A Molecular Diagnostic for Phosphorus Deficiency in Potatoes

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(Warwick, Nottingham, SCRI)

IPNC XVI, Sacramento, 28th August, 2009
Use fertilisers wisely: Reduce & recycle
Soil and Tissue Analyses to Identify Crop P-fertiliser Requirements

Soil analysis

- Used for fertiliser recommendations
- Several methods - no consensus
- Influenced by soil type and water status

Plant analysis

- Informs on plant content
- Tissues differ in P content
- Tissue P does not reflect P sufficiency

Another Alternative: Plant Physiological State
Molecular Diagnostics for Crop P Status

In nature, phosphate is scarce. Plants acclimate to P starvation through changes in gene expression. If you monitor gene expression, you can identify when a plant requires P.
Acclimatory Responses to P Starvation

Increased P acquisition
- Increase high-affinity P transport proteins
- Increased root:shoot ratio
- Acceleration of lateral root growth and root hair production
- Exudation of organic acids, RNases, and phosphatases

Internal P Economy
- Mobilise P reserves from the vacuole
- Reduced P use in energy metabolism
- Reduced transcription (RNA abundance)
- Replace P in phospholipids

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Our First Molecular Diagnostic: “Smart” Plants

Plants that tell us their physiological status

Hammond et al. (2003) Plant Physiology 132, 578-596
Our First Molecular Diagnostic: “Smart” Plants

Plants that tell us their physiological status

Low Nutrient

Promoter 1.6 kb from SQD1 gene

GUS (β-glucuronidase)
GFP (m-gfp-5-ER)

Nutrient Application

Hammond et al. (2003) Plant Physiology 132, 578-596
Smart Arabidopsis Plants

Why settle for just one gene?
Diagnostic Transcriptional Microarray

Leaf transcriptional profile from a P-deficient plant
General Experimental Design

Grow Plants → Remove P-source → Isolate RNA → Probe Microarray → Identify Regulated Genes → Physiological Insight → Targets for Breeding P-Efficient Crops → Indicators of Early Phosphorus Deficiency

- Identify Regulated Genes
Transcriptional Responses to P Starvation

Potato

Brassica

White lupin

Rice

Tomato
Effect of P-withdrawal and P-resupply on Shoot Mass of Hydroponically-Grown Potato

Effect on shoot mass after 13 days
Effect of P-withdrawal and P-resupply on Leaf-P in Hydroponically-Grown Potato

Effect on leaf P-concentration before 7 days
Genes most significantly up-regulated in the leaves of potato seven days after the withdrawal of phosphate from the nutrient solution

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<th>TIGR TC</th>
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Hammond et al., unpublished data
UDP-D-Glucose → SQD1 → UDP-sulfoquinovose → SQD2 → sulfoquinovosyldiacylglycerol

1,2-diacylglycerol → MGDG → mono-β-D-galactosyldiacylglycerol → DGDG1 → α-D-galactosyl-β-D-galactosyldiacylglycerol

Phospholipase D

Patatin like phospholipase

Glycerophosphodiester phosphodiesterase

1-acyl-sn-glycerophosphocholine → L-phosphatidate + choline

sn-glycerophosphocholine → Glycerol-3-phosphate + choline
Expression of 200 genes should predict P status
### Genes whose Expression Discriminates between P-replete and P-deficient Potatoes

<table>
<thead>
<tr>
<th>Microarray Probe ID</th>
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<th>StGI ID</th>
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Field Test of the Diagnostic Transcriptional Profile

Correctly identified P-deficient plants

Expression of 200 genes did predict P status
A Molecular Diagnostic for Phosphorus Deficiency in Potatoes

Identified promoters for ‘smart’ plant technology

Identified genes differentially regulated by P stress in potato

Improved understanding of plant responses to P stress

Identified genes for a diagnostic transcriptional microarray

Tested the diagnostic in the field

Thank-you for listening
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