Genetic dissection of the Arabidopsis thaliana ionome

David E Salt
Purdue University, USA
What is the “Ionome”

Ionome
The elemental composition of an organism, tissue or cell

Environment

Transcriptome

Metabolome

Proteome

Genome

High-throughput ionomic analysis of Arabidopsis thaliana- Organismal networks
e-Laboratory controlling workflow and data acquisition

Baxter et al., *Plant Physiol* 2007
e-Laboratory
Sample analysis and data upload

Baxter et al., Plant Physiol 2007
e-Laboratory
Data visualization and download

Baxter et al., Plant Physiol 2007
www.IonomicsHUB.org
Community ionomics HUB to share data

2,746 unique visitors

11,963 visits came from 741 cities
Identification of ionomic mutants

Fast neutron population (6000 M2)

EMS Population
Low Fe (2000 M2)

EMS Population
Low P (2000 M2)

Lahner et al., Nat Biotech 2003
Mapping of low shoot Ca ionomic mutants

Mutation mapped by DNA microarray-based BSA and deletion-mapping to At2g28670 Enhanced Suberin1 (ESB1) Baxter et al., PLoS Genetics 2009
*ESB1* acts in the root to establish the ionomic phenotype of *esb1*

**Grafting**

Grafted at 5-days

Analyzed at 5-weeks

**PCA of ionomic phenotype**

Baxter et al., PLoS Genetics (2009)
**ESB1** expressed in the endodermis and **esb1** has elevated aliphatic suberin

Gene expression: **AREX**: The Arabidopsis Gene Expression Database. [www.arexdb.org](http://www.arexdb.org)

Suberin analysis performed by Rochus Benni Franke, University of Bonn

**ESB1** endodermal expression

*Baxter et al., PLoS Genetics (2009)*
esb1 also shows reduced transpiration and increased resistance to wilting.

Increased resistance to wilting in esb1

Col-0 watered  Col-0 8d drought

dir10-1 8d drought  dir10-2 8d drought

Reduced transpiration rates in esb1

Lights on

Reduced stomatal aperture in esb1

Baxter et al., PLoS Genetics (2009)
Root suberin forms an extracellular barrier that affect water relations and mineral nutrition.

Reduced Ca translocation and water deficit signal

Stomatal closure and reduced water loss

Baxter et al., PLoS Genetics (2009)
Networks connecting genes, the ionome and the landscape
Natural variation in ionome of *A. thaliana*

*Shoot ionome in 84 accession compared to Col-0*

Large ionomic variation available for gene and allele discovery.
Shoot tissue of Ler-0/2 is low in Mo

Ler-0 84% low in Mo

Ler root drives low shoot Mo

Ler-0 QTL for low shoot Mo

Ler-0 x Col-4 RIL population

Finer mapping using microarray genotyping

QTL for low Mo in both shoot and seed on chromosome II

MOT1 is annotated as a sulphate Transporter. No functional data

mot1-1 is 95% Low in Mo

Cloning of *Ler* low Mo QTL

**Genetic complementation**

52 bp deletion in promoter in *Ler*

<table>
<thead>
<tr>
<th>Motif</th>
<th>Ler MOT1</th>
<th>Col-0 MOT1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TAAATTTGATAAGTTTAGCAAATTTTTTCTAACACAAATAAGAATC</td>
<td>TAAATTTGATAAGTTTAGCAAATTTTTTCTAACACAAATAAGAATC</td>
</tr>
<tr>
<td></td>
<td>AGATACTGTCGCCATCAAGGTTTTGCTTTATT</td>
<td>AGATACTGTCGCCATCAAGGTTTTGCTTTATT</td>
</tr>
<tr>
<td></td>
<td>GATACGATATAAAGAGATACGCTTATTGCTCTGTTTCGATACAAACCACA</td>
<td>GATACGATATAAAGAGATACGCTTATTGCTCTGTTTCGATACAAACCACA</td>
</tr>
<tr>
<td></td>
<td>AAACAGAAACAATGGAGTCTCAGTCTCAGAGAGGTCAACACGAAACCCCG</td>
<td>AAACAGAAACAATGGAGTCTCAGTCTCAGAGAGGTCAACACGAAACCCCG</td>
</tr>
</tbody>
</table>

*mot1-1* cannot complement low Mo in *Ler*

Low expression of *MOT1-1* in roots drives low shoot Mo in *Ler*

**MOT1** promoter deletion is associated with reduced Mo across 92 diverse Arabidopsis accessions.

All accession with lowest Mo have loss-of-function **MOT1** alleles including Sha and Kly-2.

**Shoot Mo (ppm)**

0.05  0.95  1.95  2.95  3.95  4.95

**Frequency**

0  2  4  6  8  10

What is the function of MOT1?

**Figure:**

- **Graph:**
  - X-axis: vector, MOT1
  - Y-axis: PPM Mo
  - MOT1 increases Mo accumulation when expressed in yeast.

- **Images:**
  - Expression of MOT1 in protodermis, epidermis, cortex and vascular tissues.
  - Mitochondrial localization indicated by MitoTracker staining.
  - Merged images showing localization of MOT1.

- **References:**
What is the function of MOT1?

First committed step in molybdopterin biosynthesis is in the mitochondria.

Perhaps mitochondria is the site for “sensing” Mo levels.
Association of *MOT1* allelic variation with soil and geographic location

Does *MOT1* determine the landscape distribution of Arabidopsis?
Acknowledgments

Salt Laboratory
Dr Daiyin Chao
Dr Ivan Baxter
Dr Ana Rus
Dr Muthukumar
Dr Hyeong Cheol Park
Prashant Hosmani
Elena Yakubov
Marina Tikhonova

Brett Lahner (Arabidopsis)
Dr John Danku (yeast)
Analytical Chemists

Dr Mourad Ouzzani (Purdue University Discovery Park Cyber Center)
Brad Kennedy, Gemez Marshall, Maged Zereba
Dr Justin Borevitz (University of Chicago)
Dr Magnus Nordborg (University Southern California)
Dr Keyan Zhao
Dr Olivier Loudet (INRA, France)
Dr Edgar Cahoon (University of Nebraska-Lincoln)
Dr Mary Lou Guerinot (Dartmouth College)