Silicon in Turfgrass

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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  Iron
Hydrogen  Molybdenum
Oxygen  Copper
Nitrogen  Manganese
Phosphorus  Chloride
Potassium  Boron
Calcium  Zinc
Magnesium  Nickel
Sulfur
‘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 (Al₂Si₂O₅(OH)₄).
- It also is found in primary aluminosilicates such as potassium feldspar (KAlSi₃O₈).
- 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

INORGANIC

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

- Si

+ Si

Ma, et al., 2006

$SiO_2 + nH_2O$
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.

De bona, 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

<table>
<thead>
<tr>
<th>Turfgrass</th>
<th>Disease</th>
<th>Reduction?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zoysiagrass</td>
<td>Leaf blight</td>
<td>Y</td>
</tr>
<tr>
<td>Creeping bentgrass</td>
<td>Root rot, brown patch, dollar spot</td>
<td>Y</td>
</tr>
<tr>
<td>KY bluegrass</td>
<td>Powdery mildew</td>
<td>Y</td>
</tr>
<tr>
<td>Bermudagrass</td>
<td><em>Bipolaris</em> leaf spot</td>
<td>Y</td>
</tr>
<tr>
<td>St. Augustinegrass</td>
<td>Gray leaf spot</td>
<td>Y</td>
</tr>
<tr>
<td>Perennial ryegrass</td>
<td>Gray leaf spot</td>
<td>Y</td>
</tr>
</tbody>
</table>

*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 ≤ 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

Influence of silicon on 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

<table>
<thead>
<tr>
<th>Application Rates (units)</th>
<th>Si applied</th>
<th>Plant species</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg ha⁻¹</td>
<td>lbs 1,000 ft⁻²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0, 0.5, 1, 2, 5 and 10 metric tons slag ha⁻¹</td>
<td>0, 100, 200, 400, 1000, 2000</td>
<td>St. Augustinegrass</td>
<td>Brecht et al., 2004, 2007</td>
</tr>
<tr>
<td>0, 0.5, 1, 2, 5 and 10 metric tons slag ha⁻¹</td>
<td>0, 100, 200, 400, 1000, 2000</td>
<td>hybrid bermudagrass</td>
<td>Datnoff and Rutherford, 2003</td>
</tr>
<tr>
<td>0, 0.5, 1, 2, 5 and 10 metric tons slag or wollastonite ha⁻¹</td>
<td>0, 100, 200, 400, 1000, 2000</td>
<td>perennial ryegrass</td>
<td>Nanayakkara et al., 2008; 2009; 2010</td>
</tr>
<tr>
<td>603 or 1205 cc 100 m⁻² potassium silicate</td>
<td>8 and 16 app⁻¹ (16 apps in all)</td>
<td>creeping bentgrass</td>
<td>Schmidt et al., 1999</td>
</tr>
<tr>
<td>0, 25 and 50 kg SiO₂ ha⁻¹ (as K silicate)</td>
<td>12 and 24 app⁻¹ (7 apps in all)</td>
<td>creeping bentgrass</td>
<td>Uriarte et al., 2004</td>
</tr>
<tr>
<td>2440 or 4880 kg slag ha⁻¹</td>
<td>353 and 706 – 2xs yr⁻¹</td>
<td>bentgrass, tall fescue</td>
<td>Zhang et al., 2006</td>
</tr>
</tbody>
</table>
What about tissue Si?

Brecht et al., 2007

Si level of > 1.1% in leaf tissue is optimal for resistance to GLS
Development of GLS in perennial ryegrass as affected by Si source and soil type.

Nanayakkara et al., 2008
## Tissue Si Content

<table>
<thead>
<tr>
<th>Response to Applied Si?</th>
<th>Turfgrass</th>
<th>Tissue Si %</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear increase</td>
<td>perennial ryegrass</td>
<td>0.4 – 1.2</td>
<td>Nanayakkara et al., 2009</td>
</tr>
<tr>
<td>Linear increase</td>
<td>bermudagrass</td>
<td>0.4 – 1.2</td>
<td>Datnoff and Rutherford, 2003</td>
</tr>
<tr>
<td>Linear increase</td>
<td>perennial ryegrass</td>
<td>0.5 – 1.5/2.5 (varied with soil/Si source)</td>
<td>Nanayakkara et al., 2008</td>
</tr>
<tr>
<td>Linear increase</td>
<td>St. Augustinegrass</td>
<td>0.4 – 1.4</td>
<td>Brecht et al., 2007</td>
</tr>
<tr>
<td>Linear increase</td>
<td>St. Augustinegrass</td>
<td>0.6 – 1.3</td>
<td>Brecht et al., 2004</td>
</tr>
<tr>
<td><strong>Linear increase</strong></td>
<td>Bentgrass, tall fescue</td>
<td>0.6 – 2.2</td>
<td>Zhang et al., 2006</td>
</tr>
</tbody>
</table>
Soil Si – Where Might We See a Response?

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

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)

<table>
<thead>
<tr>
<th>N supply (Mg L⁻¹)</th>
<th>Si supply (mg SiO₂ L⁻¹ as sodium silicate)</th>
<th>Leaf angle (between flowering stem and leaf tip)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>40</td>
<td>200*</td>
</tr>
<tr>
<td>5</td>
<td>23</td>
<td>16</td>
</tr>
<tr>
<td>20</td>
<td>53</td>
<td>40</td>
</tr>
<tr>
<td>200</td>
<td>77</td>
<td>69</td>
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</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th>Trt</th>
<th>May 25</th>
<th>June 1</th>
<th>June 4</th>
<th>June 7</th>
<th>June 11</th>
<th>June 18</th>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>golf ball roll (inches)</td>
<td></td>
</tr>
<tr>
<td>1. control</td>
<td>59 a</td>
<td>60 a</td>
<td>60 a</td>
<td>68 a</td>
<td>52 a</td>
<td>56 a</td>
</tr>
<tr>
<td>2. Si + N and K</td>
<td>55 a</td>
<td>59 a</td>
<td>56 b</td>
<td>66 a</td>
<td>46 b</td>
<td>53 a</td>
</tr>
<tr>
<td>3. N and K only</td>
<td>56 a</td>
<td>58 a</td>
<td>58 ab</td>
<td>73 a</td>
<td>47 ab</td>
<td>54 a</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th></th>
<th>June 22</th>
<th>June 25</th>
<th>June 28</th>
<th>July 5</th>
<th>July 10</th>
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<td></td>
</tr>
<tr>
<td>1. control</td>
<td>68 a</td>
<td>72 a</td>
<td>73 a</td>
<td>76 a</td>
<td>69 ab</td>
</tr>
<tr>
<td>2. Si + N and K</td>
<td>61 a</td>
<td>60 b</td>
<td>62 b</td>
<td>64 a</td>
<td>59 b</td>
</tr>
<tr>
<td>3. N and K only</td>
<td>59 a</td>
<td>60 b</td>
<td>69 ab</td>
<td>64 a</td>
<td>65 ab</td>
</tr>
</tbody>
</table>

Guertal, unpublished data
Si and Wear Tolerance?

- Seashore paspalum - ‘Sea Isle 2000’
- Foliar and drench applications of potassium silicate (20.8% SiO$_2$ and 8.3% K$_2$O) 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.