Silicon in Turfgrass

Beth Guertal

Auburn University

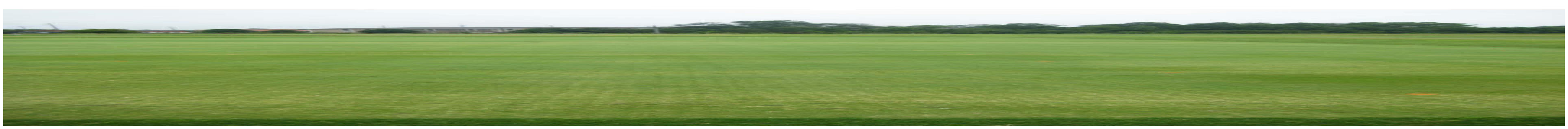
What’s an essential element?

- Plant needs it to grow and reproduce (complete life cycle).
- Nothing else can substitute for it.

Essential Elements (17)

Carbon
Hydrogen
Oxygen
Nitrogen
Phosphorus
Potassium
Calcium
Magnesium
Sulfur

Iron
Molybdenum
Copper
Manganese
Chloride
Boron
Zinc
Nickel



‘Quasi’ Essential Elements
Textbook Definition

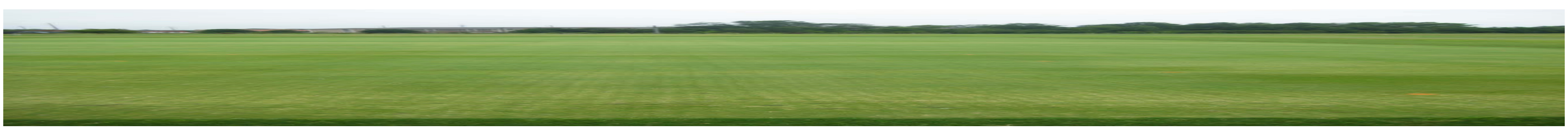
- Silicon
- Cobalt
- Aluminum
- Vanadium

Si as a Fertilizer Nutrient?

- AAPFCO elevated Si from ‘fringe’ element to a plant-beneficial substance (2012).
- ‘Demonstrated by scientific research to be beneficial to one or more species of plants’

So…..Silicon

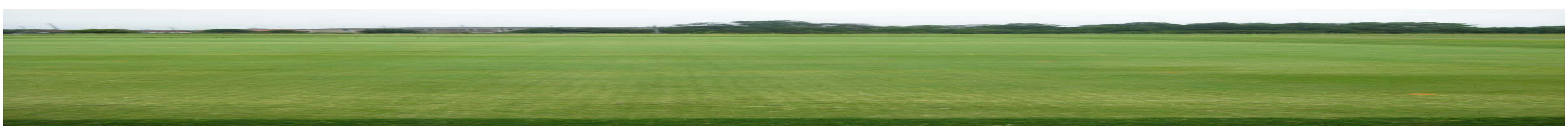
- Proven links to disease suppression.
- Possible links to improving turfgrass wear.
- Possible links to leaf blade stiffness and better ball roll.
- Possible links to improvement in drought and salinity stress.



Let’s Get the Terms Correct

- Silicon (Si) is most correctly used to identify the single atom and the abbreviation Si.
- Silicon rarely exists in this pure form in soil.
- Silicon in soils is from silicate clay minerals, such as kaolinite ($Al_2Si_2O_5(OH)_4$) .
- It also is found in primary aluminosilicates such as potassium feldspar ($KAlSi_3O_8$).
- Predominate form in soil solution is silicic acid - $Si(OH)_4$.

Raven, 2001

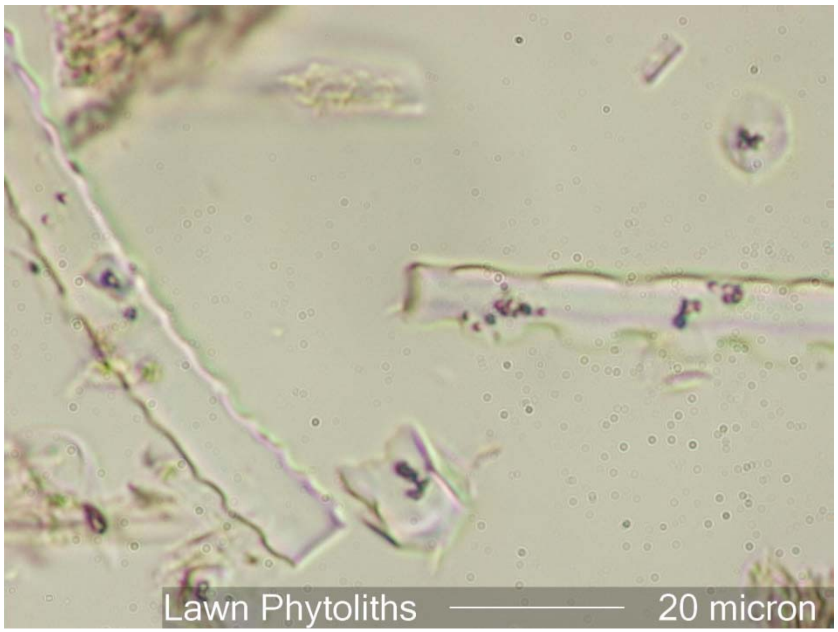


Si from Plants to Soil

- Inorganic and biogenic pools of Si.
- Inorganic weathering of aluminosilicates and clay minerals is a source of dissolved Si.
- Biogenic side provides Si from plant-based amorphous silica, primarily because of Si phytoliths.
- So, inorganic Si weathered out, plants take it up, and it is cycled back into soil.

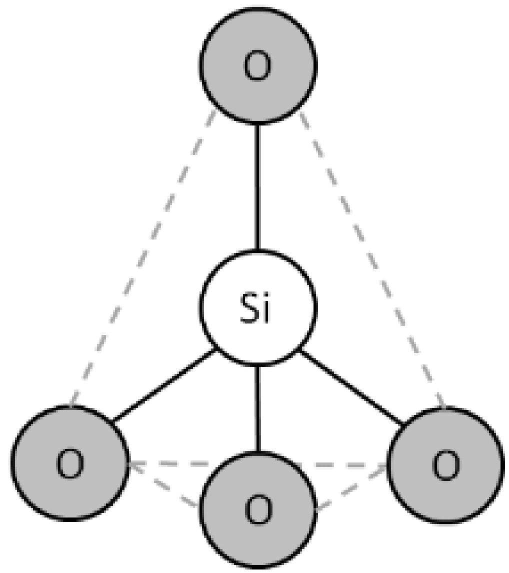
Biogenic and Inorganic Si

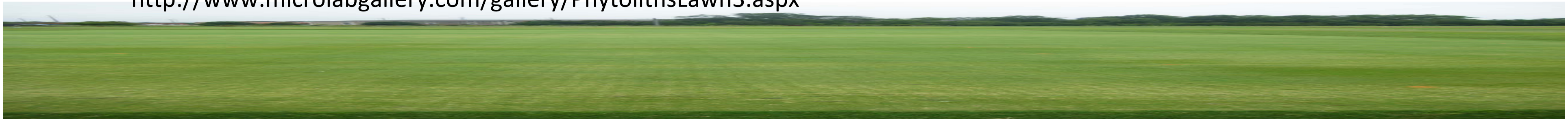
ORGANIC



http://www.microlabgallery.com/gallery/PhytolithsLawn3.aspx

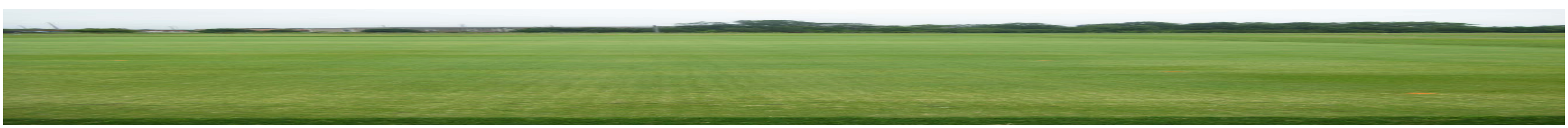
INORGANIC

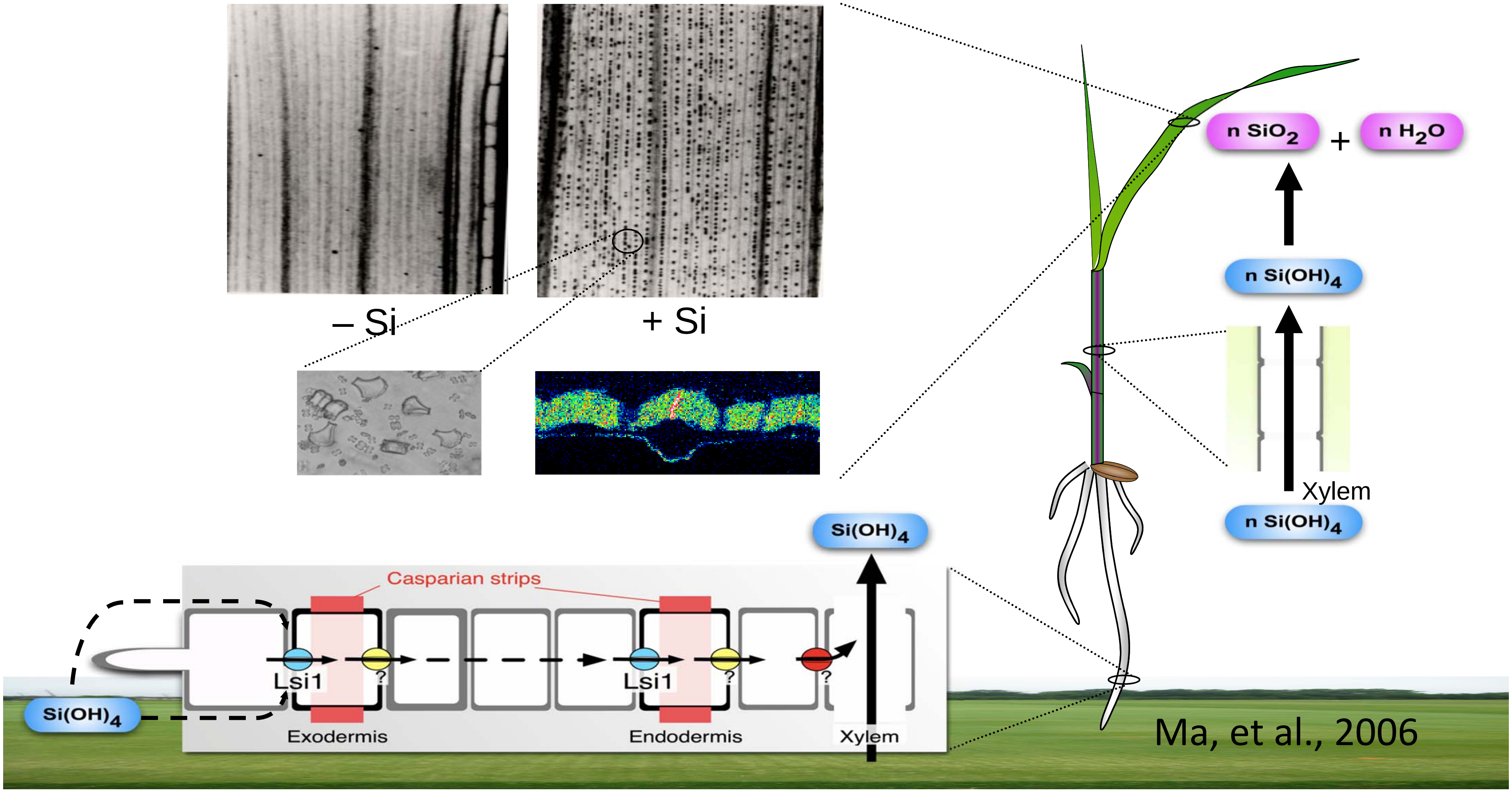




How does it get into the plant?

- Used to be two schools of thought on this.
- Still open to some discussion.
- Passive versus active.
- Taken up by roots as silicic acid - $Si(OH)_4$, deposited in plant cell walls as SiO_2
- In 2006 – clearly demonstrated active transport of Si in rice (Ma et al., 2006).




– Si
+ Si
n SiO2
+
n H2O
n Si(OH)4
Xylem
n Si(OH)4
Si(OH)4
Casparian strips
Lsi1
?
Lsi1
?
?
Si(OH)4
Exodermis
Endodermis
Xylem
Ma, et al., 2006

WHY silica? What does it do in the plant?

- Mechanical barrier – Si beneath cuticle/in cell walls.
- Faster and stronger activation of defense genes/defense enzymes.
- Photosynthesis/anti-oxidant systems improved.

Debona, Rodrigues and Datnoff, 2017

Which Plants?

How did we get to turfgrass?

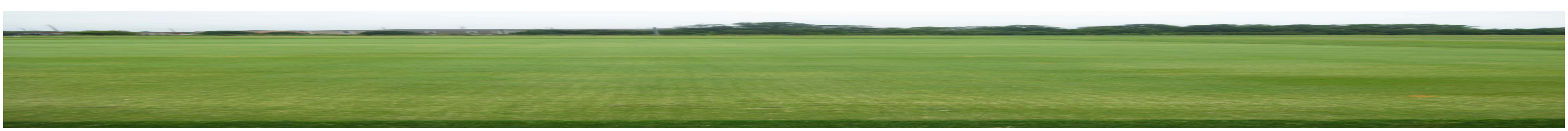
Magnaporthe grisea – rice blast

Pyricularia oryzae (Magnaporthe grisea) – gray leaf spot

Si to Reduce Disease in Turfgrasses

Turfgrass	Disease	Reduction?
Zoysiagrass	Leaf blight	Y
Creeping bentgrass	Root rot, brown patch, dollar spot	Y
KY bluegrass	Powdery mildew	Y
Bermudagrass	*Bipolaris* leaf spot	Y
St. Augustinegrass	Gray leaf spot	Y
Perennial ryegrass	Gray leaf spot	Y

Datnoff, 2005



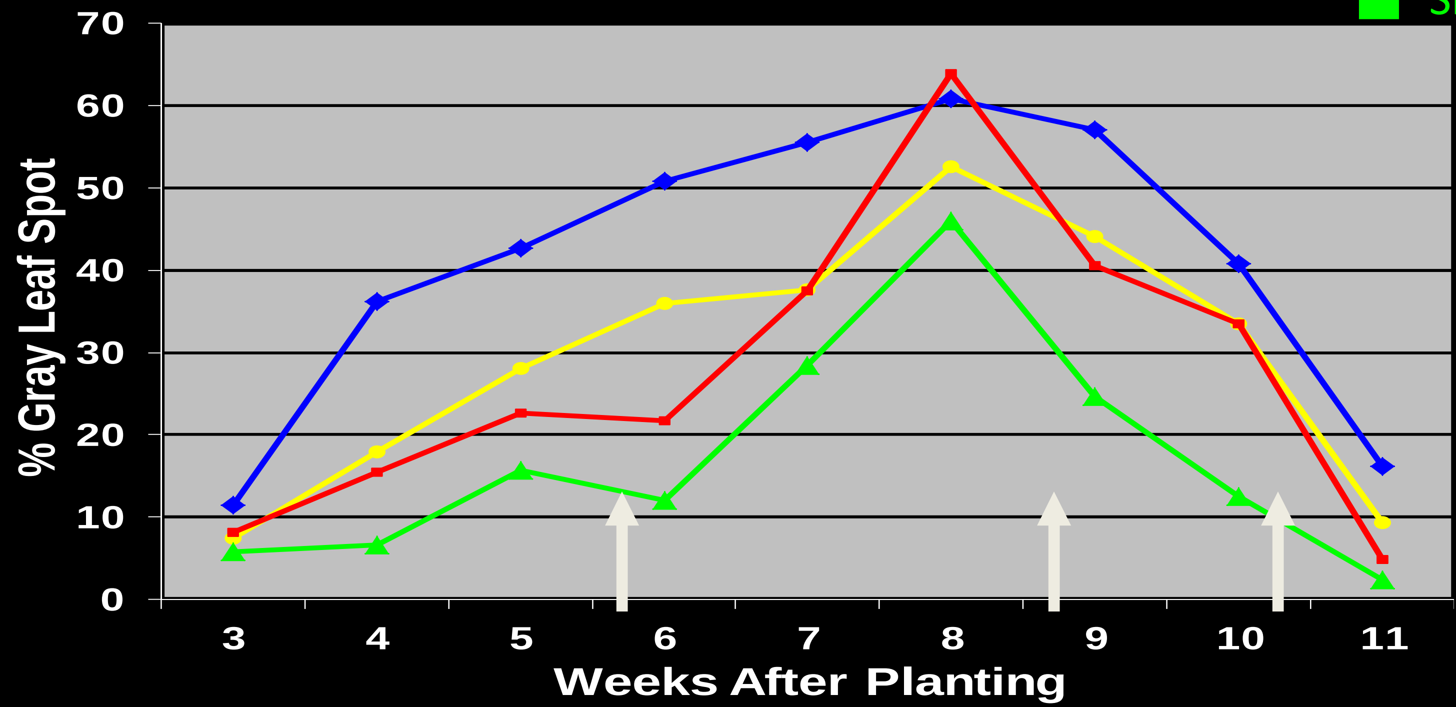
Disease progress curve for gray leaf spot development on St. Augustinegrass

Brecht et al., 2004

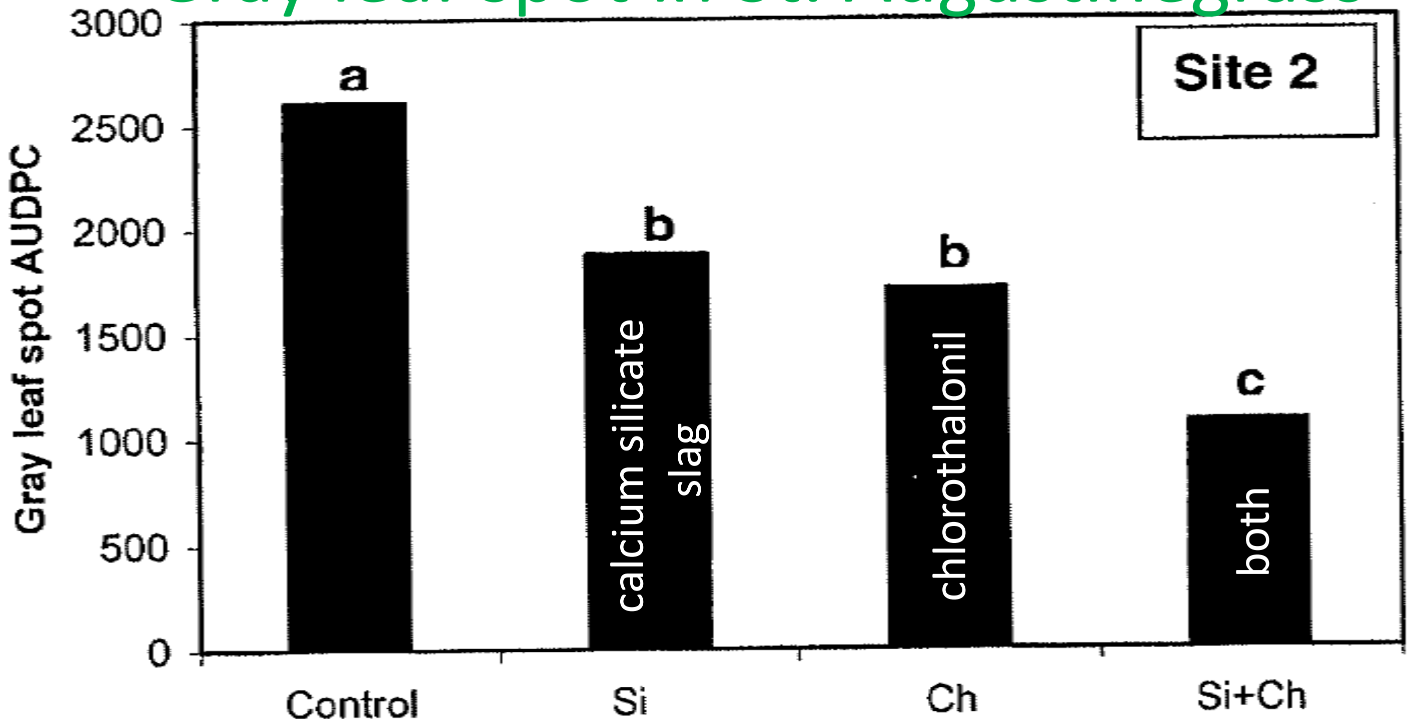
Final AUDPC

Control	2607	A
Si	1882	B
CH	1715	B
Si + CH	1078	C

$P \leq 0.05$

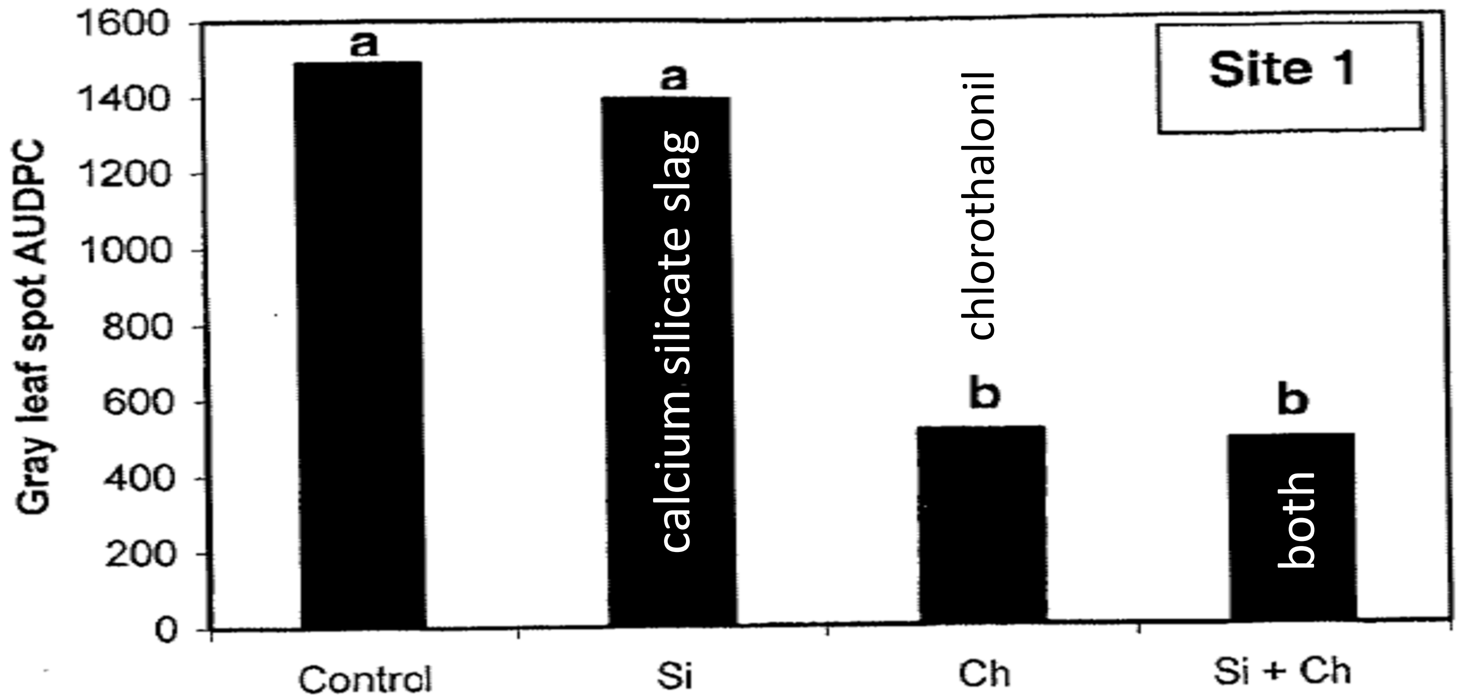


Gray leaf spot in St. Augustinegrass



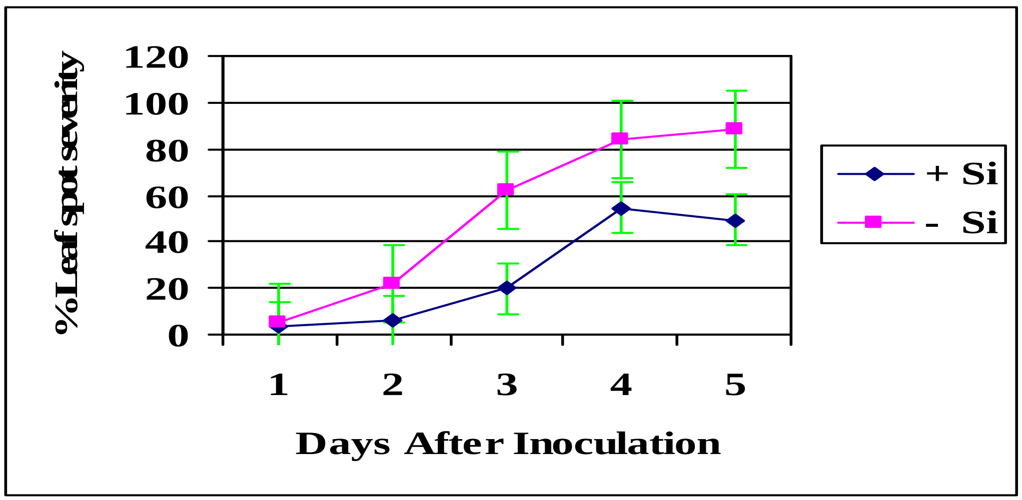
Brecht, Datnoff, Kucharek & Nagata, 2004

Does it always work?



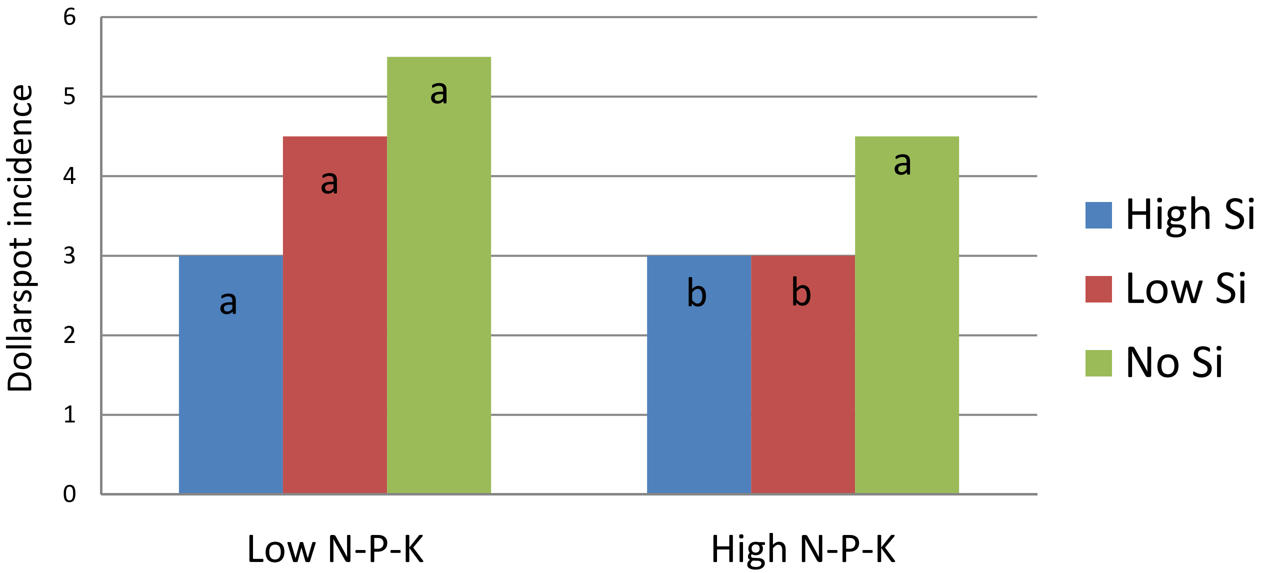
Brecht, Datnoff, Kucharek & Nagata, 2004

Bipolaris leaf spot in bermudagrass



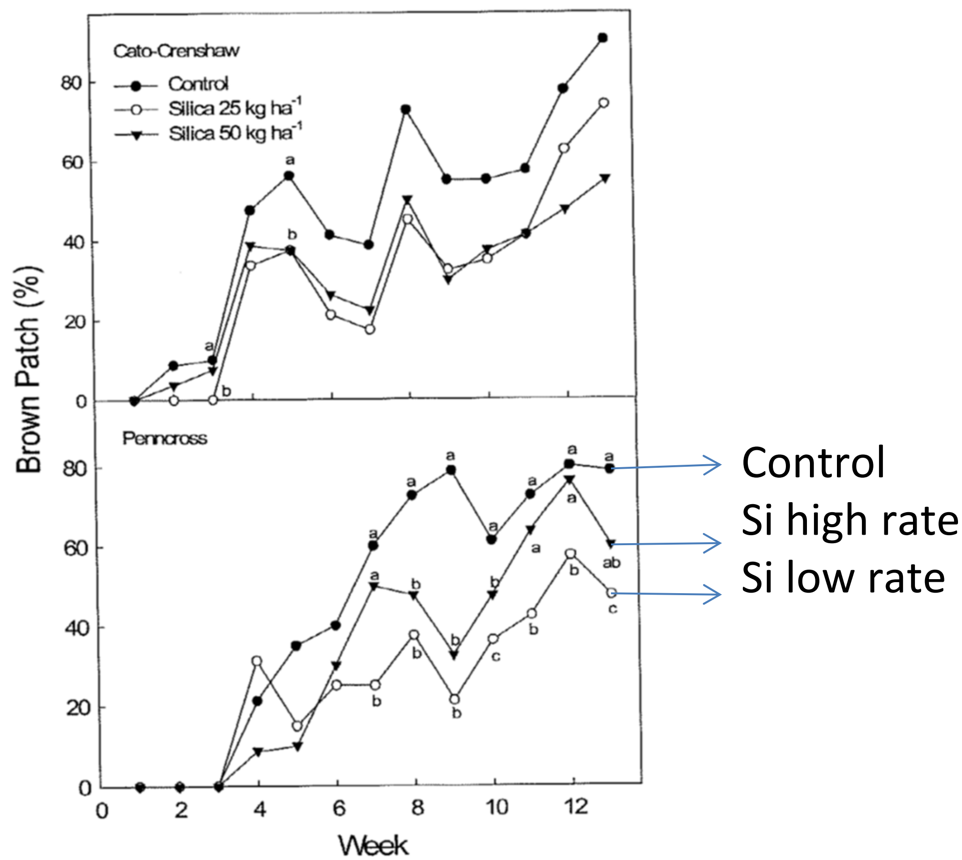
Datnoff and Rutherford, 2004

Dollarspot incidence (1-9 scale) of creeping bentgrass

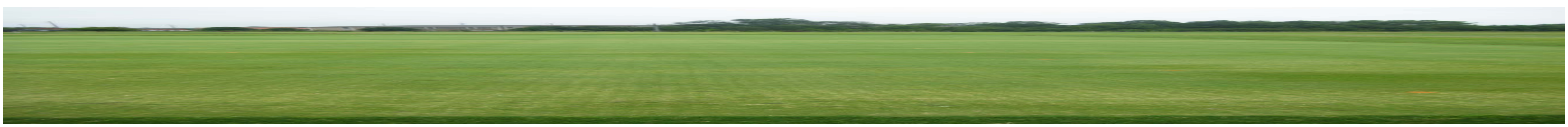


Schmidt et al., 1999

Effect of Si on percent brown patch in creeping bentgrass.

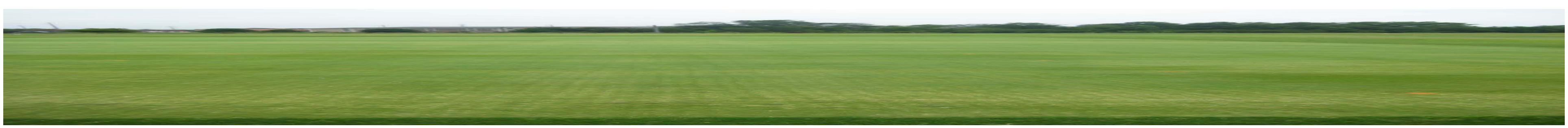


Uriarte et al., 2004

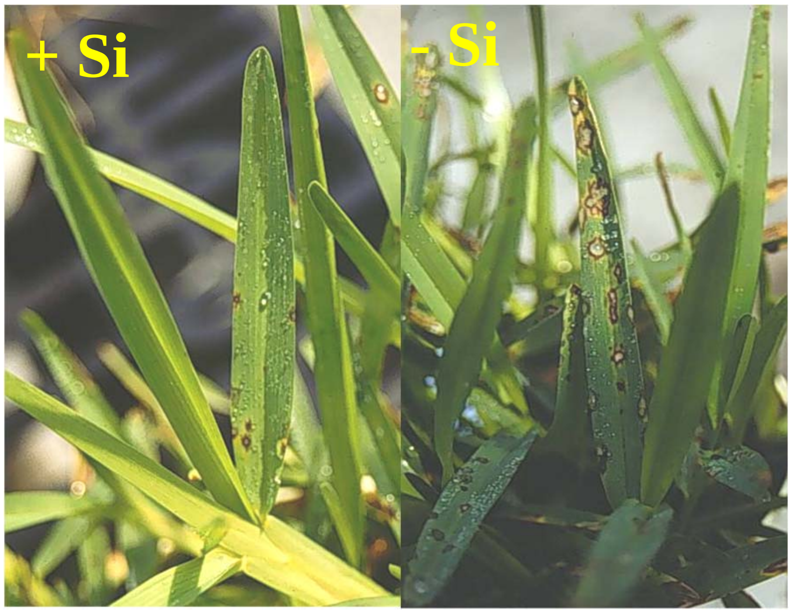


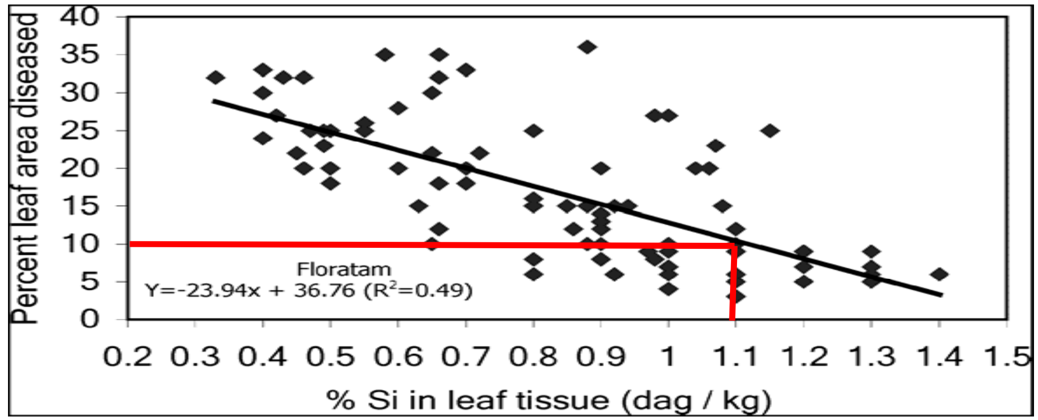
Si fertilization rates used in the studies

Application Rates (units)	Si applied	**Si applied**	Plant species	Reference
	kg ha^{-1}	**lbs 1,000 ft^{-2}**		
0, 0.5, 1, 2, 5 and 10 metric tons slag ha^{-1}	0, 100, 200, 400, 1000, 2000	**0, 2, 4, 8, 20, 40**	St. Augustinegrass	Brecht et al., 2004, 2007
0, 0.5, 1, 2, 5 and 10 metric tons slag ha^{-1}	0, 100, 200, 400, 1000, 2000	**0, 2, 4, 8, 20, 40**	hybrid bermudagrass	Datnoff and Rutherford, 2003
0, 0.5, 1, 2, 5 and 10 metric tons slag or wollastonite ha^{-1}	0, 100, 200, 400, 1000, 2000	**0, 2, 4, 8, 20, 40**	perennial ryegrass	Nanayakkara et al., 2008; 2009; 2010
603 or 1205 cc 100 m^{-2} potassium silicate	8 and 16 app^{-1} (16 apps in all)	**2.5 and 5 in total**	creeping bentgrass	Schmidt et al., 1999
0, 25 and 50 kg SiO_2 ha^{-1} (as K silicate)	12 and 24 app^{-1} (7 apps in all)	**1.7 and 3.4 in total**	creeping bentgrass	Uriarte et al., 2004
2440 or 4880 kg slag ha^{-1}	353 and 706 – 2xs yr^{-1}	**14 and 28 in total**	bentgrass, tall fescue	Zhang et al., 2006



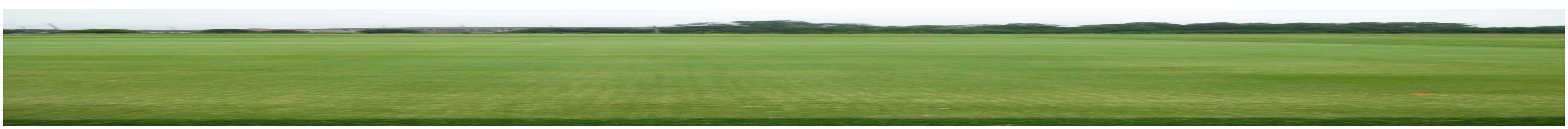
What about tissue Si?



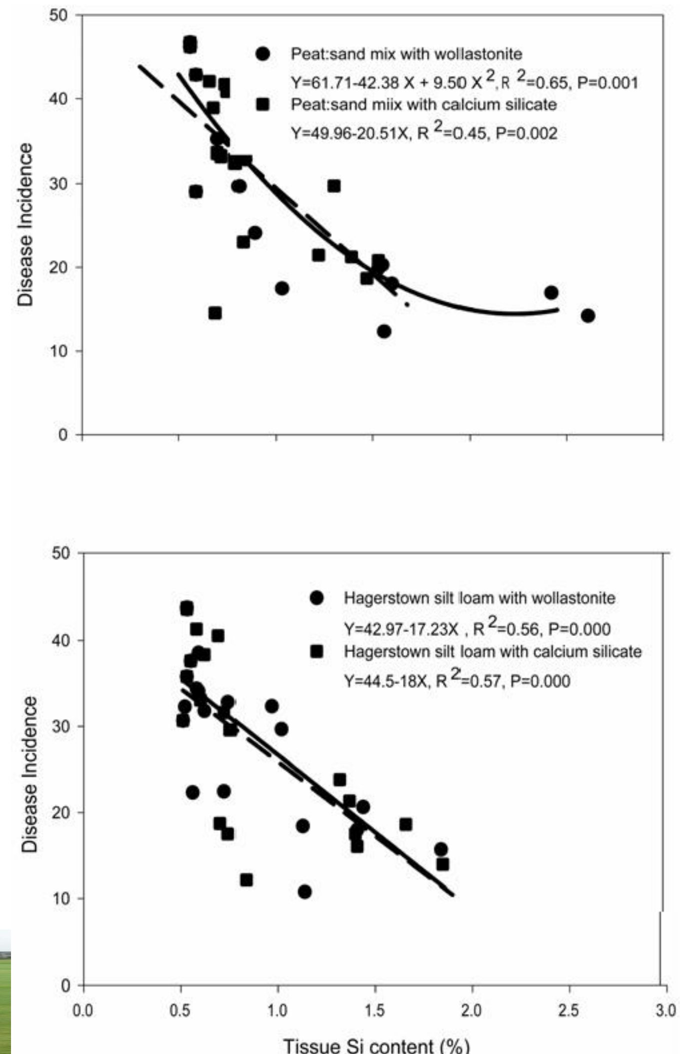


Si level of > 1.1% in leaf tissue is optimal for resistance to GLS

Brecht et al., 2007



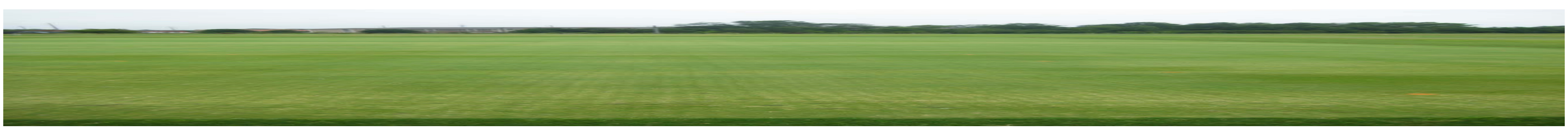
Development of GLS in perennial ryegrass as affected by Si source and soil type.



Nanayakkara et al., 2008

Tissue Si Content

Response to Applied Si?	Turfgrass	Tissue Si %	Reference
Linear increase	perennial ryegrass	0.4 – 1.2	Nanayakkara et al., 2009
Linear increase	bermudagrass	0.4 – 1.2	Datnoff and Rutherford, 2003
Linear increase	perennial ryegrass	0.5 – 1.5/2.5 (varied with soil/Si source)	Nanayakkara et al., 2008
Linear increase	St. Augustinegrass	0.4 – 1.4	Brecht et al., 2007
Linear increase	St. Augustinegrass	0.6 – 1.3	Brecht et al., 2004
*Linear increase	Bentgrass, tall fescue	0.6 – 2.2	Zhang et al., 2006



Soil Si – Where Might We See a Response?

Soil Type	Soil Si (mg kg^{-1})	Response?	Grass	Reference
Sand-based	10.6 – 12.2	No	Creeping bentgrass	Zhang et al 2006
Silty clay loam	173	No	Tall fescue	Zhang et al 2006
Histosol (organic)	14 mg L^{-1}	Yes	St. Augustinegrass	Brecht et al 2004
Sand-peat	5.2 mg L^{-1}	Yes	Perennial ryegrass	Nanayakkara et al 2008
Silt loam	70 mg L^{-1}	Yes	Perennial ryegrass	Nanayakkara et al 2008

Acetic acid extractable Si (Korndörfer et al., 2001)

Typical sufficiency level? 19 mg L^{-1}

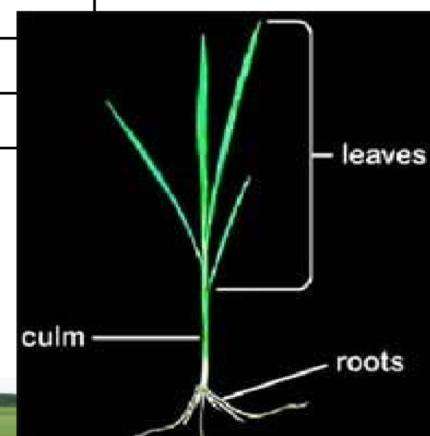
Leaf stiffness, wear and ball roll

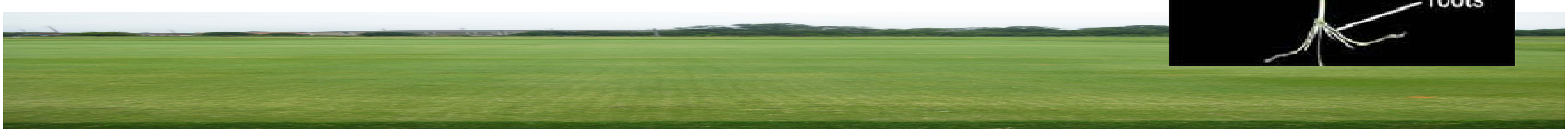
Si and Leaf Stiffness

Relationship between Si and N supply and leaf erectness in rice plants at flowering. (Yoshida et al., 1969)

N supply	Si supply (mg SiO_2 L^{-1} as sodium silicate)		
Mg L-1	0	40	200*
	Leaf angle (between flowering stem and leaf tip)		
5	23	16	11
20	53	40	19
200	77	69	22

* Soil solution Si is usually around 3-17 mg Si L^{-1}

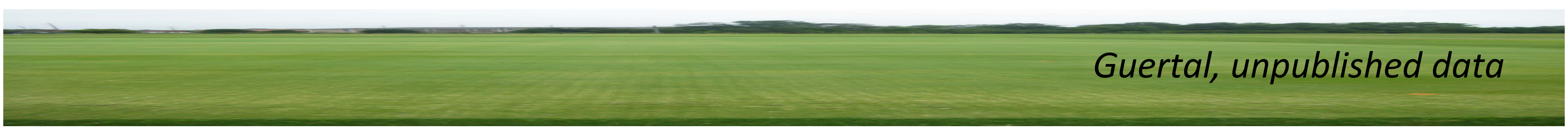




Leaf erectness and Si in turf?

Relative ball roll as measured via a **modified** stimpmeter. Numbers are shown in inches, and are the average of six rolls, with half in opposite directions. TifEagle putting green.

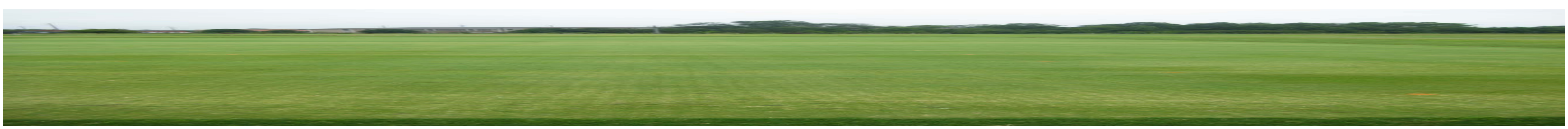
Trt	May 25	June 1	June 4	June 7	June 11	June 18
	golf ball roll (inches)					
1. control	59 a	60 a	60 a	68 a	52 a	56 a
2. Si + N and K	55 a	59 a	56 b	66 a	46 b	53 a
3. N and K only	56 a	58 a	58 ab	73 a	47 ab	54 a
	June 22	June 25	June 28	July 5	July 10	
	golf ball roll (inches)					
1. control	68 a	72 a	73 a	76 a	69 ab	
2. Si + N and K	61 a	60 b	62 b	64 a	59 b	
3. N and K only	59 a	60 b	69 ab	64 a	65 ab	



Si and Wear Tolerance?

- Seashore paspalum - ‘Sea Isle 2000’
- Foliar and drench applications of potassium silicate (20.8% SiO_2 and 8.3% K_2O) were made every-other week (4xs, May-Aug).
- Foliar Si was applied at rates of 1.1 or 2.2 kg Si ha^{-1} (1 or 2 lb Si $acre^{-1}$) and the drench treatment was applied at 22.4 kg ha-1 (20 lb $acre^{-1}$) in a 0.9 L m^{-2} water solution (960 gpa).
- Since the Si source was potassium silicate, the trial was balanced to uniformity for the supplied K using KCl.
- There was also a K only (KCl) treatment, applied at 15.6 kg K ha^{-1} (14 lb K $acre^{-1}$), which was the rate of K applied with the highest potassium silicate treatment.
- Artificial wear applied.

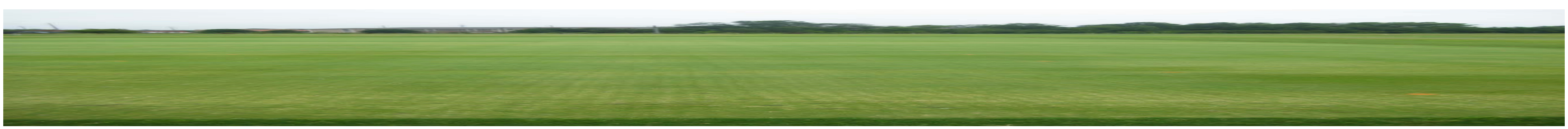
Trenholm et al., 2001



Si and Wear

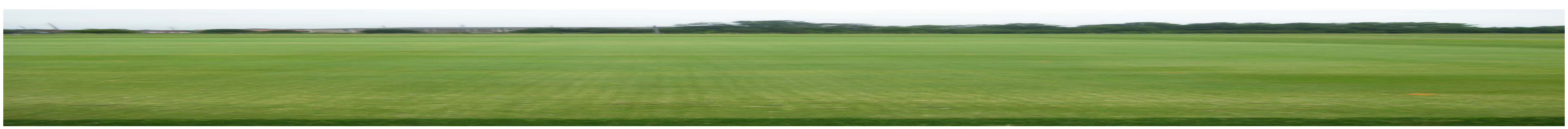
- Foliar application of Si did not enhance wear tolerance or reduce injury of seashore paspalum.
- However, when potassium silicate was applied as a drench at a high rate, wear tolerance was enhanced.
- BUT – these improvements in wear tolerance and quality were a function of the K supplied with the silicate, and not the Si alone.

Trenholm et al., 2001



Si and Drought

- Largely greenhouse trials.
- Application of Si could alleviate drought in KY bluegrass – increased antioxidant enzyme activities. (Bae et al., 2017)
- Si improved drought tolerance of St. Augustinegrass in severe drought stress, but not in moderate . (Trenholm et al., 2004)



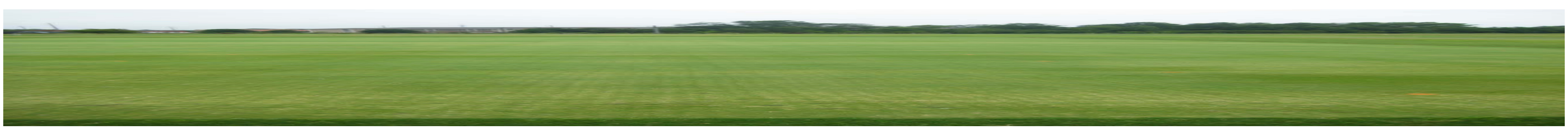
Si and Salinity

- Greenhouse work.
- Si alleviated salt stress, reduced Na in shoot and root, increased shoot number and length (bermudagrass, tall fescue, perennial ryegrass). (Esmaeili et al., 2015)
- KY bluegrass had increased leaf blade length, decreased Na in roots. (Chai et al., 2010)

Si Rates? Check sources

- Calcium silicate slag (~43% Si) – 0 to ~3,500 lb/acre. Highest rate is ~80 lb Si/M. For Gray Leaf Spot in P. rye. *(Nanayakkara et al., 2009)*
- CaSi (12% Si) at 0 to 3,050 lb/A. Highest rate is ~8 lb Si/M. For Si accumulation in bermudagrass and Poa Trivialis. *(Espinosa et al., 2013)*
- CaSi (39.3% Si) at 2000 lb/A, or **~18 lb Si/M**. This is a typical recommended rate. For creeping bentgrass resistance to cutworms and white grubs. *(Redmond and Potter, 2006)*

TARGET RATE? 11-18 lb Si 1000 ft^{-2}



Various Si Sources sold in the U.S. Market

Calcium silicate

Calcium magnesium silicate

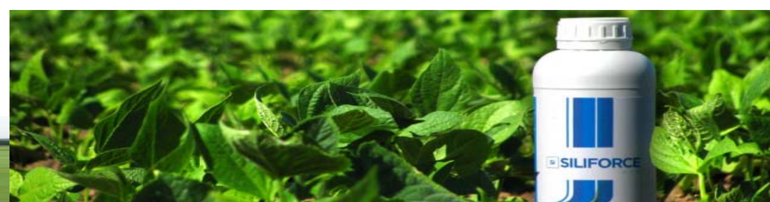
Crop residues – rice hull ash

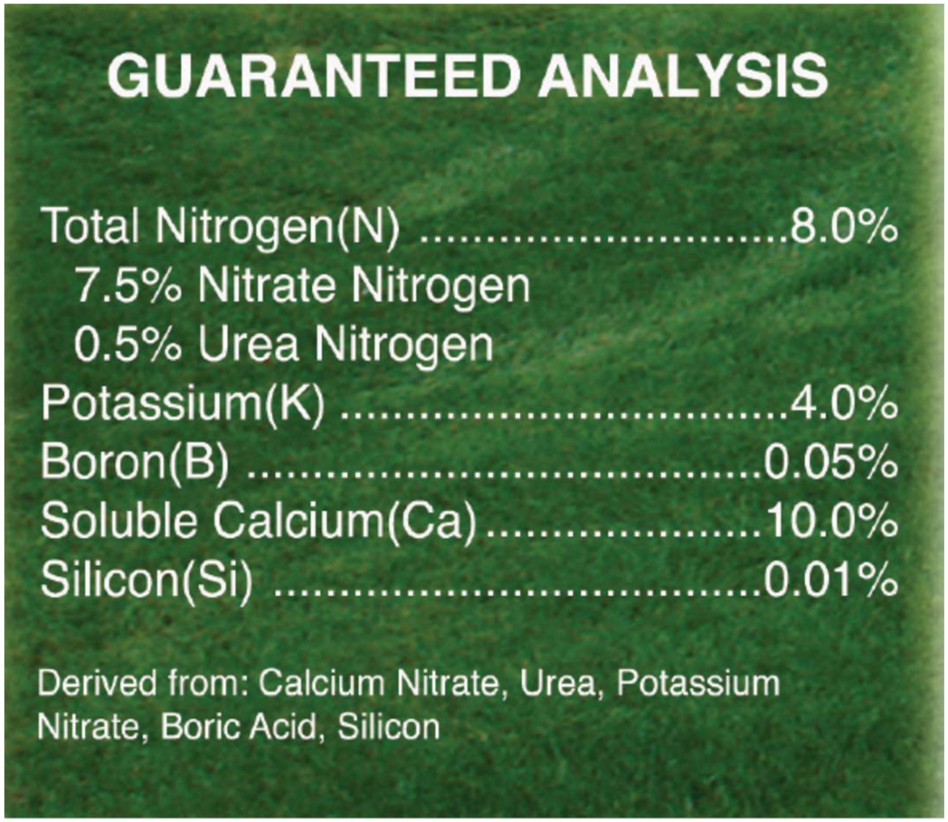
Diatomaceous earth

Orthosilicic acid

Potassium silicate

Sodium silicate



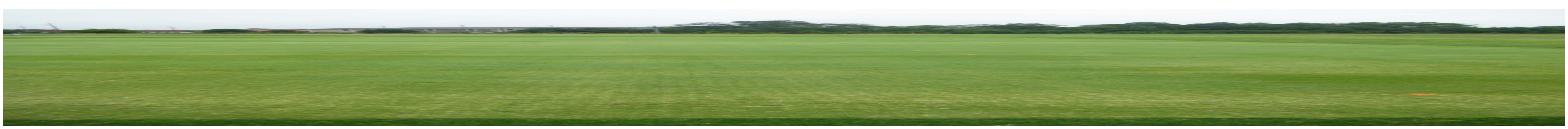


GUARANTEED ANALYSIS

Total Nitrogen(N)	8.0%
7.5% Nitrate Nitrogen	
0.5% Urea Nitrogen	
Potassium(K)	4.0%
Boron(B)	0.05%
Soluble Calcium(Ca)	10.0%
Silicon(Si)	0.01%

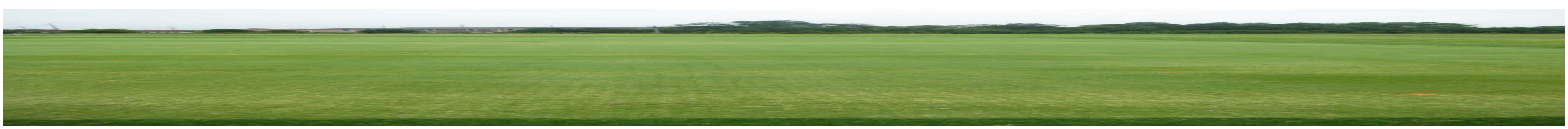
Derived from: Calcium Nitrate, Urea, Potassium Nitrate, Boric Acid, Silicon

- For Si – want 11-18 lb Si 1,000 ft^{-2}
- Recommended rate for this product (cool season) is 3-6 oz 1,000 ft^{-2}
- So, each application provides 0.0003 – 0.0006 oz Si 1,000 ft^{-2}



When might you see a response?
The research says…..

- Soil test (extractable Si) below 19 mg L^{-1} (rice).
- Tissue Si at 1% or greater.
- Application rates at 11-18 lb Si 1,000 ft^{-2}.
- No proven differences due to source, as yet.



So….Si?

- Little field evidence that Si helps with leaf stiffness, ball roll or improved wear tolerance.
- **Evidence for reductions in various diseases, in various turfgrasses.**
- Also evidence for improvements in salt or drought tolerance.
- However, most work is with Ca Silicate slag – not bad, just need more work with other products, like potassium silicate.