

A photograph of a golf course green with a blue flag. The green is surrounded by trees and mountains in the background. The text "Drive your growth rate" is overlaid on the top right of the image.

Drive your growth rate

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Implications of Turfgrass Growth Manipulation

- Carbon Partitioning & Storage
- Nutrient & Pesticide Requirements
- Recuperative Potential
- Turfgrass Performance
- Playability



Photo courtesy Andrew McDaniel

Turf managers are constantly trying to balance growth rate and turf performance

Too Fast

Just Right

Too Slow

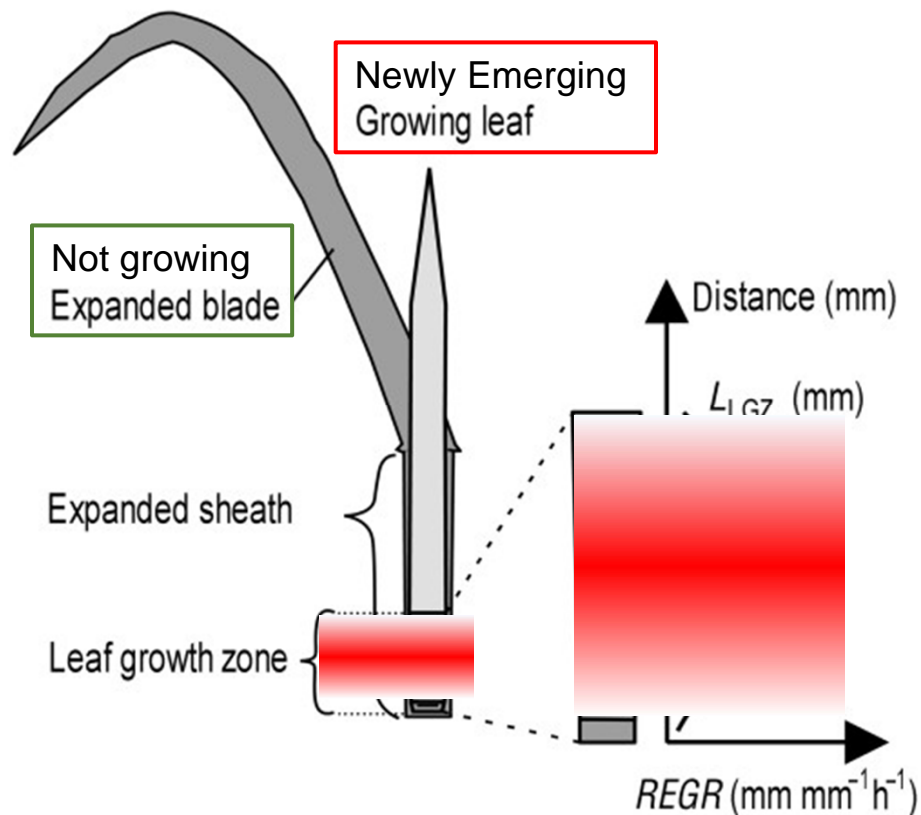
Factors impacting growth

- Soil Moisture
- Nitrogen
- PGRs

We need to define growth more precisely

Hormone called gibberellin (GA) encourages leaf elongation rate (clipping yield)

Environmental
Stimuli cause GA to
be produced in this
zone of elongation
which impact
clipping yield



Various factors impact GA production

- Environmental conditions
 - Light quality
 - Water status
 - Temperature
- Mowing practices
- Nitrogen fertilization
- PGRs

How do we manage turf growth rate?



Accelerator
Pedal

Brake Pedal

Clutch/Gear

PGR Rate

Nitrogen Availability

- Fertilizer
- Water
- Soil mineralization

Environmental Factors (GP)

- Temperature
- Light quality & quantity
- Mowing practices
- Soil water and oxygen

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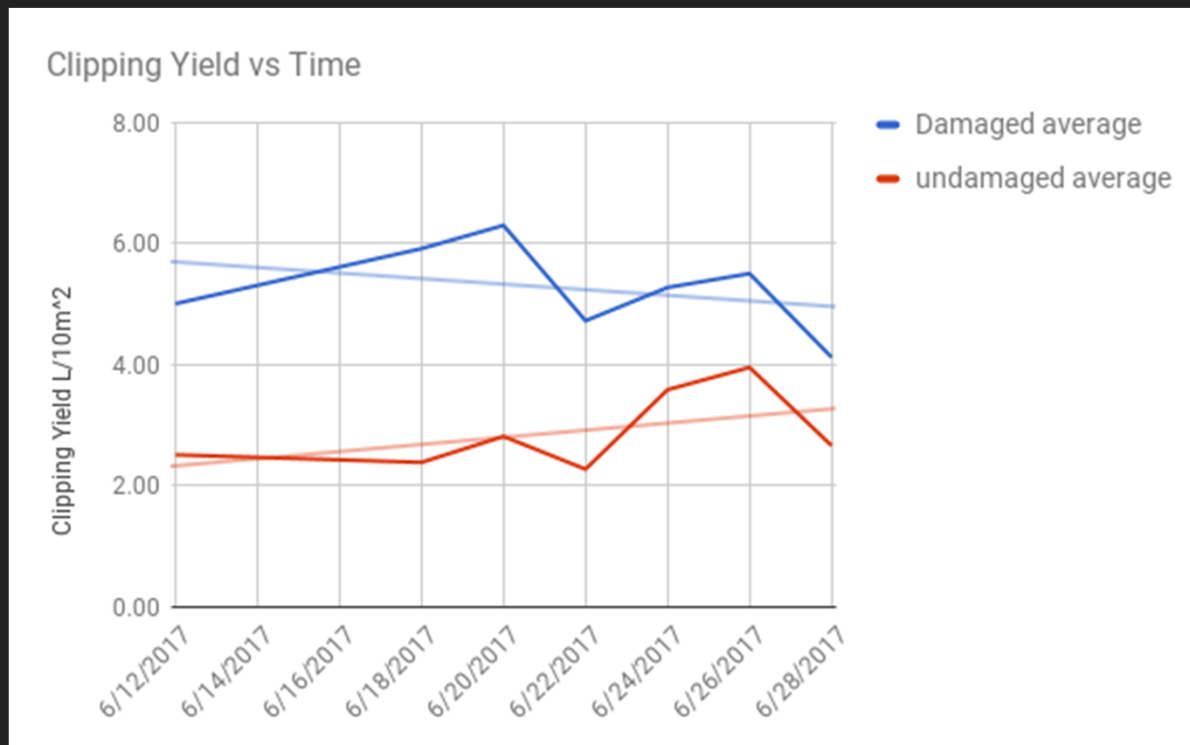


Measuring Clipping Volume To Reduce Mowing



Winter 2016-2017

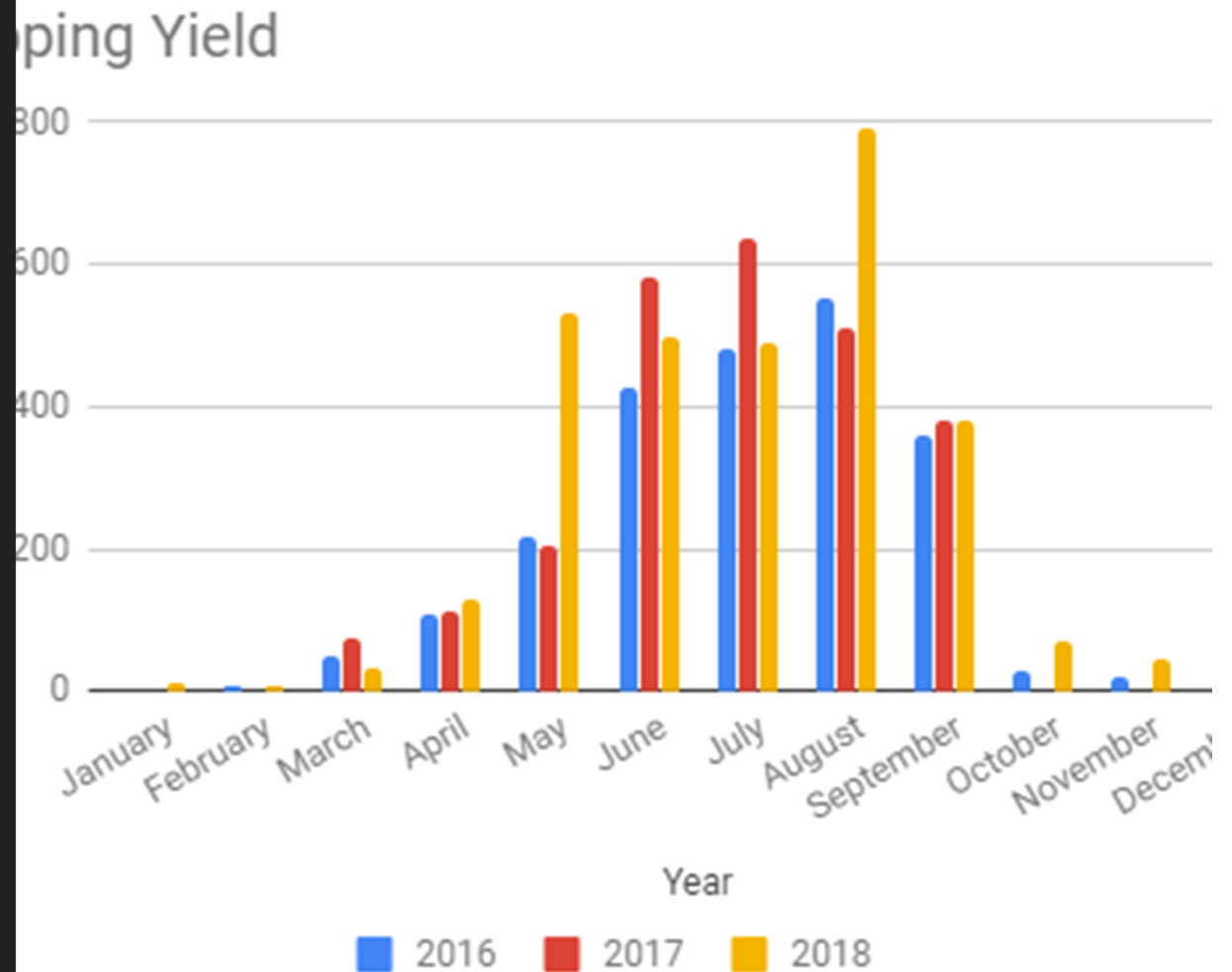
Are recovery efforts working?



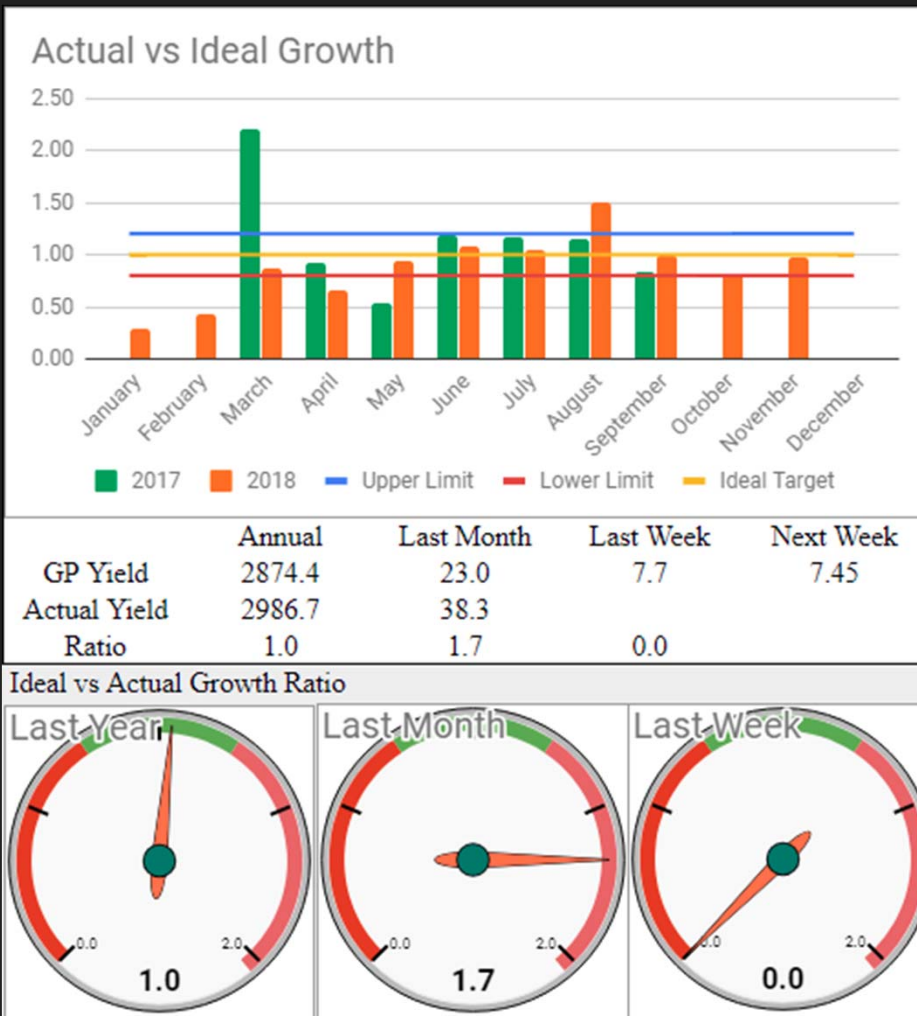


Hole Number	Area (m2)	Liters	Liters/100m2
1	280	6	2.14
2	312	18	5.77
3	291	24	8.25
4	326	15	4.60
5	289.7	15	5.18
6	350.8	9	2.57
7	310	18	5.81
8	375.3	9	2.40
9	445.5	12	2.69
LP	200	6	3.00
UP	195	3	1.54
		Average	3.99
Most recent reading date	6/18/2017		
Recent day average	3.99		
Recent Day Coefficient of variation	0.5192372389		

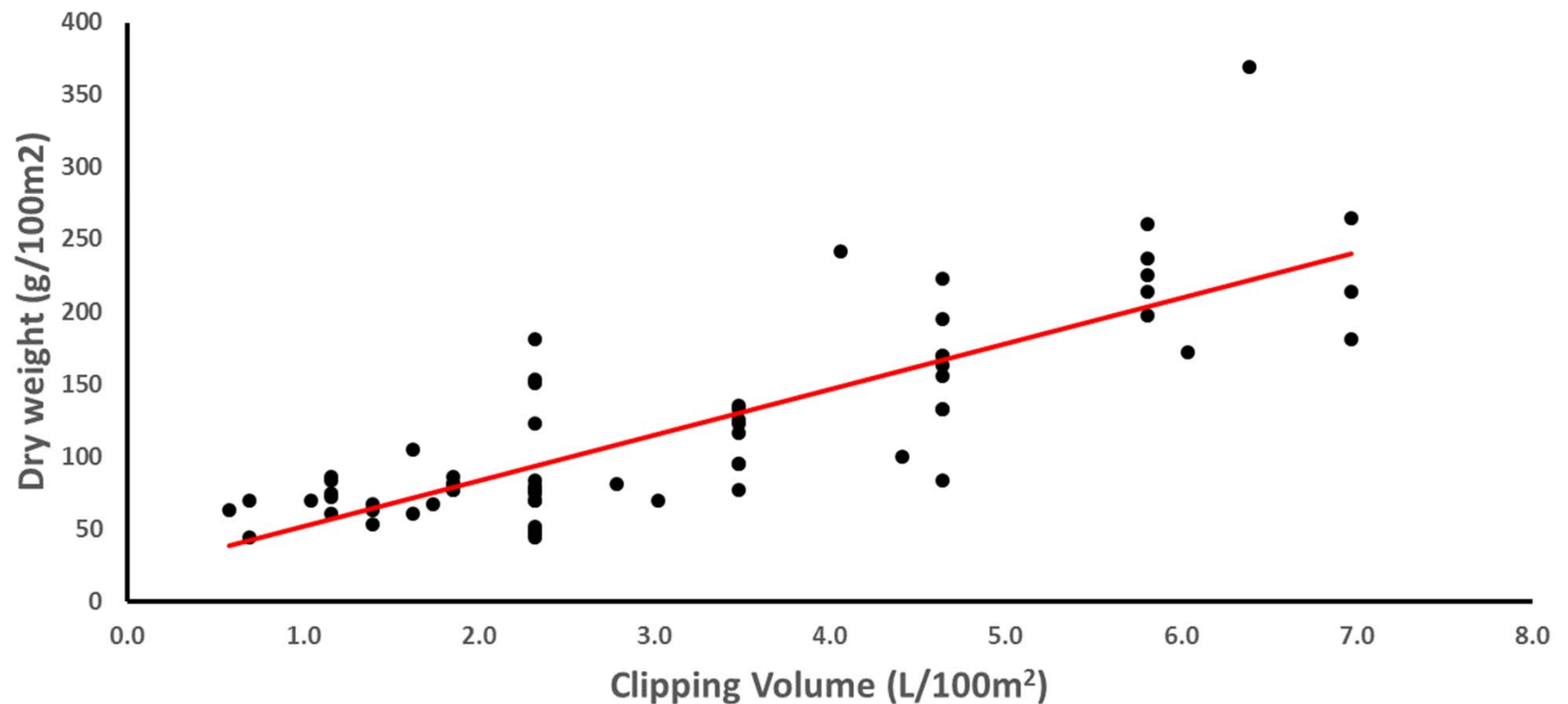
How does your
grass grow and
ideal growth
rates



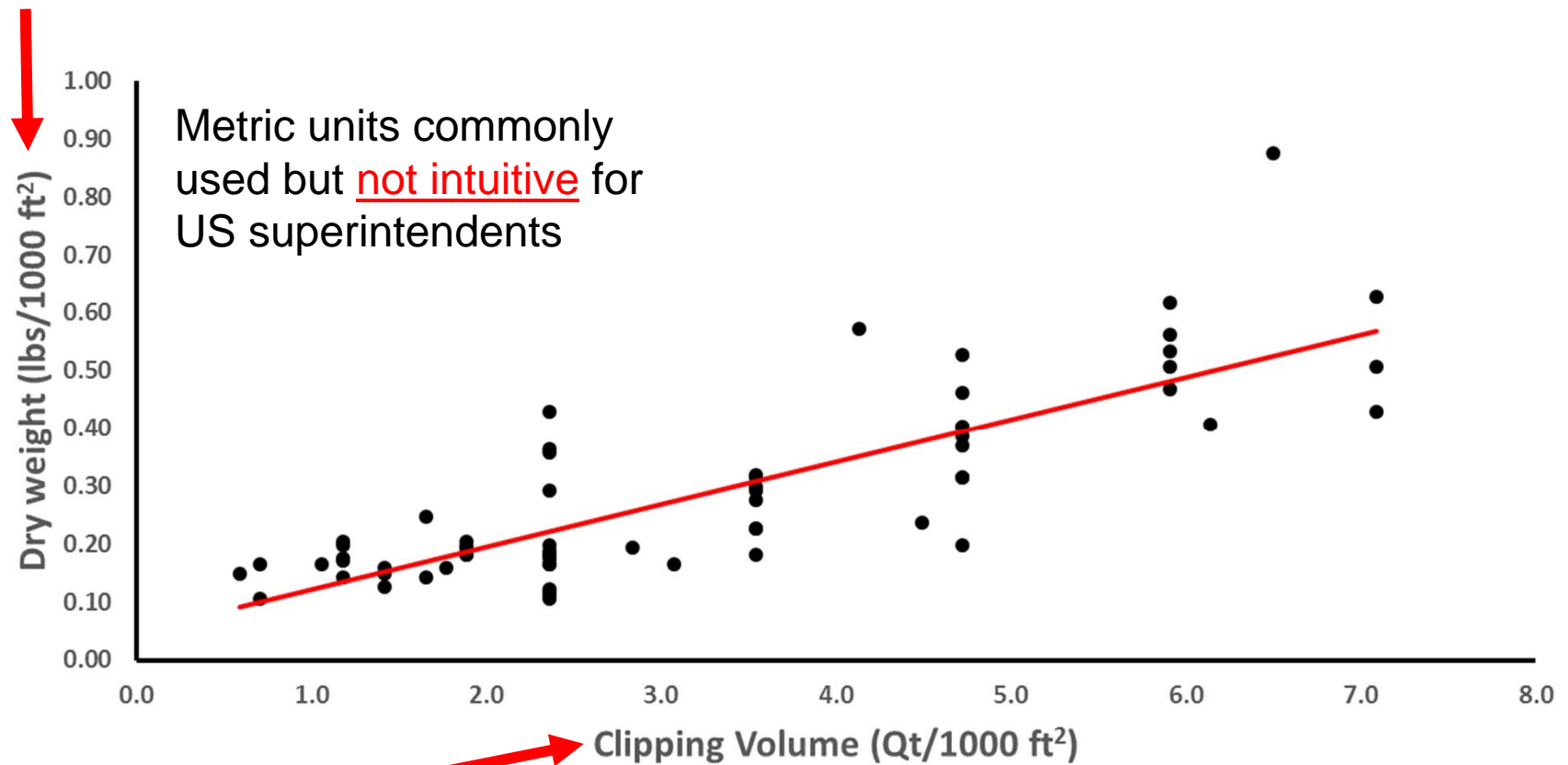
Comparing ideal
vs actual growth
rates to drive
nitrogen
application
decision making.



Clipping volume can estimate clipping yield (weight) and nutrient removal

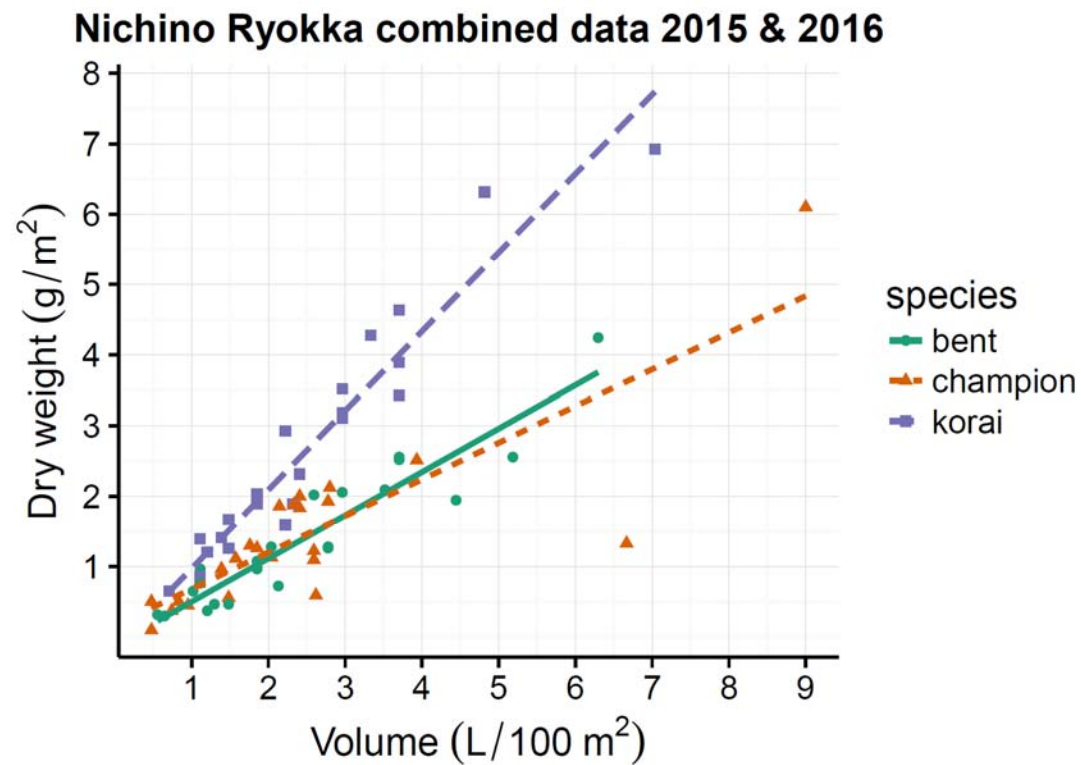


Weight (lbs/M) It's fine to use US Units (lbs/1000 ft²)



L/100 m² = Qts/1000 ft²

Bentgrass and bermudagrass have similar correlations



Data courtesy Micah Woods, PhD

How much growth is required?



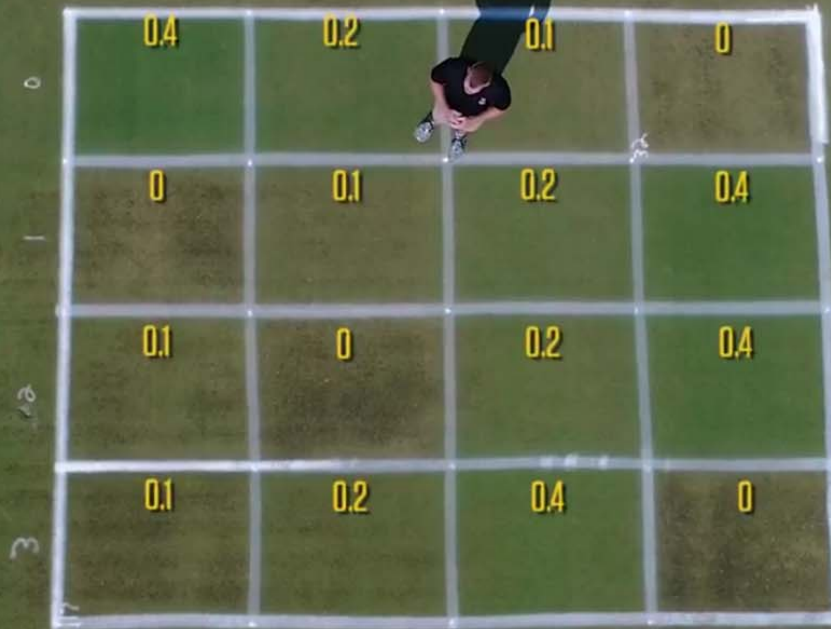


No Traffic

One Pass

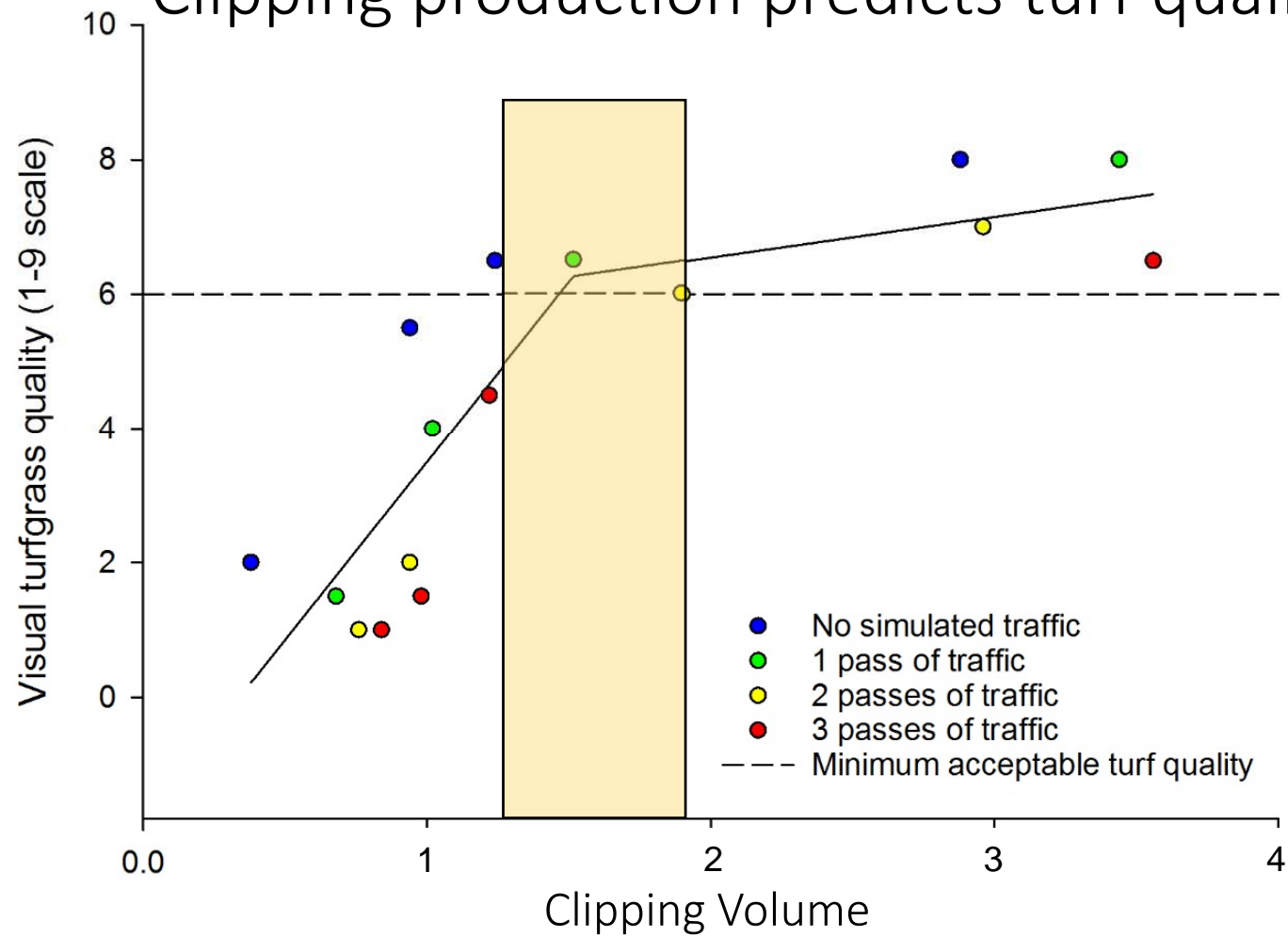
Two Pass

Three Pass

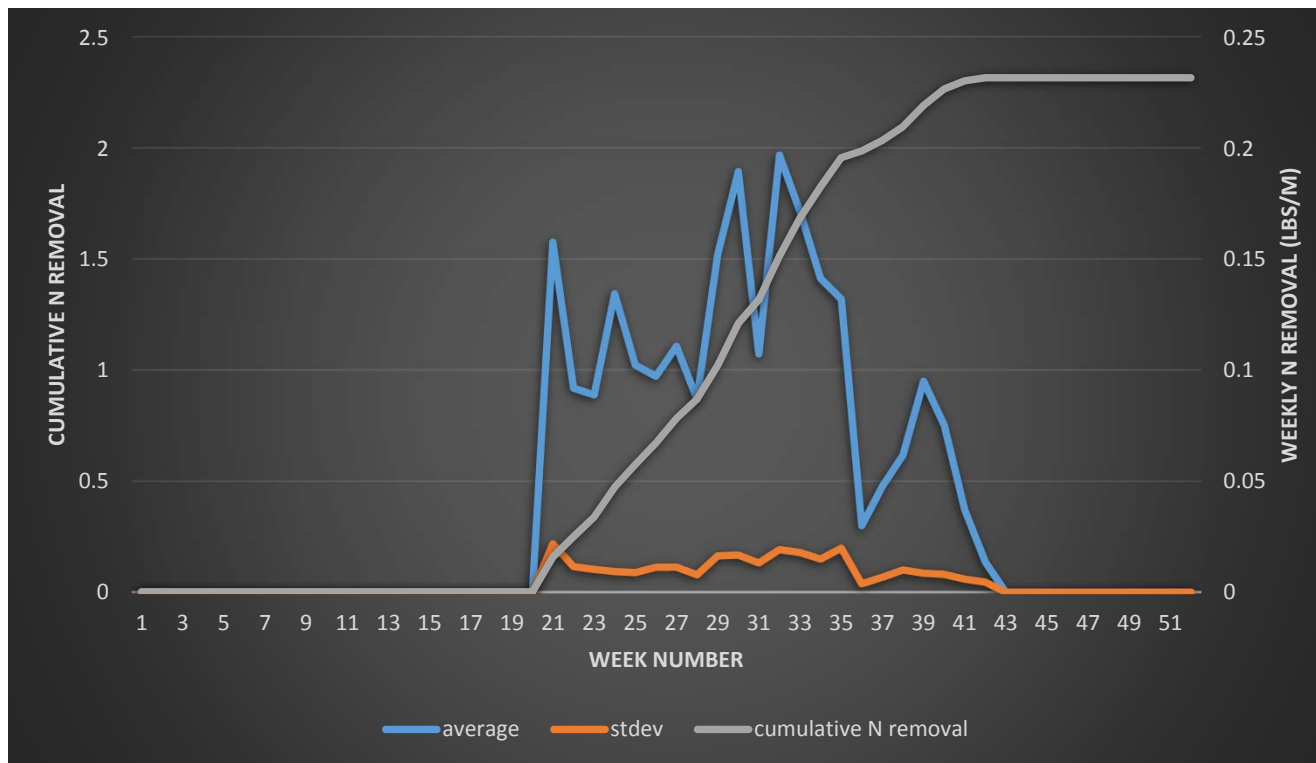


Nitrogen Applications- lbs/square foot

Clipping production predicts turf quality



Track cumulative clipping yield & estimate nutrient removal



Roughly 100 gallons of clipping volume per 1000 ft² weighs 35 lbs dry

Assuming 5% of dry tissue is nitrogen, 0.5% is P, and 2% K

Approximate N, P, K removal:

N: 1.8 lbs/M

P: 0.2 lbs/M (0.45 P₂O₅)

K: 0.7 lbs/M (0.84 K₂O)

How much fertilizer did you apply last year?

Was it close to these values?

Sand

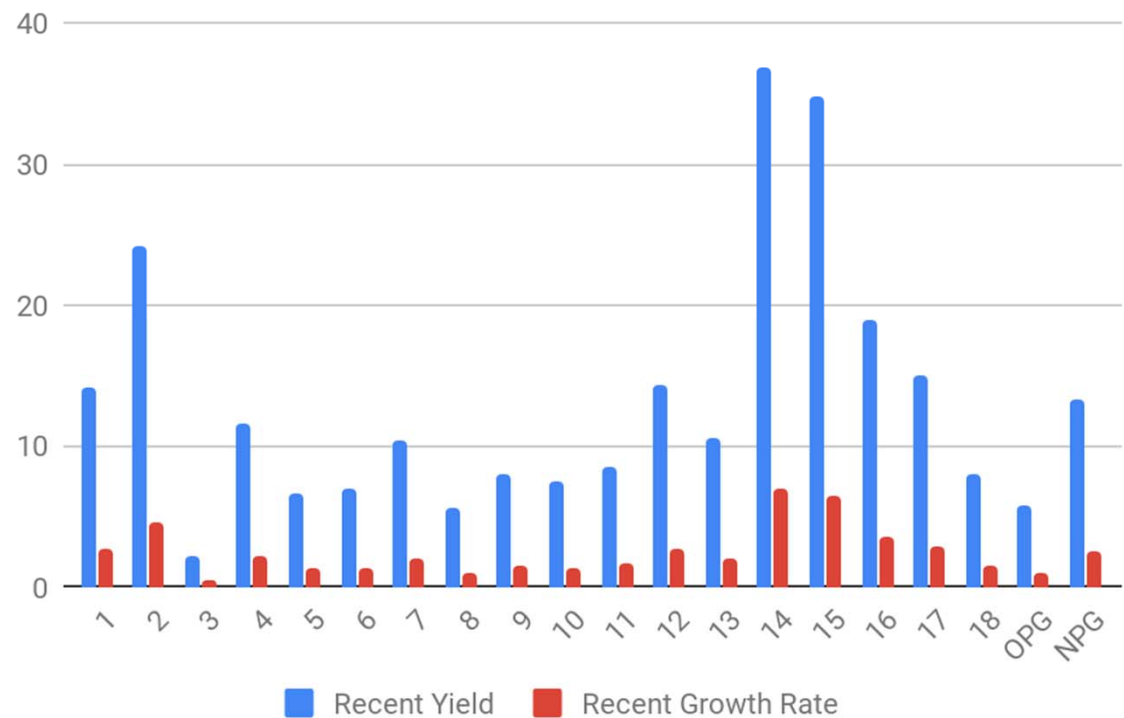


Sand Required	2075.7
Sand Applied	1,935.00
Difference	140.7
Scoops Needed	1.56

Wkh#7dgg#R#P hwhu

Growth rates on a new course

Recent Growth Rate and Yield Per Green



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PGR Rate

Nitrogen Availability

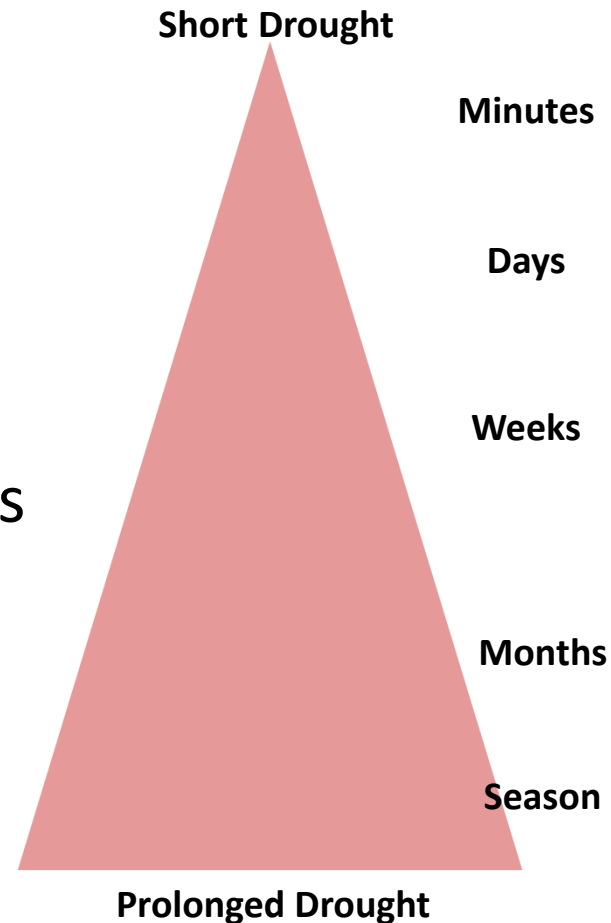
- Fertilizer
- Water
- Soil mineralization

Environmental Factors (GP)

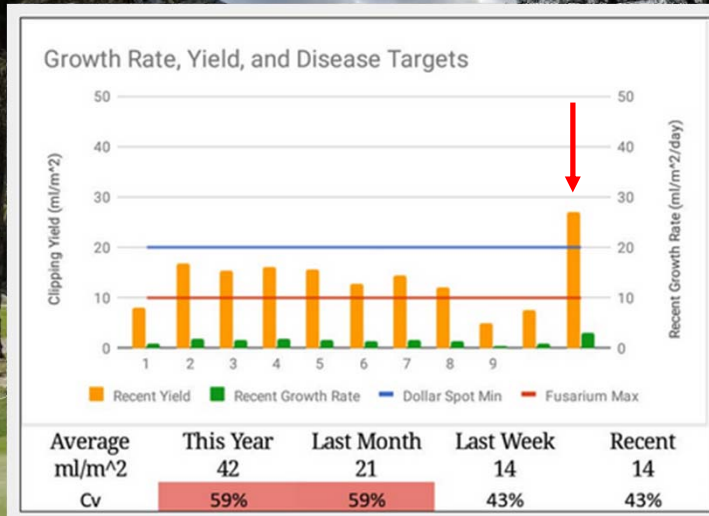
- | | |
|----------------------------|-------------------------|
| • Temperature | • Mowing practices |
| • Light quality & quantity | • Soil water and oxygen |
| • Soil nutrient levels | • Other factors |

Soil water availability strongly affects clipping yield

- Stomata Close
- **Leaf growth slows**
- **Root growth increases**
- **Cell division slows**
- Cells accumulate sugars
- Leaves and roots die
- Cells break/die
- Plant dies



Shade alters light quantity and quality



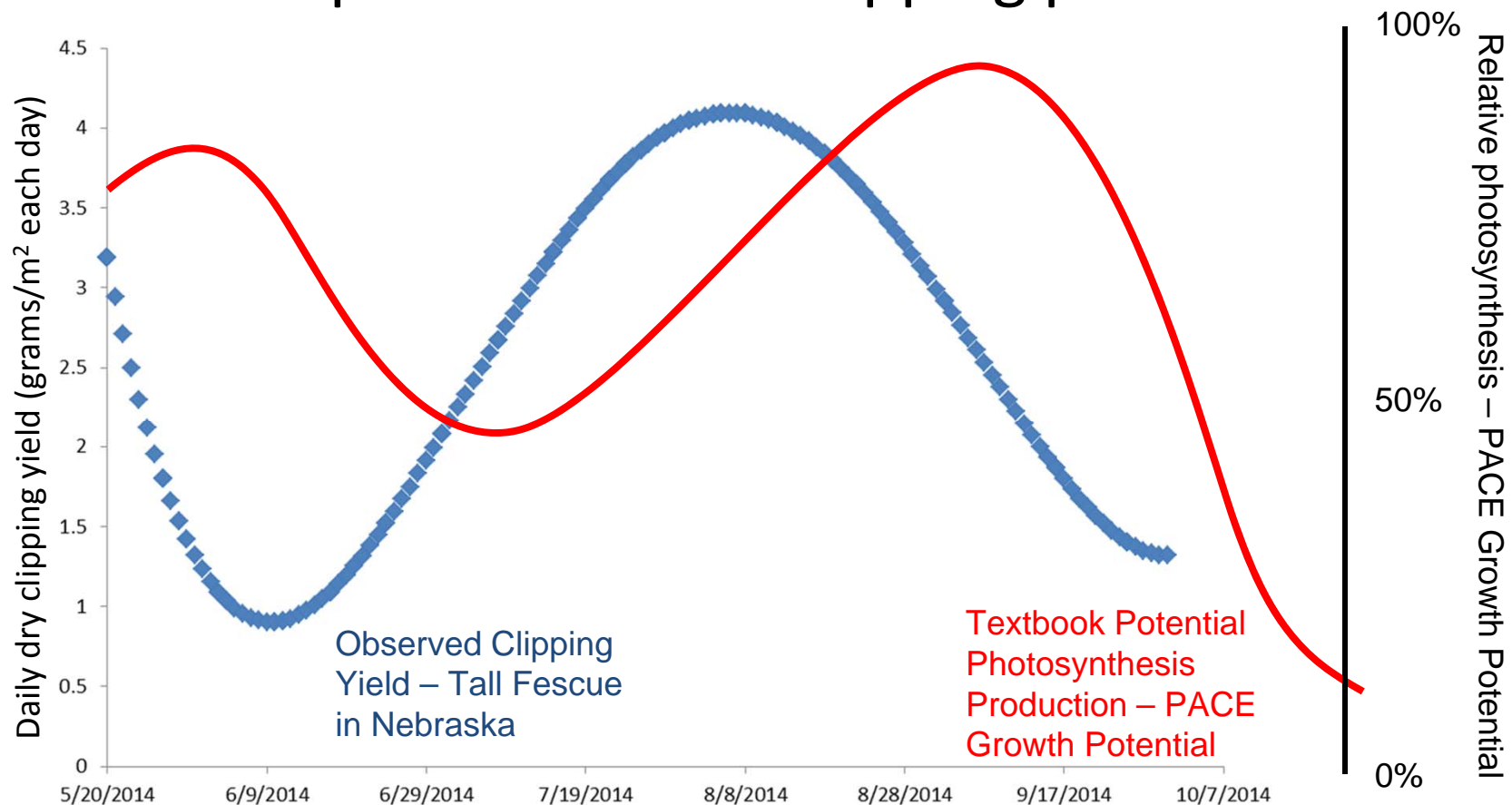
Grass tries to grow over the top of the shade

Increased expression of GA

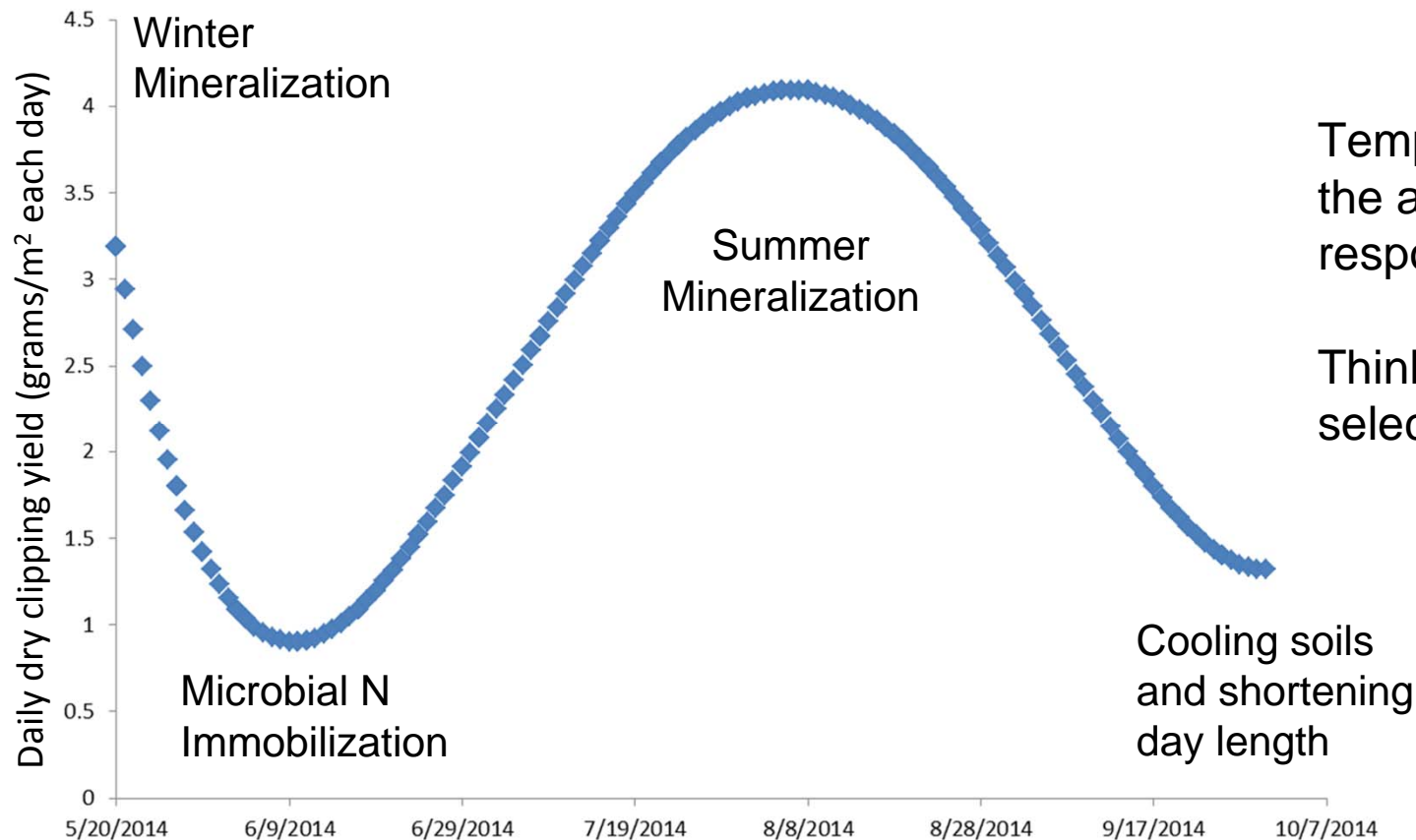
PGRs can help suppress GA over-production

Photo and data courtesy of Jason Haines

Like in shade, there is a disconnect between sugar production and clipping production



Growth rate is greatest when soil nitrogen is being release by microbes

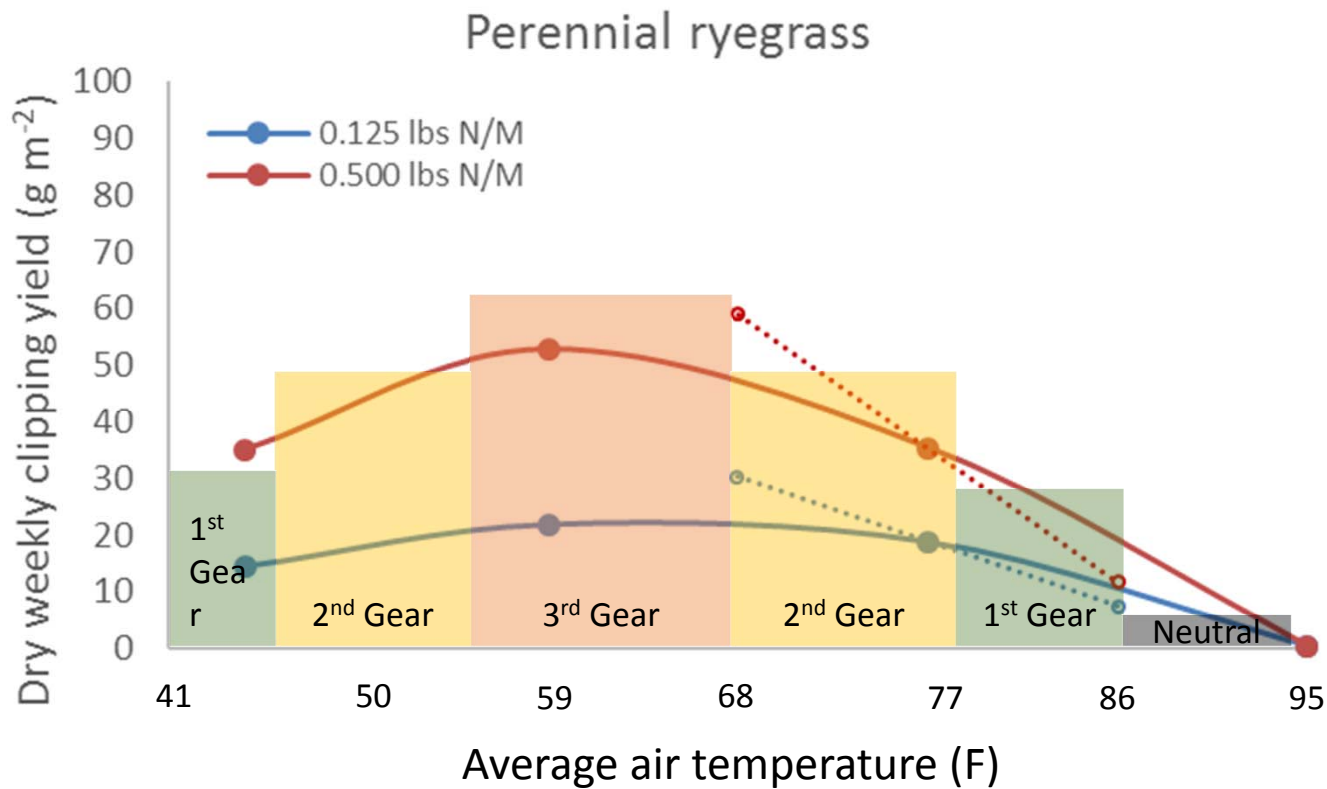


Temperature impacts the amount of growth response to nitrogen

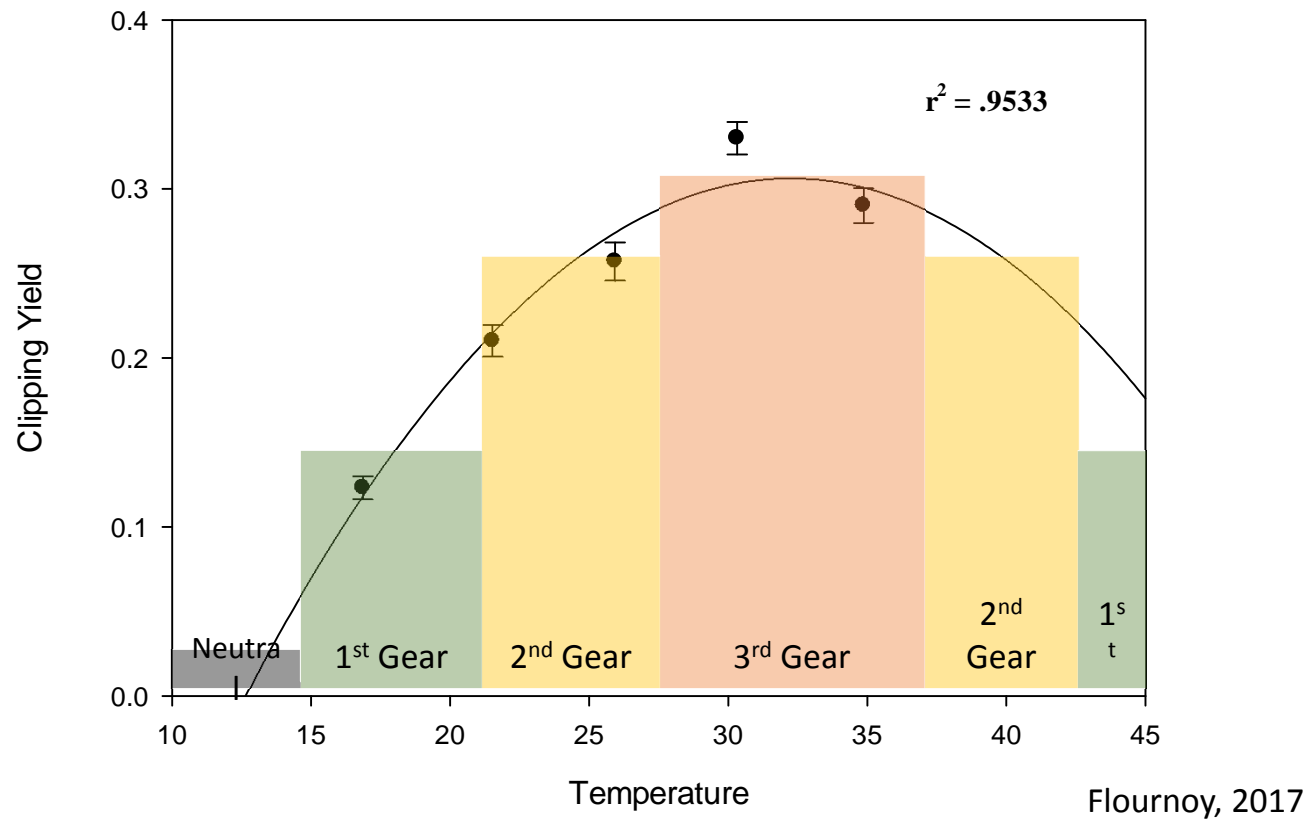
Think of the gear selector in a truck.

Cooling soils and shortening day length

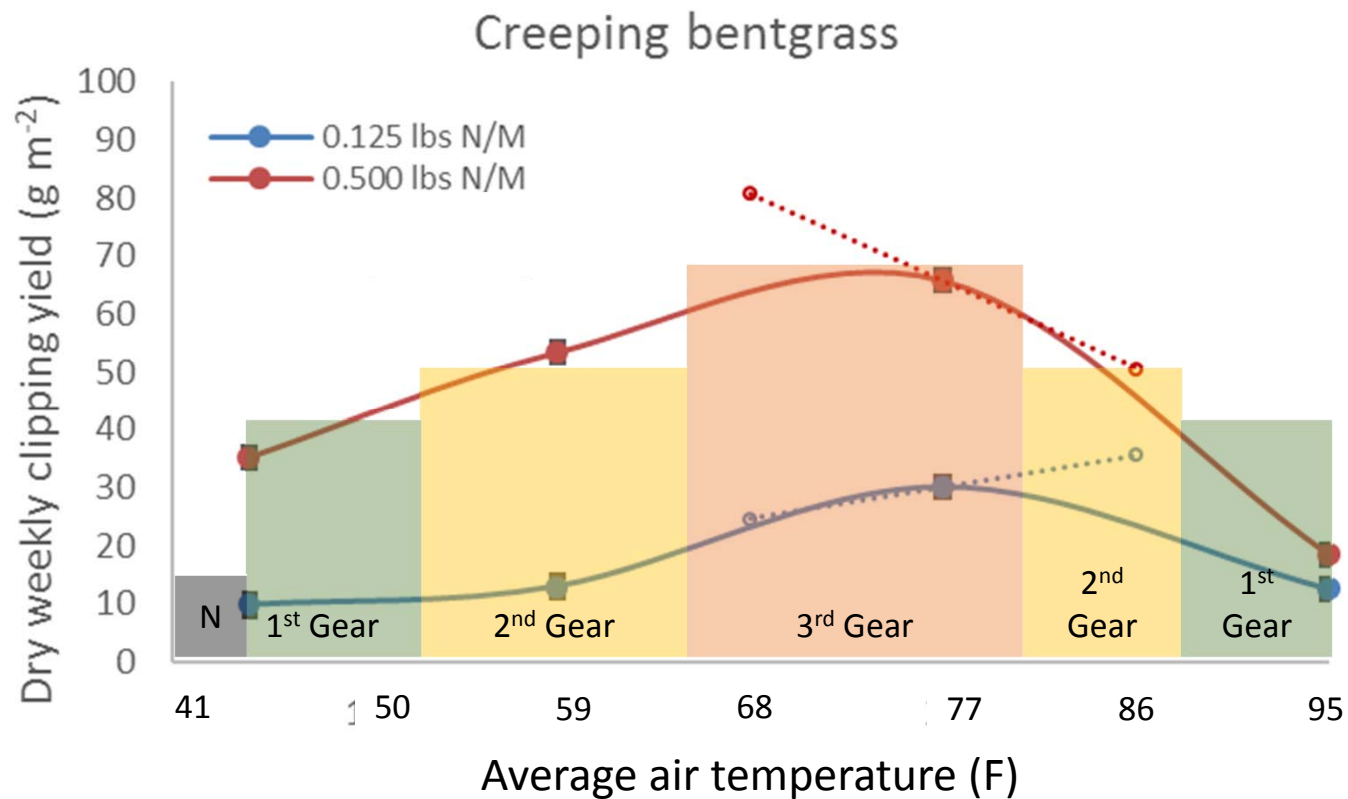
Temperature still has a big impact on nitrogen responsiveness – Picking the gear



Fertilizer and growth response of bermudagrass



Nitrogen responsiveness varies with temperature and species



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Mounting a crop sensor to a mower to estimate N and water status



Create maps to variable rate N apps or
adjust PGR applications



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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
 - Wastes time and product (money)

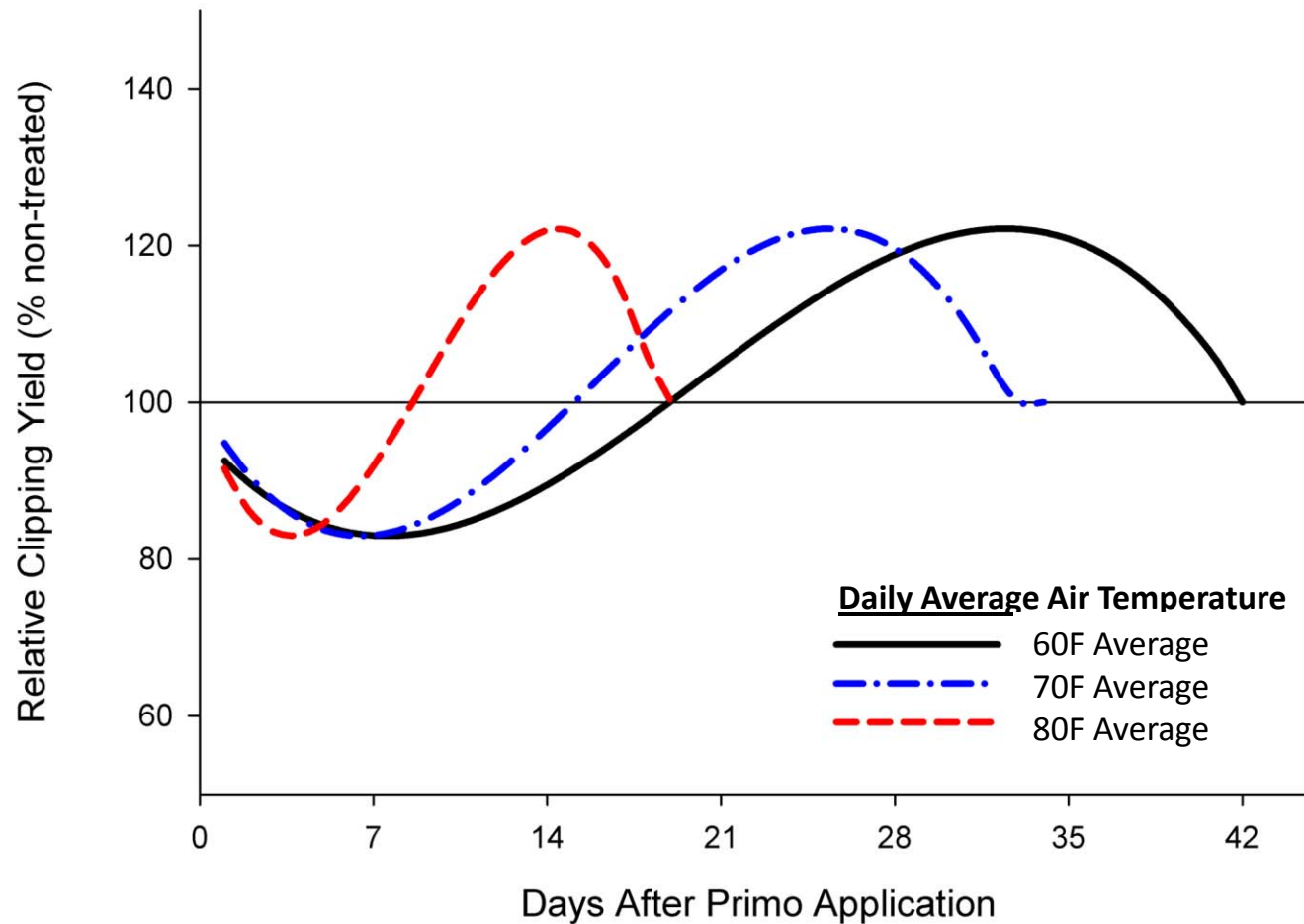
Several factors impact PGR performance

- PGR Duration: Air temperature (GDD), species, mowing practices

- PGR Intensity: Application rate*

*Applications that are more frequent than ideal will increase amount of suppression

PGR Duration is shorter at higher temp

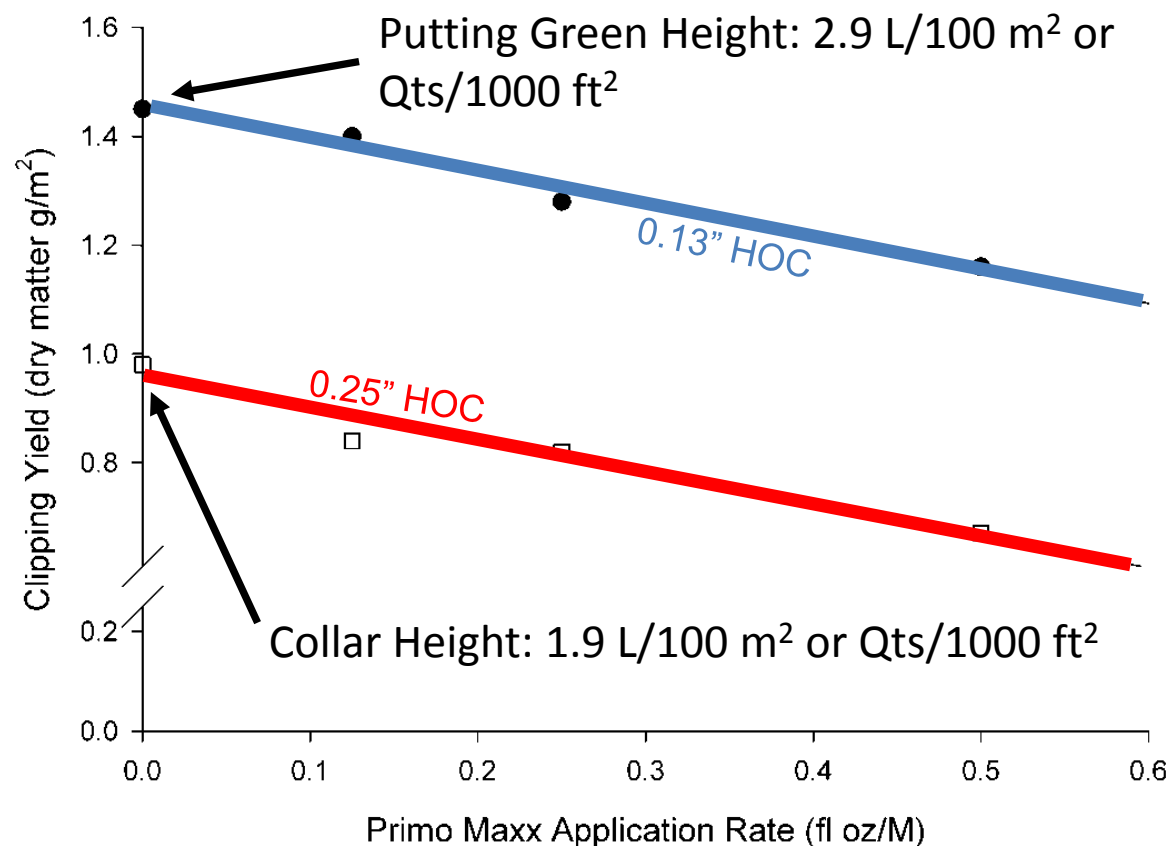


Comparing PGR Performance on cool-season greens

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*
Prohexadione-Ca	Anuew	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 GDD

* Range from low to high application rate

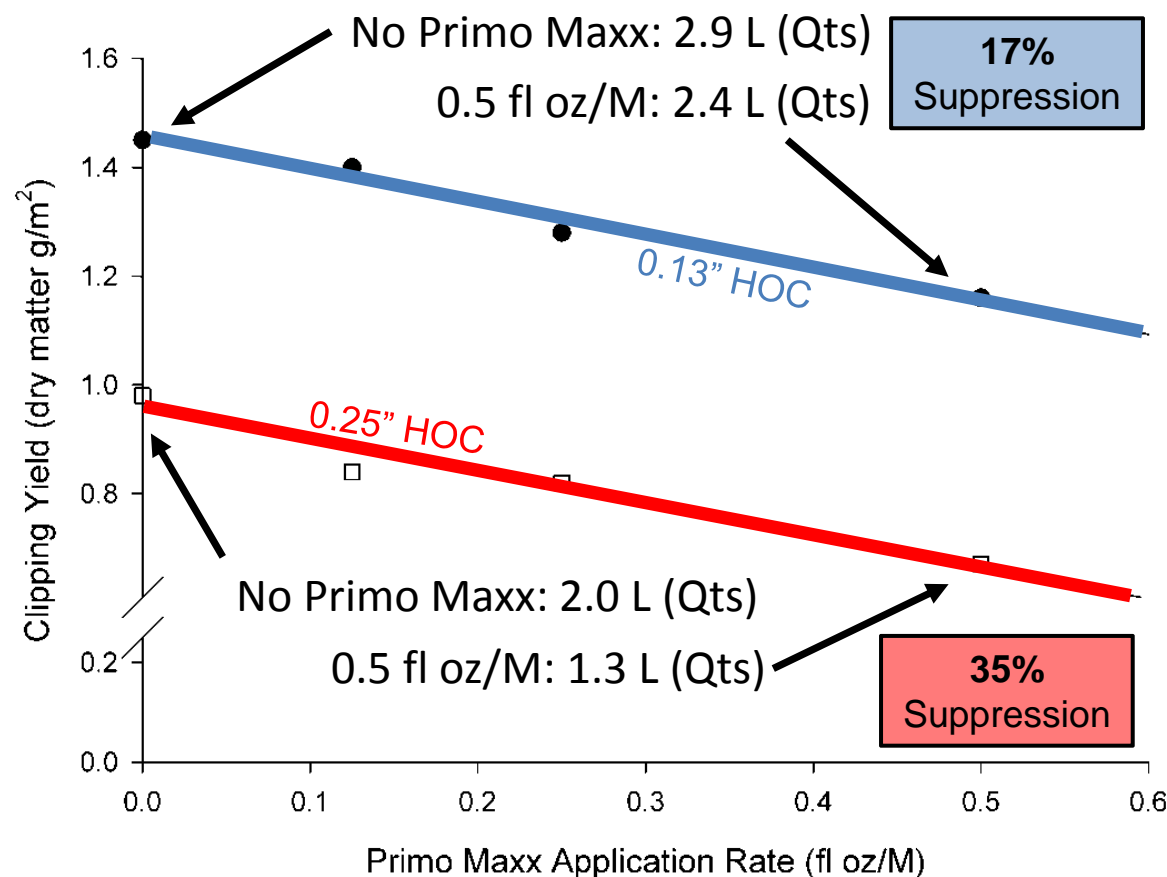
PGRs are less effective at putting green height of cut



PGRs are more effective on collars because the grow slower than greens

- PGR removed slower during mowing
- Collar height turf has lower canopy temperature
- Easier for PGR to shut down growth rate

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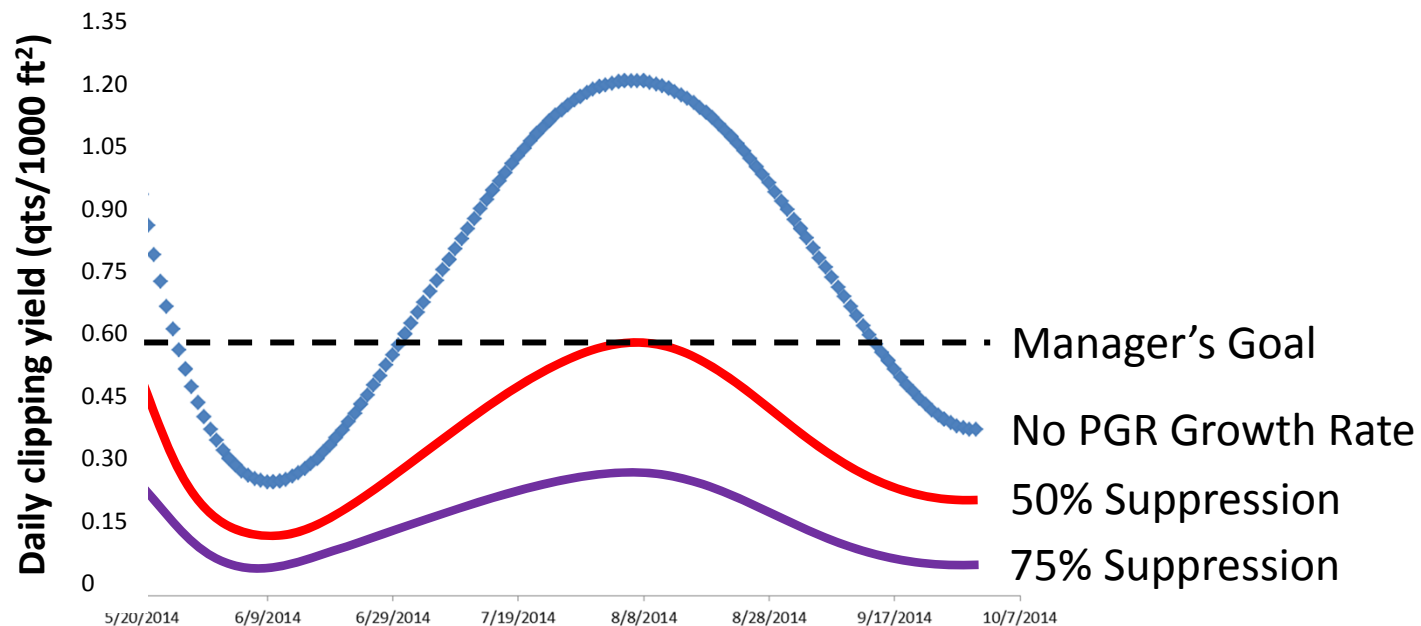
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Bentgrass Fairway Models: Much longer intervals and more suppression than greens

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
Prohexadione-Ca	Anuew	60-75%	350-380
Flurprimidol + Trinexapac-ethyl	Legacy	40-70%	320-390
Flurprimidol + Paclobutrazol + Trinexapac-ethyl	Musketeer	55-70%	350-400

Absolute yield is most important but PGRs measured as relative growth suppression

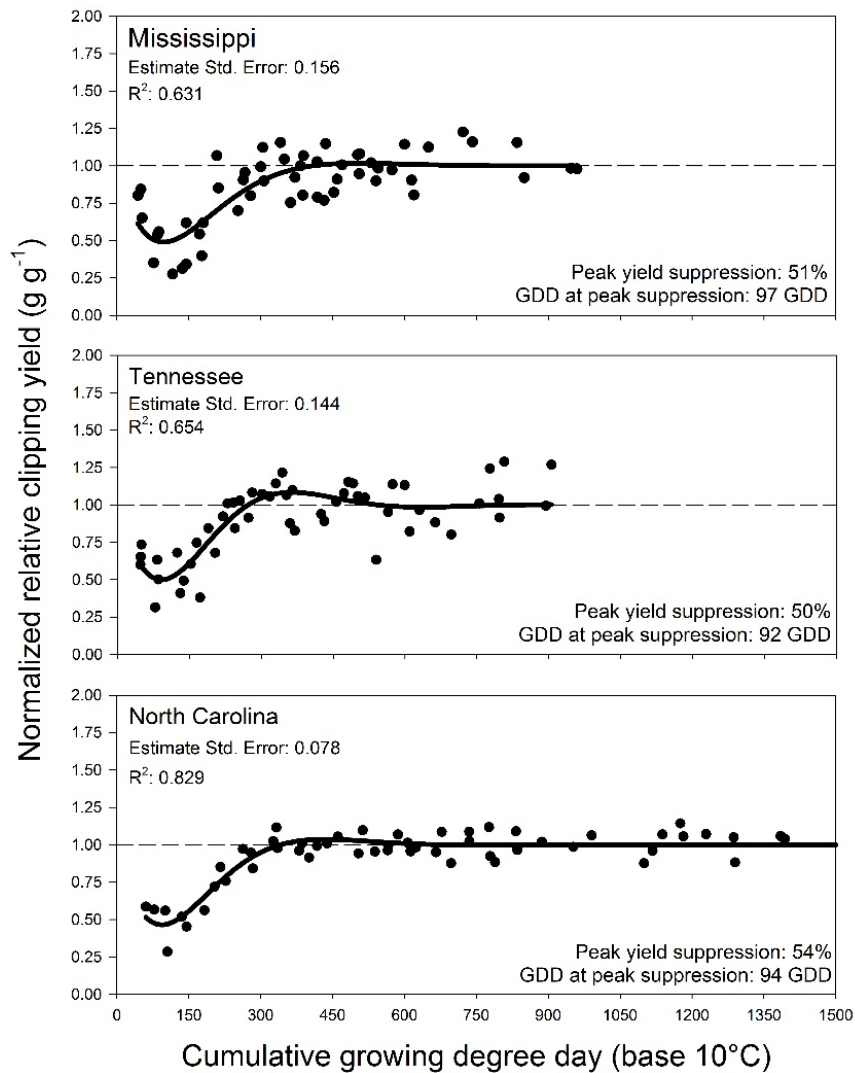
- You likely have growth rate goals -> Clipping volume
- PGR impact growth changes with growth rate



Collaborative Ultradwarf PGR Research

- PGR GDD models successfully developed in NC, TN, MS, and AL in 2016 and 2017





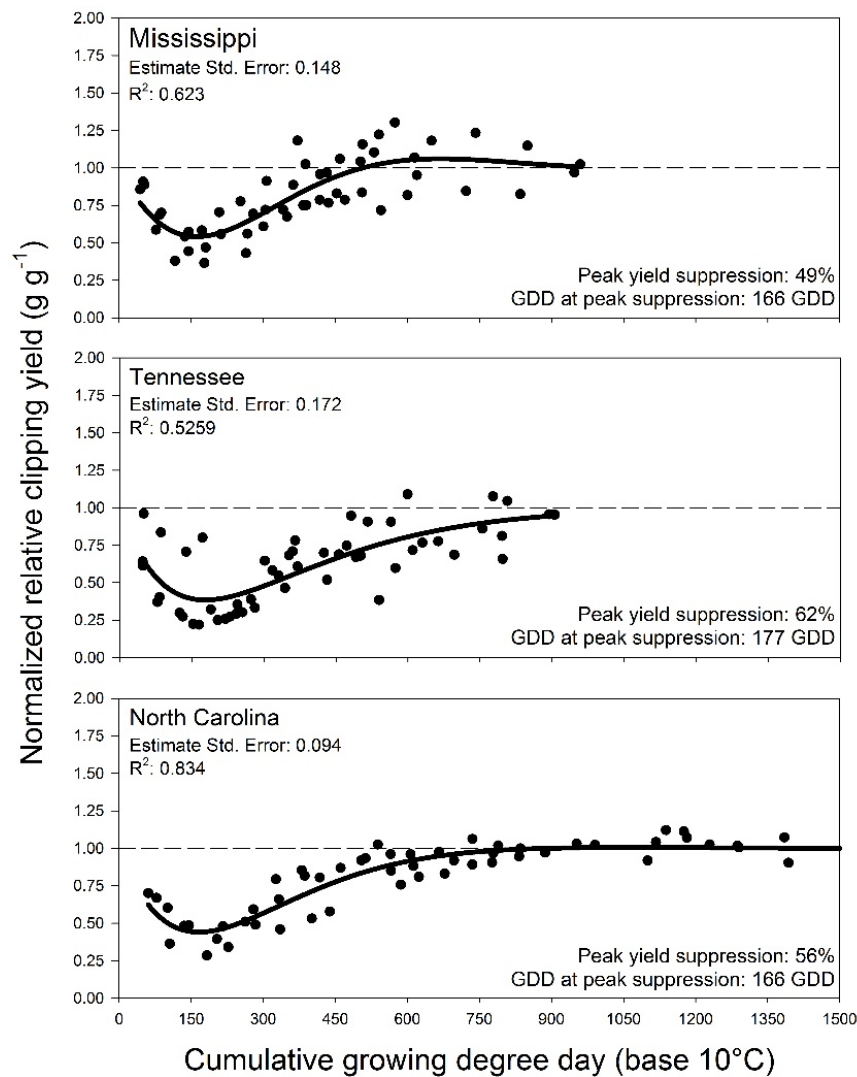
Anuew Applications

App. Rate:
8 oz/A

Peak Suppression:
50%
95 GDD
Base 10C

Re-Application Interval:
125 GDD

No Rebound Phase



Primo Maxx Applications

App. Rate:
4 fl oz/A

Peak Suppression:
50-70%
165-175 GDD
Base 10C

Re-Application Interval:
220 GDD

No Rebound Phase

Warm-season PGR intervals sound the same but are very different (base 10C)

Typical High and Low	Average Air Temp	GDD (Base 10C)	Primo Maxx (220 GDD)	Anuew (125 GDD)
50-30°F	4°C	0	Long Time!	Long Time!
70-50°F	16°C	6	36 days	21 days
80-60°F	21°C	11	20 days	11 days
90-70°F	27°C	17	13 day	7 days
100-80°F	32°C	22	10 day	6 days

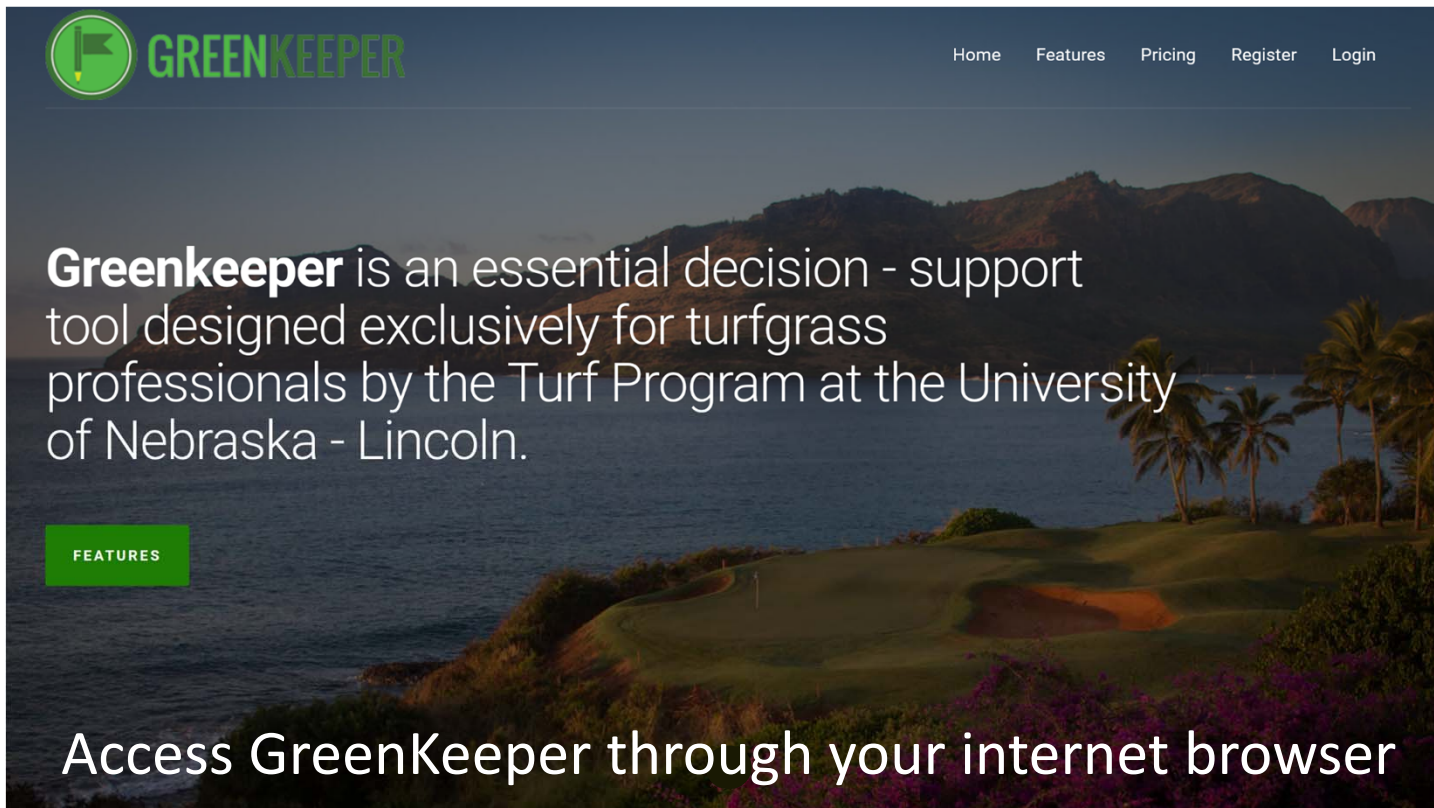
Rate effects are similar to C₃ grasses. ↑ rate = ↑ Suppression


PGR application rate, air temperature, and mowing program impact PGR performance

- PGR Duration: Air temperature (GDD), species, mowing practices
 - PGR Intensity: Application rate*
- *Applications that are more frequent than ideal will increase amount of suppression

GreenKeeperApp.com

Decision-support tool to guide turf agronomics

A screenshot of the GreenKeeperApp.com website. The background is a scenic image of a golf course at dusk or dawn, with a body of water and mountains in the distance. The website has a dark blue header with the GreenKeeper logo on the left and navigation links (Home, Features, Pricing, Register, Login) on the right. The main content area features a large text block describing the tool and a green button labeled 'FEATURES'. At the bottom, there is a white text line.

 **GREENKEEPER**

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Greenkeeper is an essential decision - support tool designed exclusively for turfgrass professionals by the Turf Program at the University of Nebraska - Lincoln.

[FEATURES](#)

Access GreenKeeper through your internet browser

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