poa & CBG combined

Gaussoin & Branham, Michigan State, 1997



Ervin & Zhang. 2007. Crop Sci. 47:2145-2151.

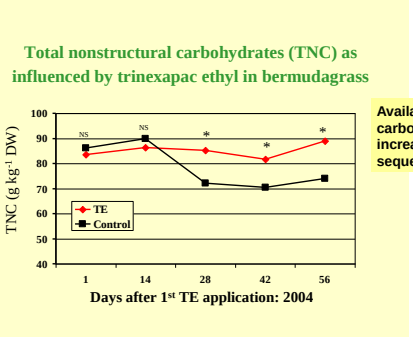
No change to slight increase in Photochemcial Efficiency due to Primo



Available carbohydrates increased with sequential apps

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

Ervin & Zhang. 2007. Crop Sci. 47:2145-2151.



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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

Ervin, Colorado State

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

Primo and Shade

- Sequential Primo use a definite Best Management Practice on Shaded Golf Course Surfaces

Why?

- ↓ GA
- ↓ leaf elongation
- ↑ carbs
- Maintain density longer

Works on C3 and C4 grasses

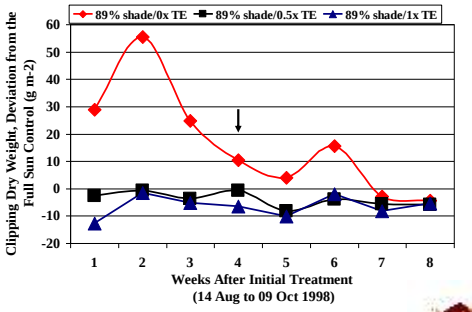
Shade signals altered growth

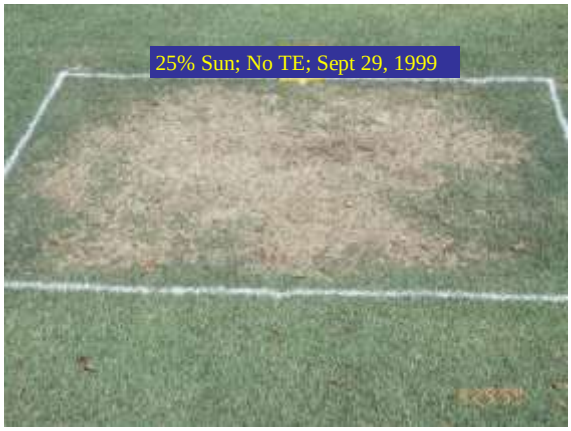
- Increase in far-red wavelengths of light signal:
  - GA production which stimulates stem and leaf cell elongation at the expense of tillering

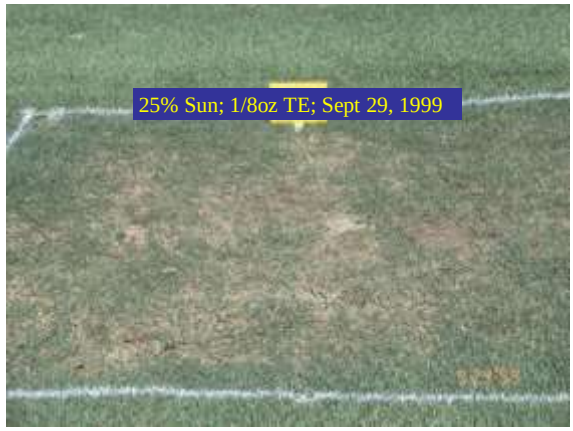
	Seedling ht (cm)	GA1-level
full sun	6	4
50% sun	10	7.5
10% sun	18	9

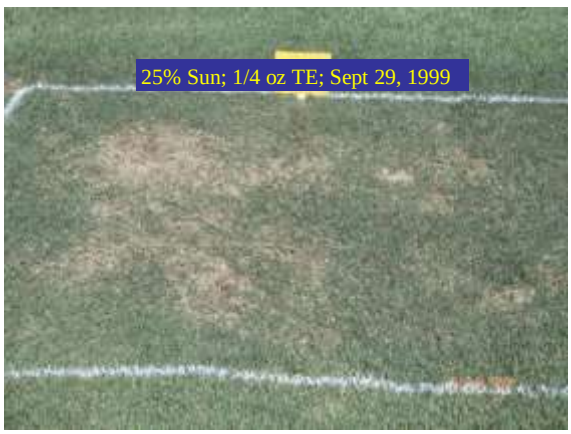
Gawronska et al., 1995, Plant Cell Phys 36(7):1361

Meyer Zoysia shoot growth respone to shade & Primo









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

Treatment	End Quality 1-9 scale	Root Strength kg force
Check	3.1 b	8.5 b
Primo	5.5 a	16.3 a
Banner	5.3 a	11.3 ab
CPR	3.0 b	8.0 b

90% shaded KBG, effects of Cutless

Stier and Rogers, Michigan State, 1999

Treatment	Quality	Verdure	Root wt
Check	4.5	0.325	0.18
Cutless 0.5 lb/A	6.2	0.538	0.15
Cutless 1.0 lb/A	4.7*	0.655	[illegible]

*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

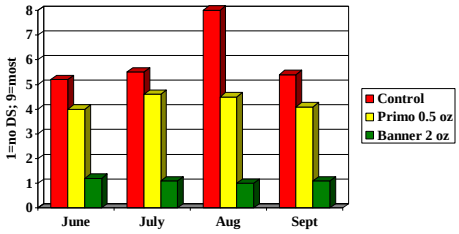
- Class A & B PGRs are structurally similar to DMI fungicides, so have mild disease control activity
- They also reduce growth which may allow contact & systemic fungicides to stay in & on the plant longer, prolonging control
- Once disease is present, some have shown that PGRs may slow recovery from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

Interaction of N & PGRs on Dollar Spot

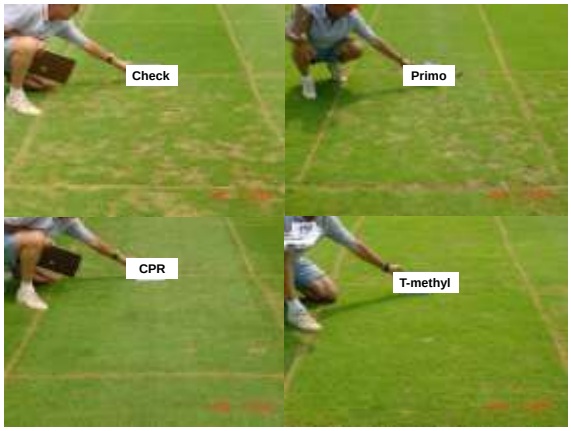
Treatment	Rate oz/M	Dollar Spot Low N	Dollar Spot High N
Check	0	75 (infection centers)	24
Cutless	0.37	29	13
Trimmit	0.37	13	8
Primo	0.53	51	23

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

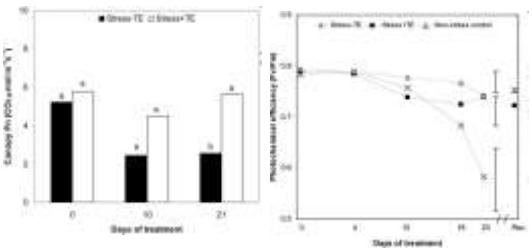
McCann & Huang, Rutgers, 2008: Bent response to Drought & Primo

	5 days Dry-down	12 days	19 days	26 days
Treatment	Photochemical Efficiency (0.8 = best; 0.5 = damage)			
Check	0.80	0.62	0.49	0.18
Primo 5 apps	0.80	0.79	0.77	0.52

Day 12 Soil Moisture:

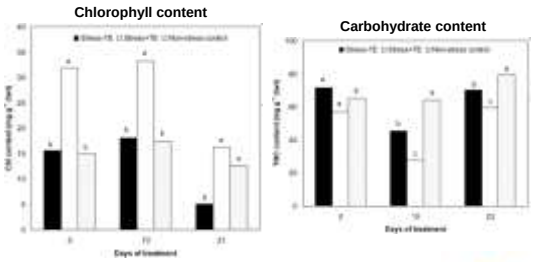
- Primo = 8.3%
- Check = 3.8%

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



From: McCann & Huang. 2007. Crop Sci. 47: 2121.

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



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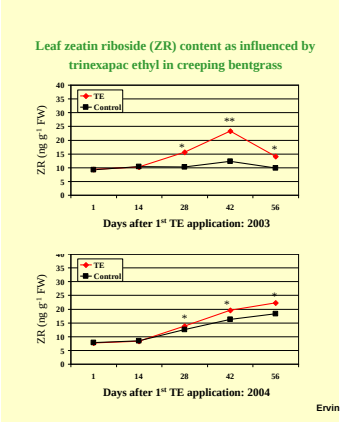
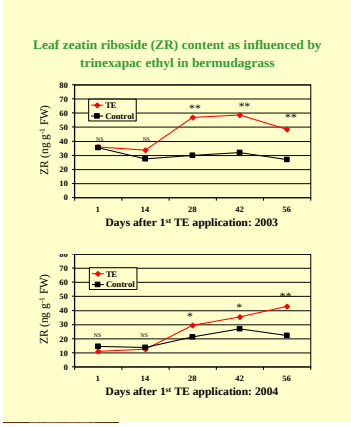


Repeated Primo apps resulted in an increase in leaf tissue cytokinin content

Ervin & Zhang. 2007. Crop Sci. 47:2145-2151.



Sequential TE apps result in more leaf cytokinins

= more tillering

= delay of senescence or stay-green effect

Ervin & Zhang. 2007. Crop Sci. 47:2145-2151.

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

Treatment	SOD antioxidant	Photochemical Efficiency	Root wt mg/pot
Primo 0.125 oz/mo	22.9 a	0.50 a	20 b
Banner 0.75 oz/mo	19.1 b	0.44 a	62 a
Check	14.8 c	0.36 b	27 b

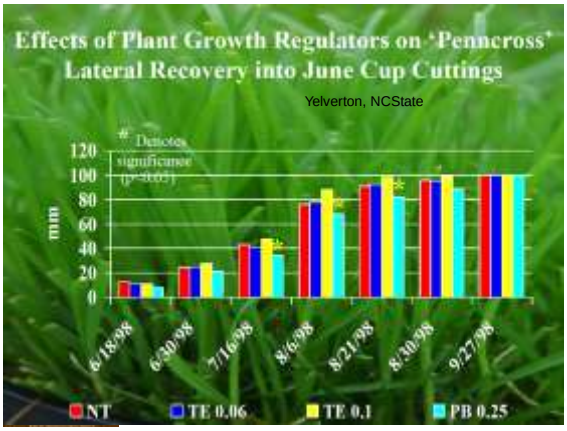
PGRs and Divot Recovery

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

	Days to 90% Divot Closure, Bentgrass			
PGR	1994 Low N	1994 High N	1995 Low N	1995 High N
Check	34	24	45	32
Cutless 16 oz/A	32	24	49	43
Trimmit 16 oz/A	34	27	49	37
Primo 22 oz/A	32	23	38	33



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 at 28 d after app

Treatment	Oz/M per 28 d	June 11	Aug 6	Oct 14
Check		8' 8"	8' 10"	8' 7"
Trimmit	0.18	8' 6"	8' 7"	9' 1"
Trimmit	0.37	8' 1"	8' 3"	8' 11"
Trimmit	0.73	8'	8' 3"	8' 10"
Primo	0.12	8' 5"	8' 7"	8' 8"

Problem: close to or during rebound phase

Fagerness et al., NCState, 2000 on Penncross

PGRs and Ball Roll Distance, Michigan State

Treatment	Rate & Interval	Av. Deviation from Check
Primo	0.1; 7-d	+8.9"
Primo	0.15; 14-d	+2.1"
Primo	0.25; 21-d	+3.5"
Trimmit	0.18; 14-d	+10.7"
Trimmit	0.18; 21-d	+10"

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

More ball roll data

TRANSITION TO KREUSER

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?

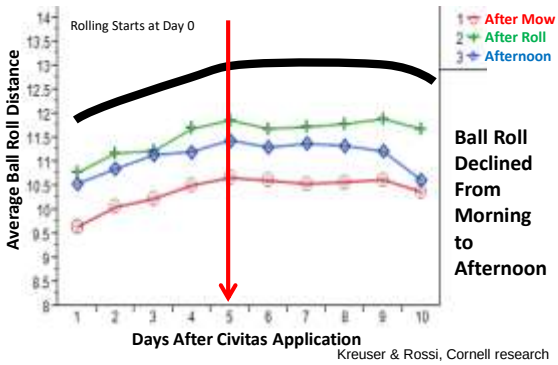
Kreuser & Rossi, Cornell research

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

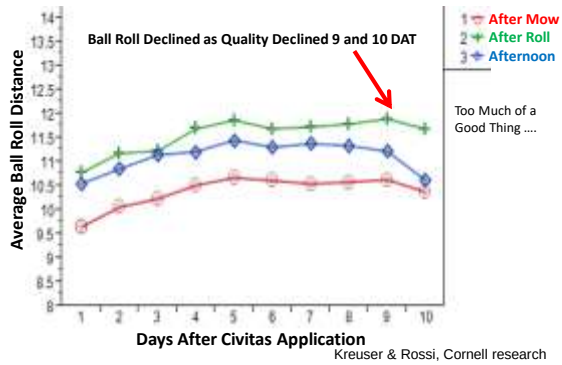
Kreuser & Rossi, Cornell research

When Are Putting Greens Fastest?



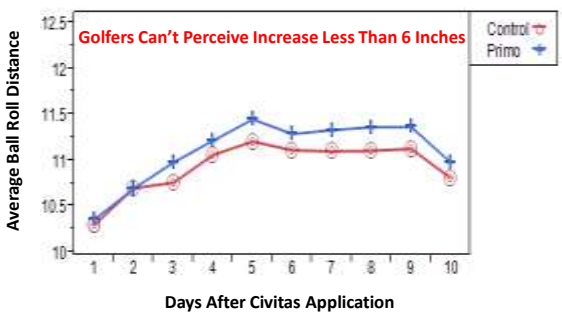
Kreuser & Rossi, Cornell research

When Are Putting Greens Fastest?



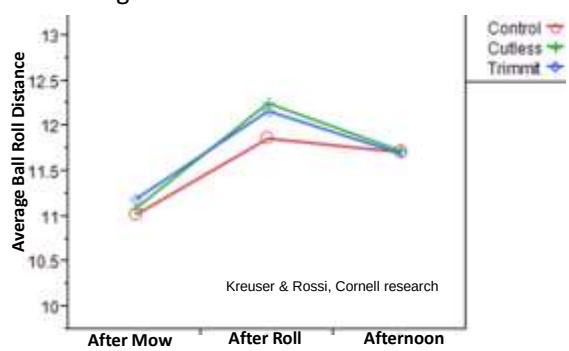
Kreuser & Rossi, Cornell research

Primo increased ball roll a little

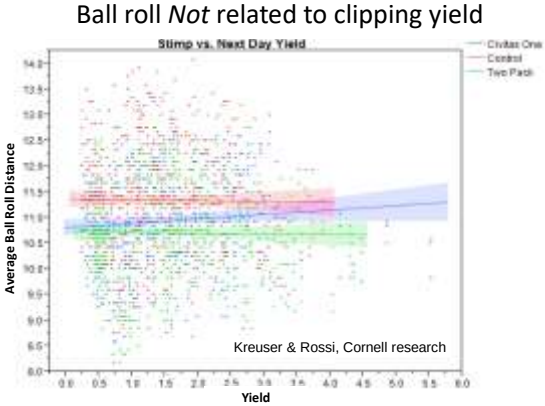


Kreuser & Rossi, Cornell research

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



Ball roll *Not* related to clipping yield



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

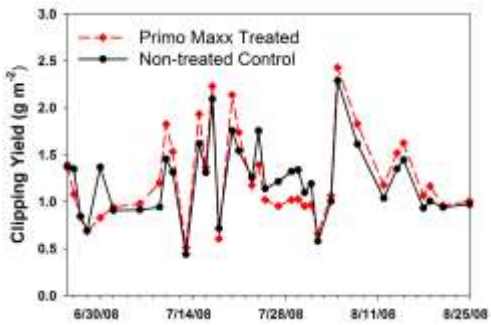
University of Nebraska Lincoln

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

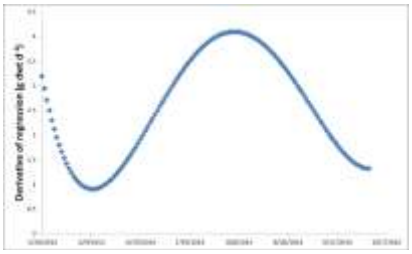
The Biggest Challenge with PGRs

Its 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

The rates presented in the **Application Rate Table** provide approximately 50% growth inhibition over a 4-week period with little or no discoloration of turf growing under favorable conditions.

Excessive turf growth, which may occur with high fertilization or during spring flushes, may require higher rates of **Any PGR** Under these conditions, **Any PGR** rates may need to be increased up to 50% to provide an adequate length of control.

For extended growth suppression up to 8 weeks, when temporary discoloration can be tolerated, a maximum of twice the recommended **Any PGR** rate from the **Application Rate Table** may be applied.

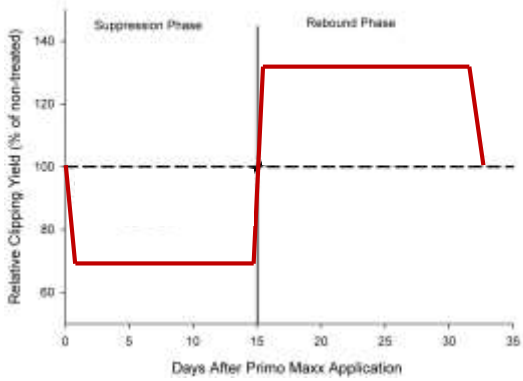
Rate can be legally increased 100%

Application Timing

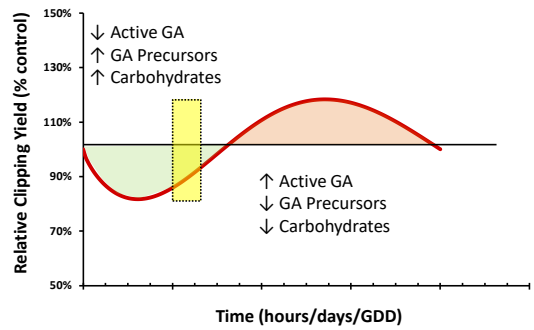
Apply **Any PGR** to actively-growing turf. If turf is going into dormancy because of high or low temperatures or lack of moisture, apply a lower rate of **Any PGR**

Repeat applications of **Any PGR** may be made as soon as the turf resumes growth or more suppression is desired, but do not apply more than 7.0 fl. oz./1,000 sq. ft. per year.

It can be re-applied as often as desired



Generalized PGR Response to Turf

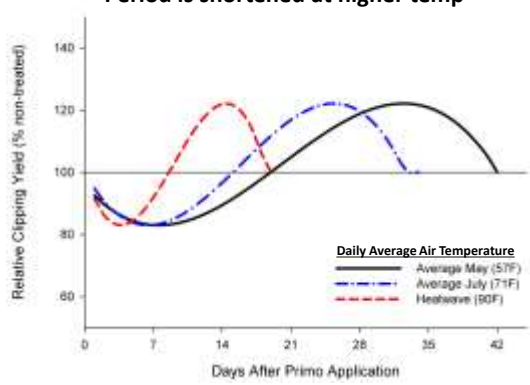


PGR Metabolism Increases with Temp

- **Decreased Efficacy During Summer**
  - **Lickfelt el 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)

Period is shortened at higher temp

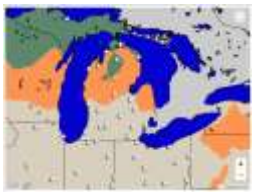


Goals for a PGR program

- 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



$$\text{Cumulative GDD} = \sum_{\text{Start Date}}^{\text{Current Date}} \left(\frac{\text{High} + \text{Low Air Temp}}{2} \right) - \text{Base Temp}$$

Growing degree days (GDD) factors in air temp

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

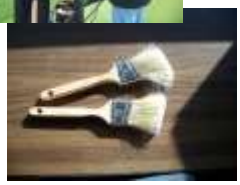
Date	High (F)	Low (F)	Average (F)	Average (C)	GDD (C)
5/1/16	75	50	63	17	17
5/2/16	72	47	60	15	32
5/3/16	85	65	75	24	56
5/4/16	93	72	83	28	84

– Tools out there (GreenKeeperApp.com)

Creating PGR GDD Models

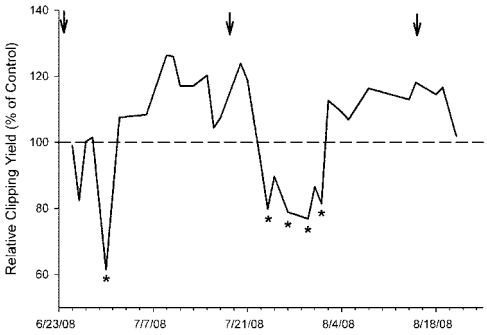
Horrible Job

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



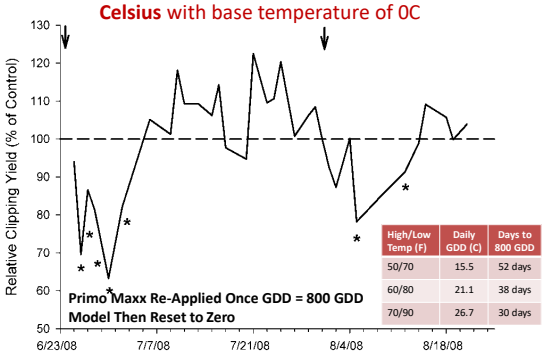
Proof of Concept: Primo Maxx on creeping bentgrass greens 2008-2010

Primo Maxx: Four Week Applications



Primo Maxx: 800 GDD Re-applications

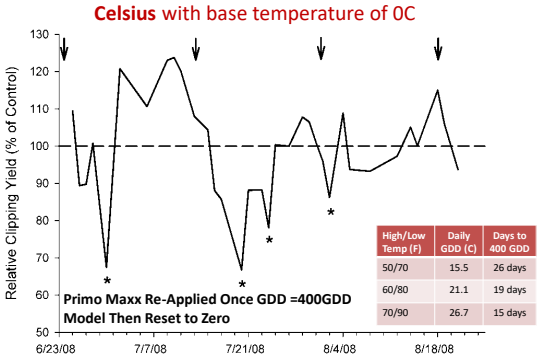
Celsius with base temperature of 0C



High/Low Temp (F)	Daily GDD (C)	Days to 800 GDD
50/70	15.5	52 days
60/80	21.1	38 days
70/90	26.7	30 days

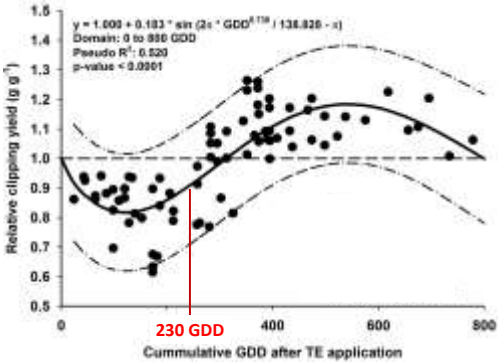
Primo Maxx: 400 GDD Re-applications

Celsius with base temperature of 0C

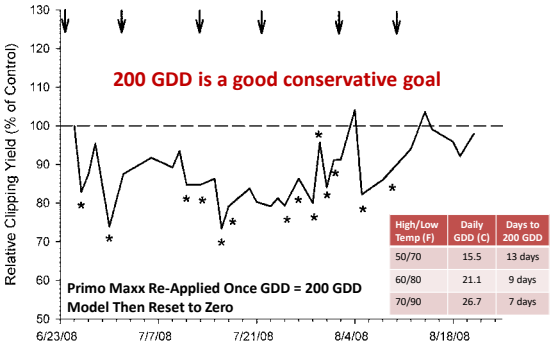


High/Low Temp (F)	Daily GDD (C)	Days to 400 GDD
50/70	15.5	26 days
60/80	21.1	19 days
70/90	26.7	15 days

Growth rates vs GDD after application

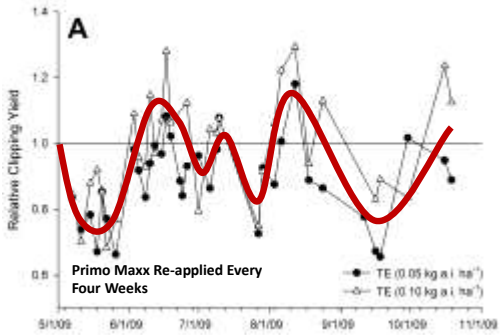


Primo Maxx: 200 GDD Re-applications



High/Low Temp (F)	Daily GDD (C)	Days to 200 GDD
50/70	15.5	13 days
60/80	21.1	9 days
70/90	26.7	7 days

Application rate had minimal impact on duration of suppression of Primo



University of Minnesota research supports 200 GDD interval

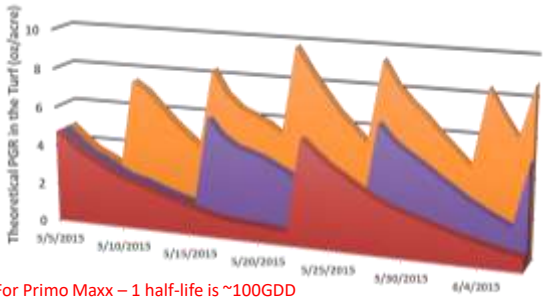
Tested lower Primo Maxx Rates

- 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

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

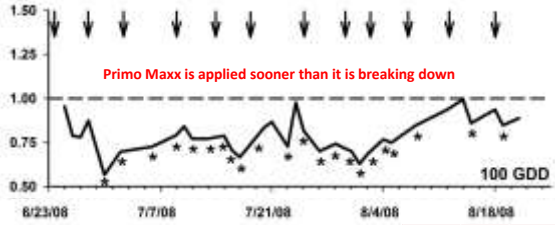
Re-applying a PGR when only half has been broken down leads to PGR accumulation

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



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

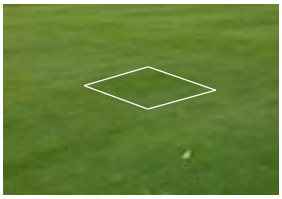
Applying Primo Maxx at 100 GDD increased growth suppression



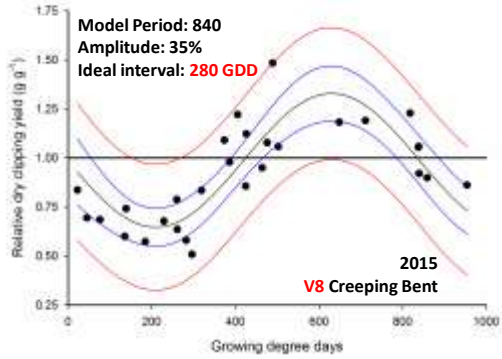
High/Low Temp (F)	Daily GDD (C)	Days to 100 GDD
50/70	15.5	6 days
60/80	21.1	5 days
70/90	26.7	4 days

Anuew PGR on the block

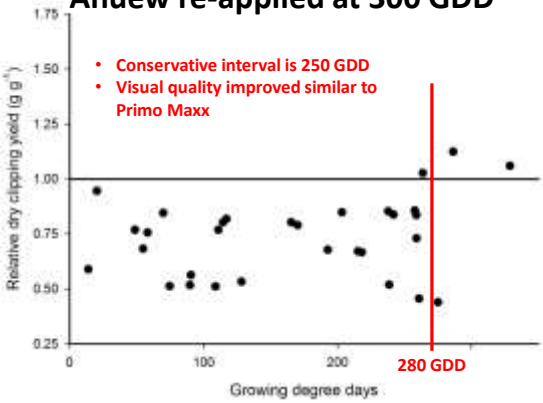
A.I.:	Prohexadione-Ca
PGR Class:	Class A – Late GA Inhibitor
Uptake:	Foliar
Formulation:	Extruded granule (dry product)
Rate Range:	1.8 to 29.1 oz/acre (0.04 to 0.67 oz/M)
	1.8 to 7.25 oz/acre – Cool-season greens
	7.25 to 14.5 oz/acre – Warm-season greens



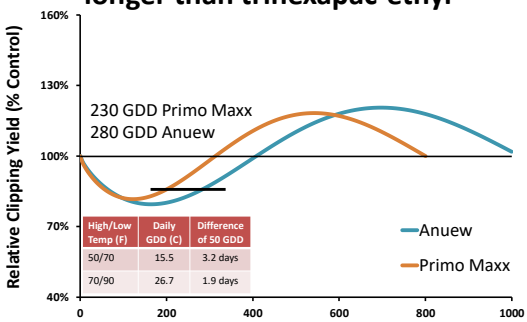
Prohexadione-Ca performance on greens



Anuew re-applied at 300 GDD



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



High/Low Temp (F)	Daily GDD (C)	Difference of 50 GDD
50/70	15.5	3.2 days
70/90	26.7	1.9 days

Goal: Develop GDD models for all PGRs

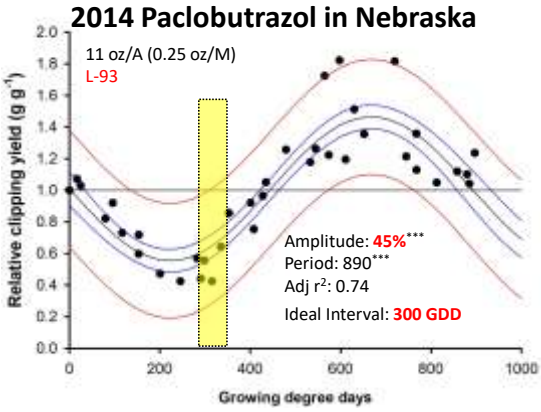
Questions:

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

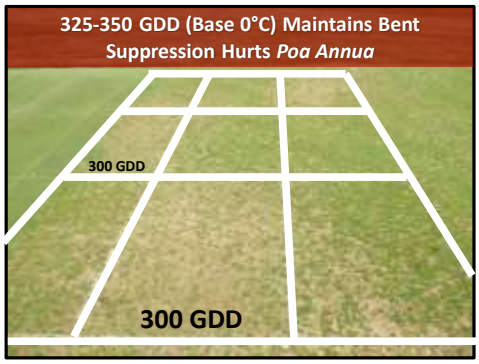
Objective:

Create GDD models for Class B PGRs

2014 Paclobutrazol in Nebraska

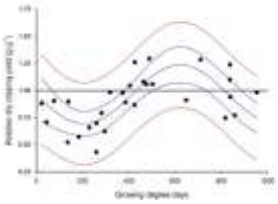


Paclo. GDD impacts annual bluegrass



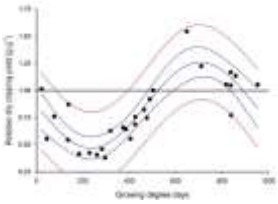
Low rate vs high rate Trimmit 2SC

5.5 oz/A (0.13 oz/M)



31% Suppression
270 GDD Interval

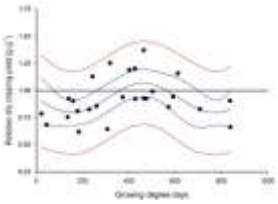
16 oz/A (0.38 oz/M)



53% Growth Suppression
310 GDD Interval

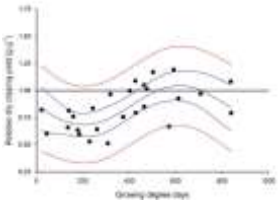
Low rate vs high rate Cutless 50W

2.0 oz/A (0.05 oz/M)



20% Suppression
200 GDD Interval

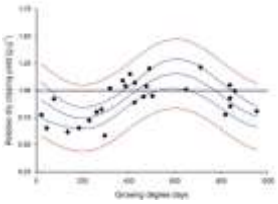
8.0 oz/A (0.18 oz/M)



32% Suppression
270 GDD Interval

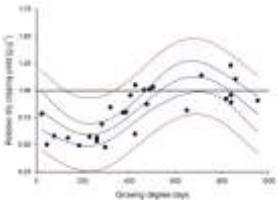
Low rate vs high rate Legacy

4.8 oz/A (0.11 oz/M)



25% Suppression
270 GDD Interval

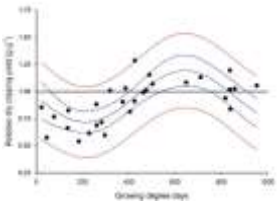
9.6 oz/A (0.22 oz/M)



41% Growth Suppression
300 GDD Interval

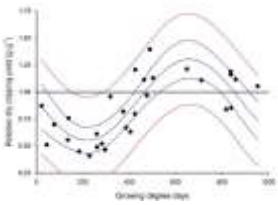
Low rate vs high rate Musketter

12 oz/A (0.27 oz/M)



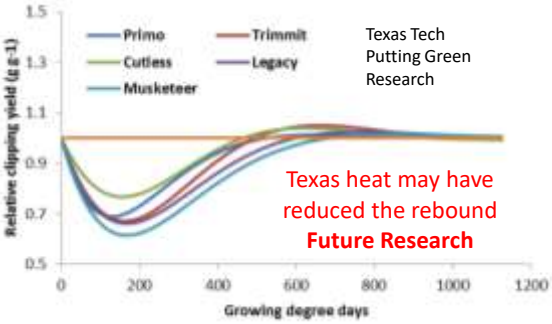
28% Suppression
290 GDD Interval

22 oz/A (0.51 oz/M)



45% Growth Suppression
290 GDD Interval

Rebound phase doesn't always occur



Comparing PGR Performance

Active Ingredient	Common Name	Growth Suppression	Duration of Effect	Ideal GDD
Trinexapac-ethyl	Primo Maxx	20%	800 GDD	230 GDD
Paclobutrazol	Trimmit	30-50%*	850-950 GDD*	280-310 GDD*
Flurprimidol	Cutless	20-30%*	600-800 GDD*	210-270 GDD*
Anuew	Prohexadione-Ca	25%	840 GDD	280 GDD
Flurprimidol + Trinexapac-ethyl	Legacy	20-35%*	810-910 GDD*	270-300 GDD*
Flurprimidol + Paclobutrazol + Trinexapac-ethyl	Musketeer	25-40%*	880 GDD	290

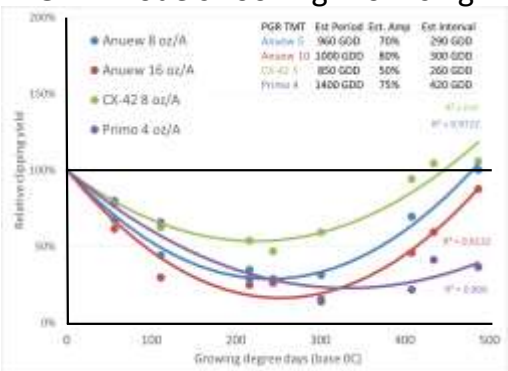
* Range from low to high application rate

GDD Models for Ultradwarf Greens

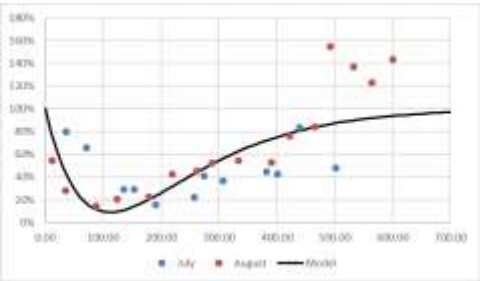
Collaborative PGR Research

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

GDD Models Looking Promising



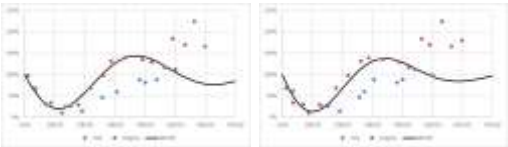
Primo Maxx Performance on UD



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

Anuew Performance on Champion

8 oz/Acre Rate **16 oz/Acre Rate**



- 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

Primo and Anuew Performance on UD

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

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

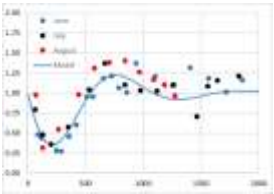
Bentgrass Fairways

Wide Range of Rates

Product	Rate (oz/A)	Liquid/dry
Control	0	na
Anuew	7	Dry
Anuew	15	Dry
Cutless MEC	25	Liquid
Cutless MEC	49	Liquid
Legacy	10	Liquid
Legacy	20	Liquid
Musketeer	18	Liquid
Musketeer	30	Liquid
Primo Maxx	11	Liquid
Primo Maxx	33	Liquid
Trimmit 2SC	16	Liquid
Trimmit 2SC	32	Liquid

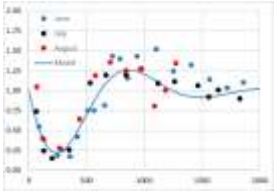
Low rate vs high rate Anuew

7.0 oz/A (0.05 oz/M)



60% Suppression
350 GDD Interval

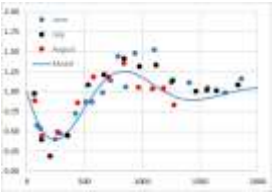
15.0 oz/A (0.18 oz/M)



75% Suppression
380 GDD Interval

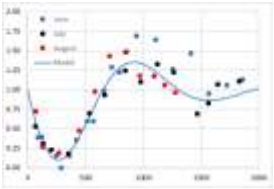
Low rate vs high rate Primo Maxx

11 oz/A (0.11 oz/M)



55% Suppression
350 GDD Interval

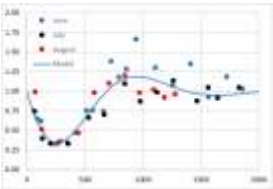
33 oz/A (0.22 oz/M)



80% Growth Suppression
380 GDD Interval

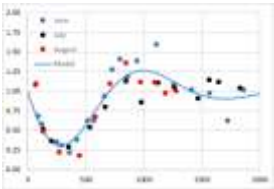
Low rate vs high rate Trimmit 2SC

16 oz/A (0.13 oz/M)



70% Suppression
480 GDD Interval

32 oz/A (0.38 oz/M)



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

Active Ingredient	Common Name	Growth Suppression	Ideal GDD
Trinexapac-ethyl	Primo Maxx	55-80%	350-380
Paclobutrazol	Trimmit	70-80%	480-640
Flurprimidol	Cutless	30-40%	380-410
Anuew	Prohexadione-Ca	60-75%	350-380
Flurprimidol + Trinexapac-ethyl	Legacy	40-70%	320-390
Flurprimidol + Paclobutrazol + Trinexapac-ethyl	Musketeer	55-70%	350-400

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

Over-regulation is common

- Misapplications less serious that 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

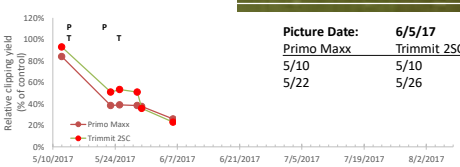
- Collar decline is a widespread issue across the golf industry
- Causes: Mower turns, soils, slower growing turf, PGRs?
  - Hypothesis: Collars and warm-season turf have longer intervals and more suppression than cool-season greens. Greens applications lead to excessive amounts of growth suppression.

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

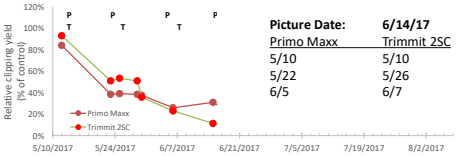
These intervals typically suppression bent greens by **20 and 35%**, respectively.



Picture Date:	6/5/17
Primo Maxx	Trimmit 2SC
5/10	5/10
5/22	5/26

One week later, phytotoxicity is becoming more apparent

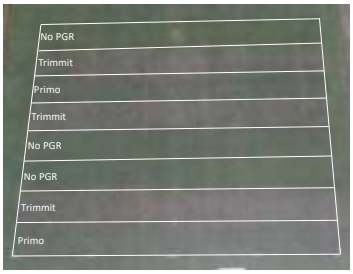
Suppression 70-90%

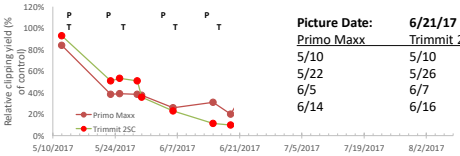


Picture Date:	6/14/17
Primo Maxx	Trimmit 2SC
5/10	5/10
5/22	5/26
6/5	6/7

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

Suppression 80-95%





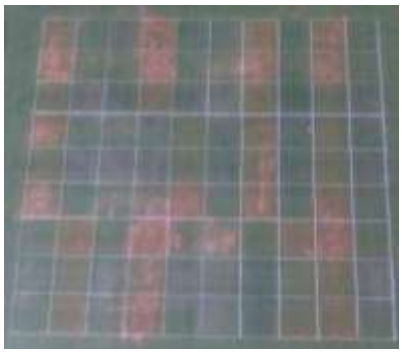
Picture Date:	6/21/17
Primo Maxx	Trimmit 2SC
5/10	5/10
5/22	5/26
6/5	6/7
6/14	6/16

Recovery from PGR Over-regulation

2 Days After Recovery Treatments

Recovery from PGR Over-regulation

Too Much of a Good Thing Possible



Recovery Treatments

Product/Treatment	Rate (HOC)
RyzUp (low-label) - Gibberellin	0.3 oz/A
RyzUp (mid-label) - Gibberellin	0.6 oz/A
Seaweed Extract (SWE)	3 oz/1000 ft^2
SWE + GA (low)	0.3 oz/A + 3 oz/1000 ft^2
SWE + GA (med)	0.6 oz/A + 3 oz/1000 ft^2
Iron sulfate	1 oz product/1000 ft^2
Nitrogen fertilizer (2x)	Extra 0.2 lbs N/1000 ft^2
Nitrogen fertilizer (3x)	Extra 0.4 lbs N/1000 ft^2
Lowered Mowing Height	0.300”
Non-treated control	Nothing applied

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

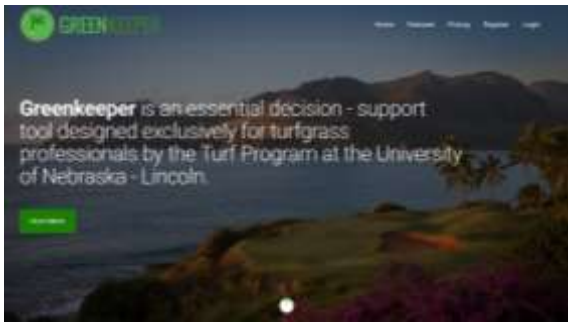
Second application led to collapse of control and Primo treated; Trimmit OK

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

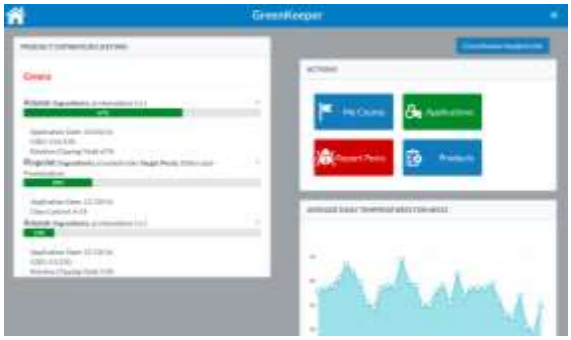
GREENKEEPER

Always Free!

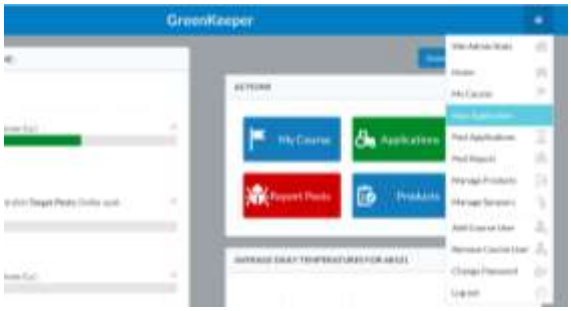
- Sprayer Math & Mixing Instructions
- Automatically Track PGR GDD
- Crowdsourcing Pest Reports
- Product and Weather Logs
- Add Multiple Users
- Twitter Integration

www.GreenKeeperApp.com

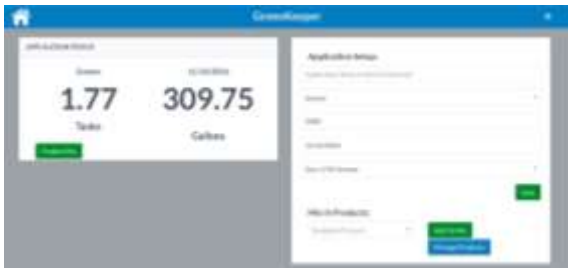
Current Homepage



Making a new application in GreenKeeper



Define the area, sprayer, and excess square footage



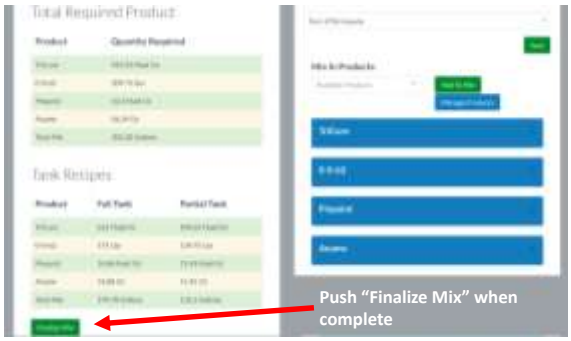
New in 2017: Define area or number of tanks

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.

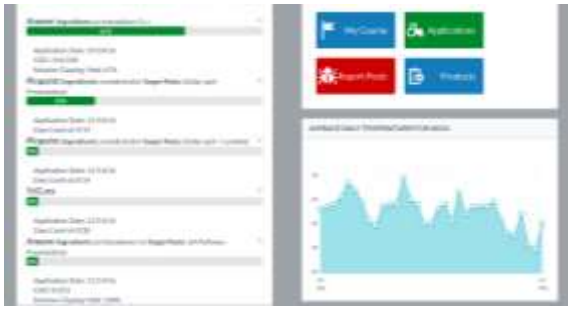
Total product required and mixing instructions provided real time



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:

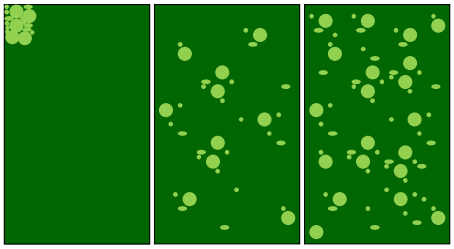
"Regulation was the best I've ever had. Clippings would barely cover the bottom of the bucket to a 1-inch depth. If weather interfered with proper 150 GDD timing, an increase in clippings was always seen, but re-applying at next application would bring everything back to normal."

Poa section

Outline

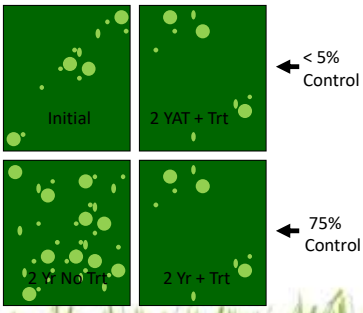
1. Control/Suppression with data from Dr. A.J. Powell (Univ KY) and Dr. Shawn Askew (VT)
2. Paclobutrazol + FeSO4 data from Ervin (VT)
3. Seedhead suppression data from Adam Van Dyke

Poa Populations x Time



5% Poa 10% Poa 20% Poa

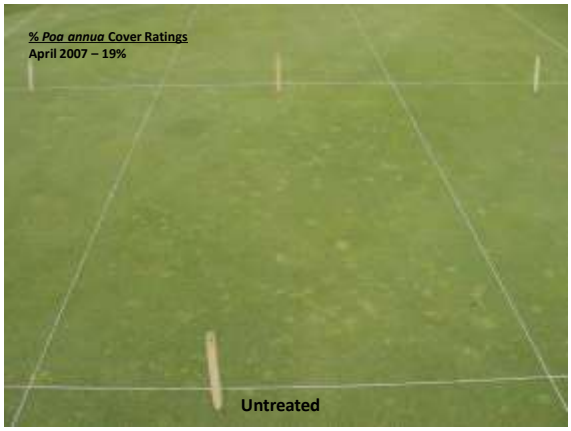
Poa Populations x Time

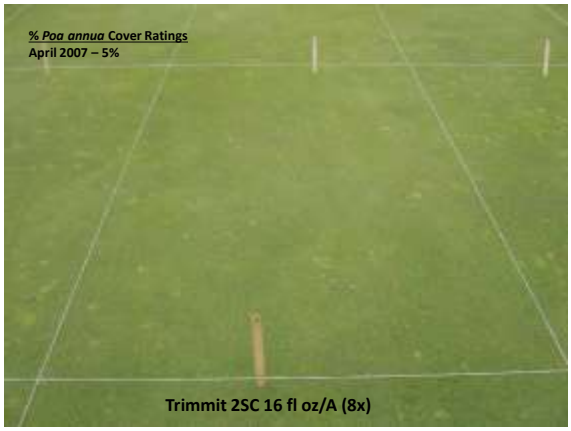


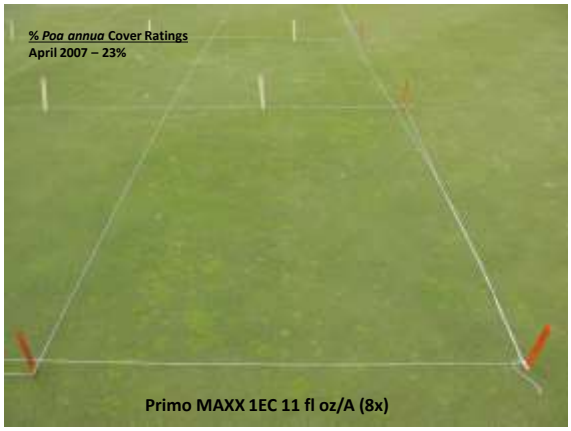
How do PGR's Affect Poa Populations?

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







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)

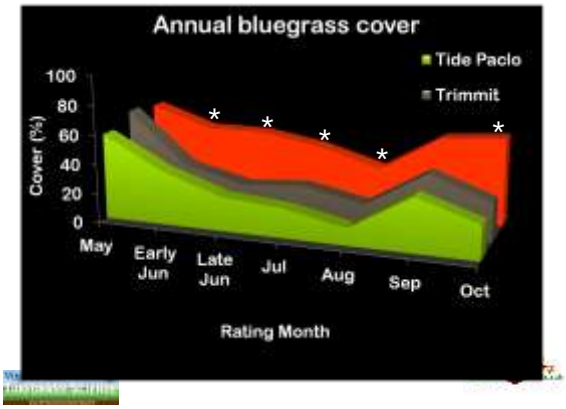
- To evaluate post patent formulations of paclobutrazol and trinexapac ethyl compared to proprietary products for *Poa annua* suppression and creeping bentgrass putting green quality

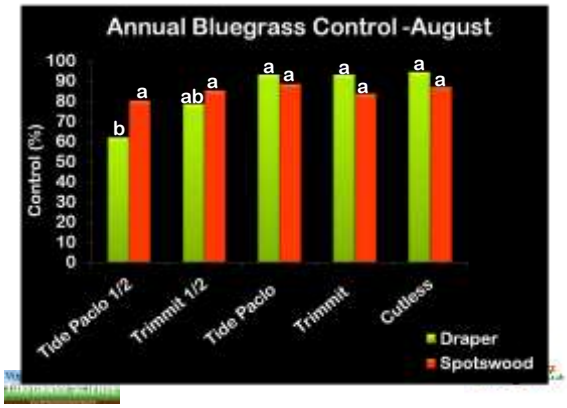
- Both of these plant growth regulators are available from multiple sources following recent patent expiration
- In the current economic climate turf managers are more likely to consider post-patent products for cost savings

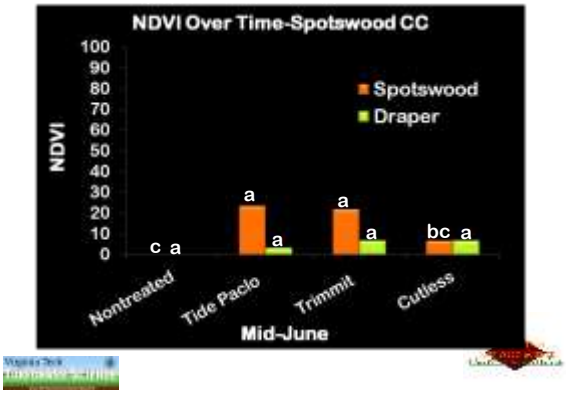
Locations

Treatment Programs

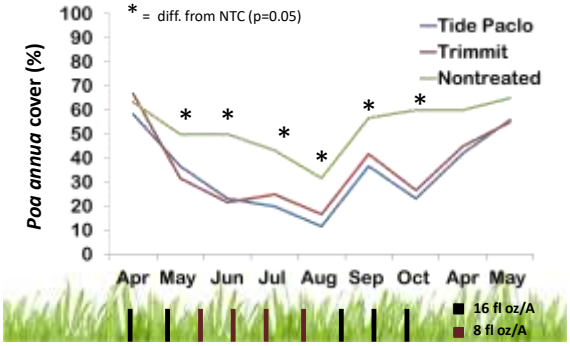
Trt	Spring(2X)	Summer (3X)	Fall (3X)
1	Trimmit (16 oz/A)	Trimmit (8 oz/A) + Primo Maxx (0.125 oz/M)	Trimmit (16 oz/A)
2	Tide Paclo (16 oz/A)	Tide Paclo (8 oz/A) + T-nex (0.125 oz/M)	Tide Paclo (16 oz/A)
3	Trimmit (8 oz/A)	Trimmit (4 oz/A) + Primo Maxx (0.125 oz/M)	Trimmit (8 oz/A)
4	Tide Paclo (8 oz/A)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







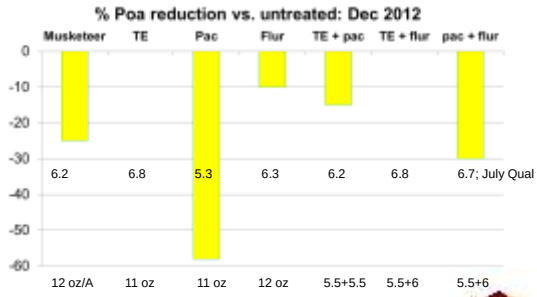
Effect of Two Paclobutrazol Products on Poa annua Cover Over Time on Two Virginia, USA Golf Putting Greens in 2010-2011



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**

PGR combination effects on Poa control in L93 green:
June 2012 Poa cover began at average of 20%; 2 wk interval, 8 apps



Ervin, VT trial

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

Portmarnock mostly fescue green

Background: Influential consultants, Jim Arthur: <u>Practical Greenkeeping</u>

"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."

Book reads like it largely influenced Greenway program

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_4SO_4 every 2 wks, 16 times = 1.6 lbs N/yr
- Diseases controlled with chlorothalonil & strobis
- 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)

Applied every 2 weeks, in 1 gal water/M from March into Nov, watered in next day

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)

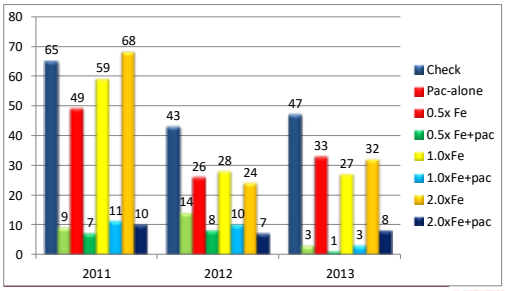
Plots in March

Plots in October

Close-up of high Fe/pac plot

Poa collapse in high Fe plot, Aug

Percent Poa over Time: May 2011-13



High Fe rates reduced Dollar Spot

Dollar spot and Moss, Sept.

infection centers or colony centers, golf tee count

Treatment	Dollar spot	Moss
0Fe, Pac	28	34
0Fe, SWE	45	6
0Fe, Ck	89	8
4Fe, Pac	21	33
4Fe, SWE	60	10
4Fe, Ck	55	9
8Fe, Pac	7	19
8Fe, SWE	34	1
8Fe, Ck	32	1
16Fe, Pac	3	5
16Fe, SWE	16	0
16Fe, Ck	15	1

Pac and Fe-sulfate reduced DS most

SWE-alone reduced DS

High Fe-sulfate reduced DS very well

Aggressive Pac caused more moss, but Fe offset

Soil test data, 1-inch depth after 3 yrs

Treatment	pH	P, ppm	K, ppm
0 Fe	5.96	4.5	14.5
4 Fe	6.03	4.0	13
8 Fe	6.09	4.3	12.8
16 Fe	5.95	4.5	11.3

Initial values: 6.22 29 28
Nov 2010

Potable water used for irrigation; pH = 7.6

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?

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"

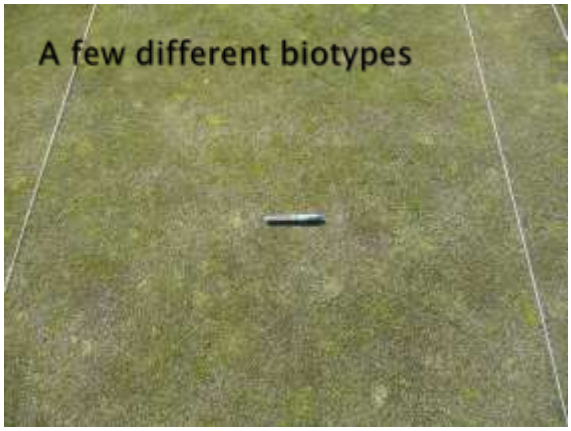
Intermediate-types

Perennial-types
Poa annua L. var. *reptans*
"cultured types"

AKA biotypes

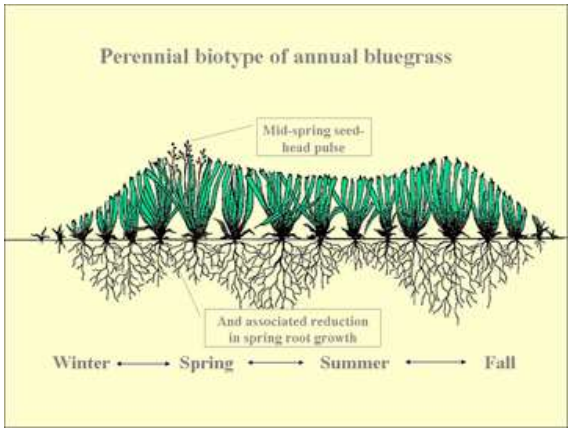
Why the complexity?

- Parents: *Poa infirma* & *Poa supina*
  - Both diploids
  - 2 sets of chromosomes (14 total)
- Annual bluegrass is a tetraploid
  - 2n x 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, <u>flowering</u>
  - Annual-types
    - Continual flowering with pulses
      - 44 to 149 days from germination to flower
  - Perennial-types
    - More seasonal flowering



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

PGRs for seedhead control

- 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

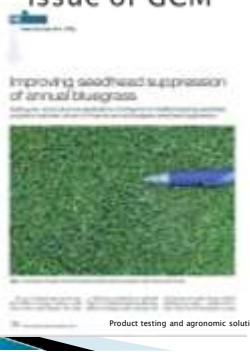
Timing seedhead sprays

- 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

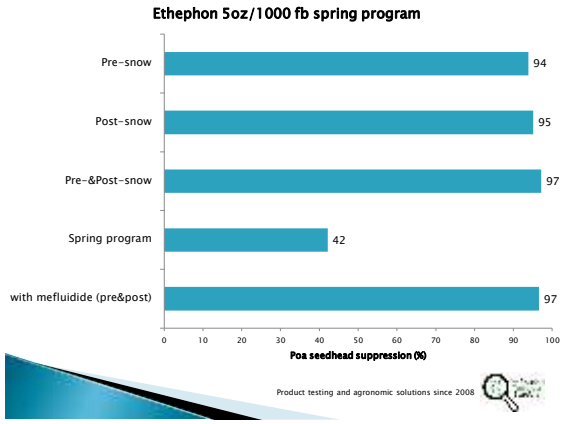
- Pre-snow
  - Ethephon 5oz/1000 in 2 Gal water/1000
  - Embark TO 10oz/A = 0.2oz/1000
  - Embark 2S 1oz/A = 0.02oz/1000
- Post-snow
  - Ethephon 5oz/1000
  - Embark TO 10oz/A
  - Embark 2S 1oz/A
- Combination of Pre- & Post-snow timings
  - First assessment of Proxy+Embark
- Spring program check

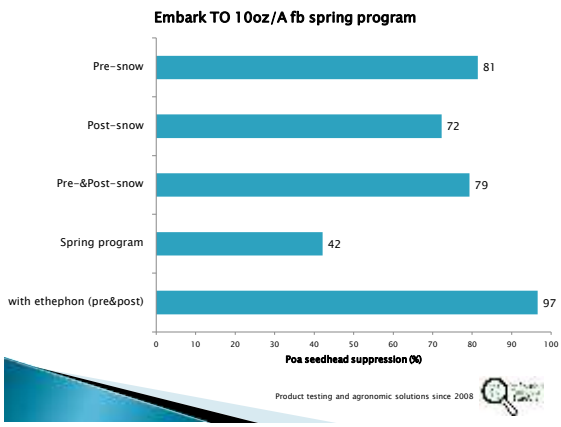
Product testing and agronomic solutions since 2008

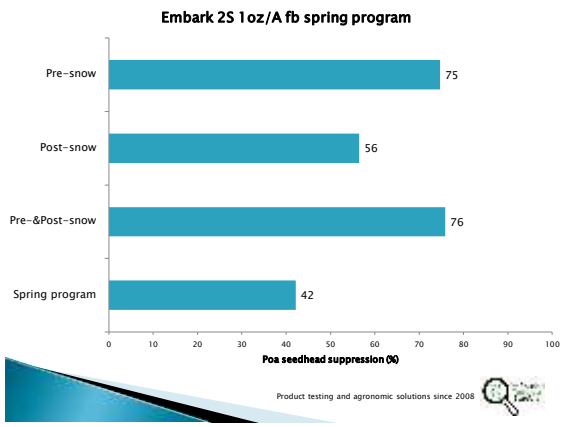
Details

- Pre-snow timing November 18, 2014
- Post-snow timing February 12, 2015
- Normal spring DD-based program
  - Initiated 350 DD_{B32F} (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!

Product testing and agronomic solutions since 2008







Turf quality

		March	May	June
Ethephon 2SL	with mefluidide	5.3 a	6.7 a	ns
Ethephon 2SL	Pre-snow	4.9 ab	6.3 ab	ns
Ethephon 2SL	Post-snow	4.6 ab	6.7 a	ns
Ethephon 2SL	Pre-&Post-snow	5.0 ab	6.3 ab	ns
Embark TO	Pre-snow	ns	ns	ns
Embark TO	Post-snow	ns	ns	ns
Embark TO	Pre-&Post-snow	ns	ns	ns
Spring program		4.0 c	5.3 cd	5.7 abc
Embark 2S	Pre-snow	ns	ns	ns
Embark 2S	Post-snow	ns	ns	ns
Embark 2S	Pre-&Post-snow	ns	ns	ns
Untreated		4.0 c	5.0 d	5.0 c

IGCSA-sponsored research 2015-16

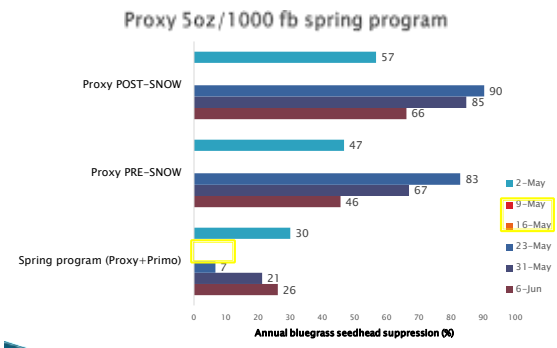
- 60:40 Bent:Poa green in SLC, UT
  - River Oaks GC
  - 1980s
  - Sand-based style
  - Frequent history of PGRs in spring
- Proxy 5oz/1000 in 2 Gal/1000
  - Pre-snow Nov. 17th
  - Post-snow Feb. 19th
- fb spring program

Two Apps
March 11th & April 12th
Proxy+Primo

Product testing and agronomic solutions since 2008

May 9th thru 16th…topdressing

- Effective integrated approach for seedhead control…



Product testing and agronomic solutions since 2008

RMGCSA-sponsored research 2016-17

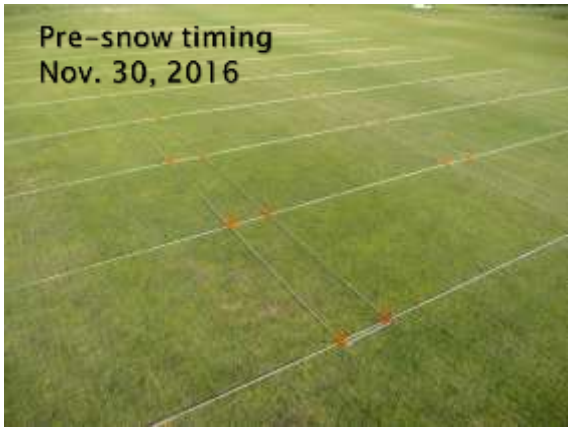
- 80:20 Poa:Bent green in Denver, CO
  - Murphy Creek GC
  - Late 1990's
  - Sand rootzone
  - Frequent history of PGRs throughout year

Product testing and agronomic solutions since 2008

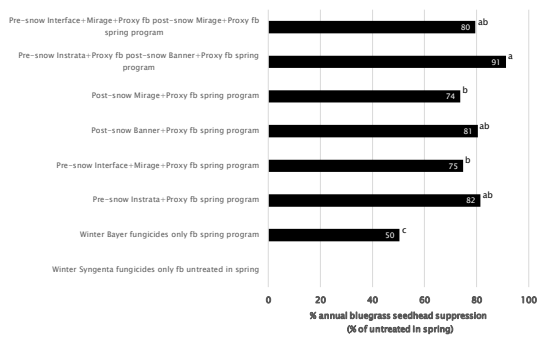
RMGCSA-sponsored research 2016-17 treatments

- 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

Product testing and agronomic solutions since 2008



Proxy and snow mold fungicide mixtures



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 Ethelyne pathways

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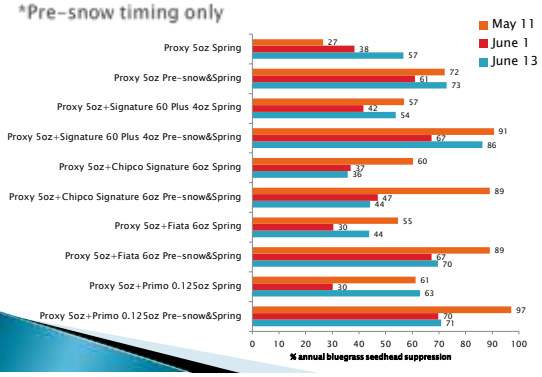
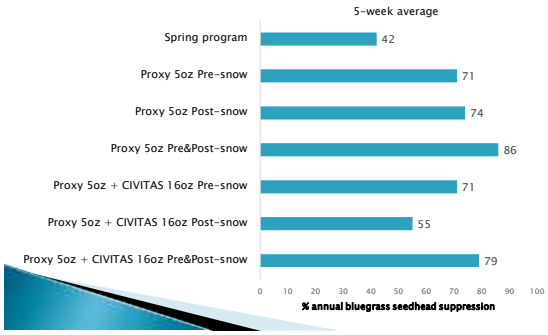
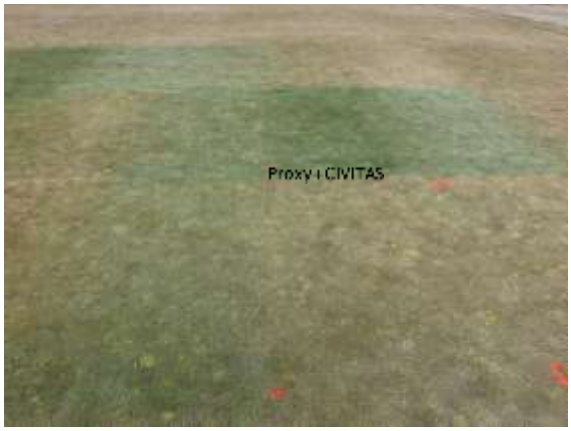
SAR inducer products

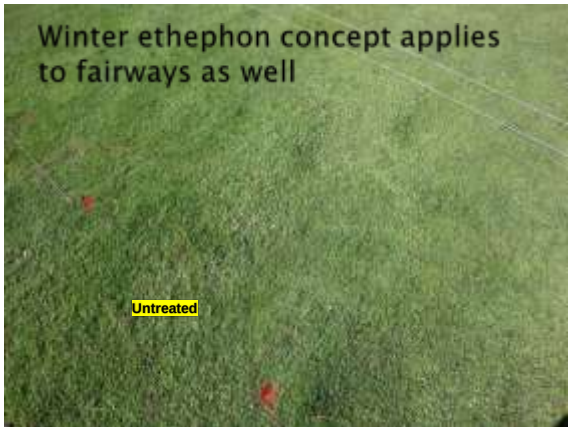
*Pre-snow timing only



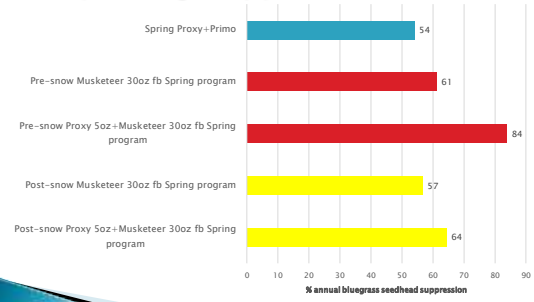
Proxy+CIVITAS mixtures

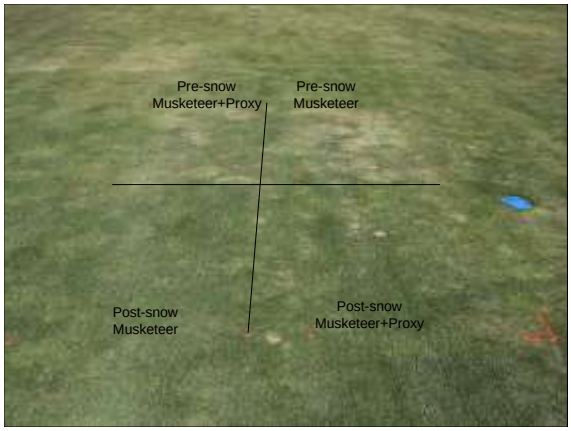




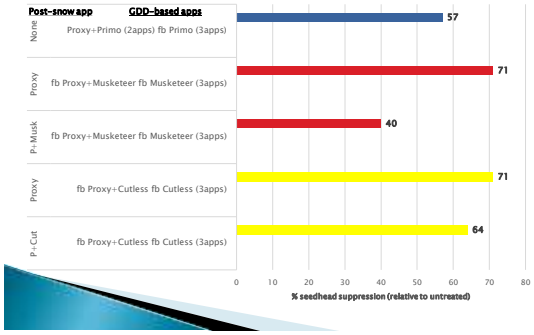


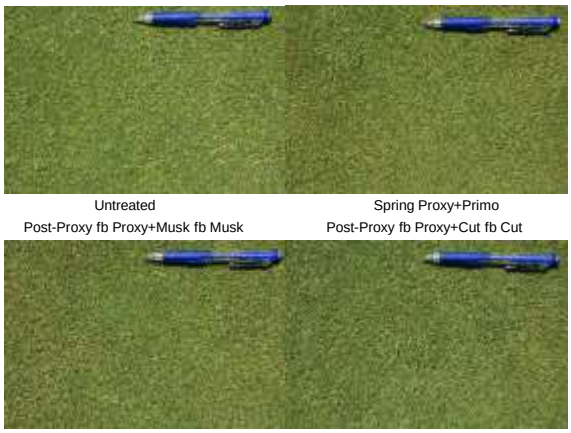
Fairway seedhead control with Proxy & single apps of Musketeer





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





Recap

- 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

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Thanks for your attention

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SEMINAR WRAP-UP

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