Strawberry I

Tuesday morning 9:00 am

Where: Grand Gallery (main level) Room A & B  
MI Recertification credits: 2 (1C, COMM CORE, PRIV CORE)  
OH Recertification credits: 0.5 (presentations as marked)  
CCA Credits: SW(0.5) PM(0.5) CM(1.5)  
Moderator: Kevin Schooley, Ontario Berry Growers

9:00 am  The Intricacies of Silicon Fertilization (OH: 2B, 0.5 hr)  
• Richard Belanger, Laval Univ., Quebec

9:45 am  Emerging Technologies: How Can These Help Strawberry Growers  
• Pam Fisher, Ontario Ministry of Agriculture and Food  
• Kevin Schooley, Ontario Berry Growers

10:15 am  Getting the Most out of Your Irrigation System  
• Jean Caron, Univ. of Laval, Quebec

11:00 am  Home Grown Innovations - Show and Tell  
• Scott Thompson, Thompson Strawberry Farm, Bristol, WI, Panel  
Moderator

12:00 noon  Session Ends
The intricacies of silicon fertilization

Richard Bélanger

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While being classified as non-essential for plant growth, silicon (Si) has long been recognized for its prophylactic properties against a wide array of biotic and abiotic stresses. However, practical use of Si has been hampered by conflicting reports about its mode of action, application, and mostly about how and what plants can benefit from Si. The recent discovery of Si transporters in rice, along with new developments in genomics and sequencing data now make it possible to investigate with precision what plant species possess the molecular tools to uptake Si from the soil. In this context, strawberry remains enigmatic because it is considered a poor accumulator of Si and yet is the subject of several reports linking Si fertilization with benefits. Over the last few months, we have investigated the presence and expression of Si transporters in strawberry, along with Si accumulation in different cultivars and the effect of Si fertilization against strawberry powdery mildew. As will be discussed in the presentation, combining molecular approaches with field applications should lead to optimal recommendations for strawberry growers interested in exploiting the beneficial properties of Si.

References


The Intricacies of Silicon Fertilization

Richard Bélanger, Université Laval

December 6, 2016

North American Berry Conference
Grand Rapids, Michigan

What is Si in nature?

• Silicon: Pure Si; virtually absent in nature
• Silica: SiO₂: quartz, sand, non soluble
• Silicate: SiO₂ mixed with sodium, calcium, aluminium and potassium
• Low solubility ranging from 0.1 to 0.6 mM in soils
• Silicic acid: soluble form of Si in the form SiOH4. Maximum solubility is 1.7 mM at physiological pH (5-7). Only form that a plant can absorb

And yet...

Si content in plant tissues may vary between 0.1 to 10%

E.g. Graminaceae

Rice and sugarcane accumulate large quantities of Si in the form of silica gel SiO₂·nH₂O

Savant et al. 1999

Silicon in agriculture in the literature

Over 1000 papers reporting beneficial effects...

Disease resistance
Abiotic stress tolerance
Yield and quality
First reports in Chinese and Japanese literature in the 1920’s

First comprehensive report in USA by Wagner in 1940

Beneficial in many plant/pathogen interactions
- Consensus: prophylactic role

The beneficial effects of Si appear to be correlated with the intrinsic ability of a plant to accumulate Si

How does silicon protect plants against diseases/stress?

How do plants absorb Si?

Silicon transport in plants
From the roots to the leaves: e.g. WHEAT

Water flux
The influx transporter Lsi1 is the essential filter for Si absorption in plants: 

...plants absorb or not Si on the basis of presence of Lsi1 or not

E.g.

- Plants known to have Lsi1 and absorb Si:
  - Cucurbita
  - Rice
  - Sugarcane
  - Soybean
  - Others...

- Plants lacking Lsi1 and unable to absorb Si:
  - Arabidopsis
  - Canola
  - Rocket
  - Gerbers

Silicon transport in plants

Lsi1 proteins specifically belong to the nodulin 26-like intrinsic protein (NIPs) a sub-family of aquaporins

Silicon transport in plants

Hypothesis

Can we predict if a plant can absorb Si on the basis of the presence of NIP-III aquaporins?

Identification of NIPs in 25 plant species through comparative genomics approach and phylogenetic analysis

All Known Si transporters grouped in NIP-III
Hypothesis

Can we predict if a plant can absorb Si on the basis of the presence of NIP-III aquaporins?

No report of significant Si accumulation in any of the species belonging to the Solanaceae.

**Tomato known as poor accumulator has putative Si transporter (SINIP2-1)!

Inability may be because of Structural variation in protein?

**Hypothesis

Does spacing between NPA domains regulate Si permeability?

Functional evaluation of NIP2-1 genes with different NPA spacing was done by heterologous expression.
Functional evaluation of genes with different NPA spacings

- Species confirmed for Si uptake ability
- Candidate genes cloned from poplar and tomato: mutation and heterologous expression in Xenopus oocytes

Results

Effect of NPA spacing changes in poplar

Spacing between NPA domains was changed from 108 to 107 and 109 either by adding or removing 1 a.a. in PtNIP2-1 of poplar

Effect of NPA spacing changes in tomato

Si uptake in oocytes

Attempt to create functional protein in tomato

- Species confirmed for Si uptake ability
- Candidate genes cloned from poplar and tomato: mutation and heterologous expression in Xenopus oocytes
In summary

Only and all plants possessing a NIPIII aquaporin with a GSGR pore and a NPA-NPA distance of 108 amino acids can absorb Si in the form of silicic acid.

It is now possible to easily predict what plants can absorb Si with molecular tools.

What about strawberry?

Literature

- Ma (2004): Strawberry is a non-accumulator of Silicon
- Miyake and Seki (1986): 1.29% Si
- Liang et al. (2006): Strawberry uptakes Si passively
- Kato et al. (2006): 0.9% more under Si treatment
Full aquaporin analysis in *Fragaria vesca*

**Homologous genes found in *Fragaria ananassa***

In theory, strawberry has the proper genetic tools to absorb silicic acid from the soil...

**The role of silicon in the suppression of strawberry powdery mildew***

**Genomic search for Lsi1 candidate proteins**

```
>AF010523.12.1.g0001.3_f+1_gGGLIVTVMIYAVGHISGA
>AF010523.12.1.g0001.3_f+1_gGGLIVTVMIYAVGHISGA
>AF010523.12.1.g0001.3_f+1_gGGLIVTVMIYAVGHISGA
```
Experimental design

Seascape
Charlotte
Monterey
Albion
Verity

- Day neutral cultivars
- Silicon amendment: Liquid potassium silicate (Kasil®) at a concentration of 1.7 mM
- Disease: Natural powdery mildew infection

Analyses:

- Silicon content
- Powdery mildew incidence
- Yield and fruit quality

Silicon content analysis

In conclusion

Strawberry has the proper genetic tools (aquaporins) to absorb Si

During the course of a season, strawberry plants can absorb as much as 3% Si

 Silicon feeding had an excellent prophylactic role against powdery mildew on strawberry, which led to a better yield

Constant supply of Si in the form of silicic acid is preferable to maximize absorption
Getting the Most out of Your Irrigation System in Strawberry

Jean Caron, Lelia Anderson, Guillaume Sauvageau and Laurence Gendron
Université Laval, Département des Sols et de Génie Agroalimentaire
Corresponding author: Jean.caron@fsaa.ulaval.ca

Introduction

- 86% of the strawberry of North America grown in California, along with Florida (7%) and Québec (3.5%) and Ontario (3.5%)
- Water is becoming increasingly scarce in California, and under increasing controlled use elsewhere.

Evapotranspiration (ETo):

- ETo is the loss of water by evaporation (from soil and plant surfaces) and transpiration (from plant tissues)
- Estimates of Et for a specific crop and area are used for irrigation scheduling:

\[
\text{Crop Et} = \text{ETo} \times \text{Kc}
\]

Introduction

Cuts may be imposed to strawberry growers to save water, with limited information on the impact on crop yield.

This also increases pressure to get more crop per drop

A new approach was recently proposed to manage irrigation and offers the opportunity to maximize yield and generate water savings without affecting yield, getting the most of your irrigation system
Complementing ET in managing irrigation

- ET: For a runner, adjusting your diet based on your weekly weight basis or your past calorie consumption: risk of reducing your efforts due to underfeeding if rate of feeding does not feed enough

- Tension real time: heart and calorie monitor: you will adjust your food intake based on your real-time consumption and your feeding rate hence optimizing your efforts. Irrigation initiated at a tension threshold \( h_c \) to provide adequate soil water flux to the plant. It considers actual ET \( (s_0 + q_0) \) to make sure the plant is properly supplied during peak activity (in real time).

\[
\begin{align*}
\text{Leaching depth} & \quad \text{\& \quad soil hydraulic properties} \\
\text{\& \quad root flux} & \quad \text{\& \quad root transpiration} \\
\text{Tension Irrigation Threshold} & \quad (h_c)
\end{align*}
\]

Part 1: Comparing grower managed (Crop ET and visual assessment) with a real time tensiometer approach

Saving water

- Stay within the blue: initiate irrigation before being out of the blue zone with the top tensiometer: likely avoid prewetting and risk of slaking

- Stop it before the lower tensiometer hits low values: avoid waterlogging and leaching

Using tension or suction forces to drive irrigation decisions

Stopping irrigation: tension drops

Initiating irrigation: threshold reached

Newer approach to maintain the crop in a non-limiting flux situation (below \( h_c \)) with two tensiometers
Comparing irrigation threshold to initiate irrigation (top of the blue band)

Determine $h_c$ to get top yield irrespective of water use (2011-2014)

Irrigation treatments applied though the growth cycle (CRBD with 5 replicates)

<table>
<thead>
<tr>
<th>Establishment</th>
<th>Small roots &amp; low ET</th>
<th>Deep rooting &amp; large canopy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 20 kPa</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 20 kPa</td>
<td></td>
</tr>
</tbody>
</table>

Parameters Measured

Plant performance and hydric stress measurements (Weekly measurements from January to June)

- Yield in sub-sampling sites
- Size of the fruits (caliber)
- Fruit quality using Brix index
- Plant size (canopy area)
- Leaf Water Potential (SWP) using pressure chamber
- Leaf temperature with infrared thermometer

Parameters Measured

Soil sampling and soil analysis (3 soil samples/plot)

Initial properties
- Texture
- Saturated Hydraulic Conductivity (Ksat)
- Soil Water Retention Curves
- Salinity (Electrical Conductivity (EC)) and pH

Weekly determination
- Soil salinity from SSE method (1:1 suspension)
- Soil salinity (EC) using suction lysimeter
- Amount of water/ha using flowmeters (non replicated though)

Results for 2012 to 2015 in California and Québec

Plant performance and water used (Weekly measurements from January to June)

15 minute real time soil water potential at 15 cm and 30 cm (3 reps) using wireless Hortau tensiometers

Irrigation initiated by the irrigator (2012, 13, 14) or automated (2015)

Watsonville Salinas Oxnard

- Soil series:
  - Clear Lake clay
  - Salinas Clay
  - Mocho silty loam
  - Hueneme sandy loam

- Yield difference from optimum thresholds:
  - 16% (8,000 pounds per acre)
  - 17%
  - 14%

- Optimum tension (bars top of blue band):
  - 10
  - 13
  - 8

- Acre foot/Acre difference between treatments:
  - 0.30
  - 0.15
  - 0.15

- Percentage of crop ET for top yield:
  - 75
  - 49
  - 114

Effects of real time irrigation management on strawberry production:

- Real-time irrigation: summarizing
- Real time management:
  - Irrigation triggered
  - Irrigation stopped before leaching
    - Fast leaching = 0 kPa
  - Etc management:
    - Irrigation triggered too late
    - Too long irrigation = leaching and waterlogging
Flux is important to be maintained non limiting through irrigation

<table>
<thead>
<tr>
<th>Year</th>
<th>Soil Type</th>
<th>Region</th>
<th>Grower</th>
<th>% of crop ET</th>
<th>Yield Increase Relative to Grower</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>Clay</td>
<td>CA</td>
<td>100</td>
<td>93</td>
<td>0</td>
</tr>
<tr>
<td>2013</td>
<td>Clay</td>
<td>CA</td>
<td>144</td>
<td>84</td>
<td>0</td>
</tr>
<tr>
<td>2014</td>
<td>Clay</td>
<td>CA</td>
<td>83</td>
<td>83</td>
<td>26</td>
</tr>
<tr>
<td>2012</td>
<td>Silty Clay Loam</td>
<td>CA</td>
<td>163</td>
<td>68</td>
<td>27</td>
</tr>
<tr>
<td>2013</td>
<td>Sandy Loam</td>
<td>CA</td>
<td>93</td>
<td>128</td>
<td>6</td>
</tr>
<tr>
<td>2014</td>
<td>Sandy Loam</td>
<td>CA</td>
<td>100</td>
<td>154</td>
<td>7</td>
</tr>
<tr>
<td>2012</td>
<td>Gravelly Clay Loam</td>
<td>QC</td>
<td>35</td>
<td>42</td>
<td>20</td>
</tr>
<tr>
<td>2013</td>
<td>Gravelly Clay Loam</td>
<td>QC</td>
<td>49</td>
<td>42</td>
<td>18</td>
</tr>
<tr>
<td>2014</td>
<td>Gravelly Clay Loam</td>
<td>QC</td>
<td>52</td>
<td>63</td>
<td>0</td>
</tr>
</tbody>
</table>

Average Water Use in Percentage of Crop ET (CA oasis): 132, 103, 18

CA: California; QC: Québec

Cost-benefit Analysis – Case study of a 50-acre farm

profit: conventional management triggers irrigation at -15 kPa, on average. We are looking at the gains and losses associated with the management based on tension at -10 kPa compared to conventional management at -15 kPa, for a 50 acre-farm.

<table>
<thead>
<tr>
<th>LOSSES</th>
<th>GAINS</th>
</tr>
</thead>
<tbody>
<tr>
<td>INCREASED COSTS</td>
<td>REDUCED COSTS</td>
</tr>
<tr>
<td>Increased Variable Costs</td>
<td>Reduced Variable Costs</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>Operating Costs</td>
</tr>
<tr>
<td>Wireless Tensiometer Technology</td>
<td>Water Savings</td>
</tr>
<tr>
<td>Annual Service Fees</td>
<td>Total Water Savings</td>
</tr>
<tr>
<td>Initial Costs (Shipment &amp; Installation)</td>
<td>Total 40,341</td>
</tr>
<tr>
<td>Depreciation (0% interest)</td>
<td>Total 66,000</td>
</tr>
<tr>
<td>Initial Costs</td>
<td>Total 40,341</td>
</tr>
<tr>
<td>Net Change in Profit</td>
<td>25,659</td>
</tr>
</tbody>
</table>

Part 2: Using a real time tensiometer approach to manage deficit irrigation
Adjusting critical irrigation threshold

- $h_c$ is expected to vary during the season because rooting depth ($L$) and crop ET ($E_T$) vary
  \[
  h_c = \frac{1}{\alpha^m} \frac{E_T^m - E_T^m}{\alpha^m - 1} - L.
  \]
- Software and controllers could allow adjustment for increasing root and increasing ET and implement them for managing irrigation
- Alternatively, a simpler approach could maintain a lower (-35 kPa) threshold when the roots and the plants are small and move to a higher (-10 kPa threshold) when the plants get bigger to save water.
Weighted Yields for 2015:
(a) Weighted Total Yield (Fresh + Freezer) during the whole season (January 9th to June 11th 2015);
(b) Weighted Marketable Yield (Fresh Market) from January 9th to April 2nd 2015;
(c) Relative Marketable Yield (Fresh) from January 9th to April 2nd 2015.

Summary of the performances for both years

Irrigation treatments  Relative yield  Water used

<table>
<thead>
<tr>
<th>Grower</th>
<th>% acre-foot per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10 kPa</td>
<td>100</td>
</tr>
<tr>
<td>-35 kPa</td>
<td>93</td>
</tr>
<tr>
<td>Partial deficit</td>
<td>94</td>
</tr>
<tr>
<td>Root</td>
<td>98</td>
</tr>
<tr>
<td>Variable</td>
<td>98</td>
</tr>
<tr>
<td>Reference ET</td>
<td>-</td>
</tr>
</tbody>
</table>

Water use efficiency and relative yield

Sandy loam

<table>
<thead>
<tr>
<th>Sandy loam rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step</td>
</tr>
<tr>
<td>Dry</td>
</tr>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>Wet</td>
</tr>
<tr>
<td>Screen</td>
</tr>
</tbody>
</table>

Clay loam

<table>
<thead>
<tr>
<th>Clay loam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step</td>
</tr>
<tr>
<td>Wet</td>
</tr>
<tr>
<td>100% ET</td>
</tr>
<tr>
<td>100% ET</td>
</tr>
<tr>
<td>Grower</td>
</tr>
</tbody>
</table>

Graph showing the relationship between soil matric potential (kPa) and water use efficiency (kg/ha cm).

Fig. 1. Effect of the (1) average soil matric potential reached before irrigations and (2) irrigation management method on predicted total WU (1 acft = 3047 m³ ha⁻¹) using data from eight experimental sites (centered regression line).
Deficit Irrigation – using wireless tensiometers

Impact on profit of a deficit irrigation (-15, -20, -30 kPa) relative to a wet management based on tension (-10 kPa)

<table>
<thead>
<tr>
<th>Deficit</th>
<th>Yield decrease (relative to -10 kPa)</th>
<th>Water savings (relative to -10 kPa)</th>
<th>Net Gain/Loss ($ac^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>-2.80</td>
<td>-0.14</td>
<td>-2.66 ($2.66)</td>
</tr>
<tr>
<td>20</td>
<td>-3.56</td>
<td>-0.27</td>
<td>-3.83 ($3.83)</td>
</tr>
<tr>
<td>30</td>
<td>-5.30</td>
<td>-0.54</td>
<td>-5.84 ($5.84)</td>
</tr>
</tbody>
</table>

Conclusions

• Real time management at -10 kPa is important for more crop per drop and higher revenues.
• Target is -10 kPa to initiate irrigation, any stress even early in the season has generated yield decreases and revenue losses.
• Water savings do not compensate for yield losses but at a cost of 1000-5000$ per acre-foot.

Thank you

Colleagues, students, research assistants:
Carole Boily, Amélie Ricard, Julien Corrèse, Valérie Bernier, Guillaume Létourneau, Benjamin Pary, Laurence Gendron.

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