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Novel Advances in Powdery Scab Management

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22nd August 2023 - Potato NZ, Christchurch

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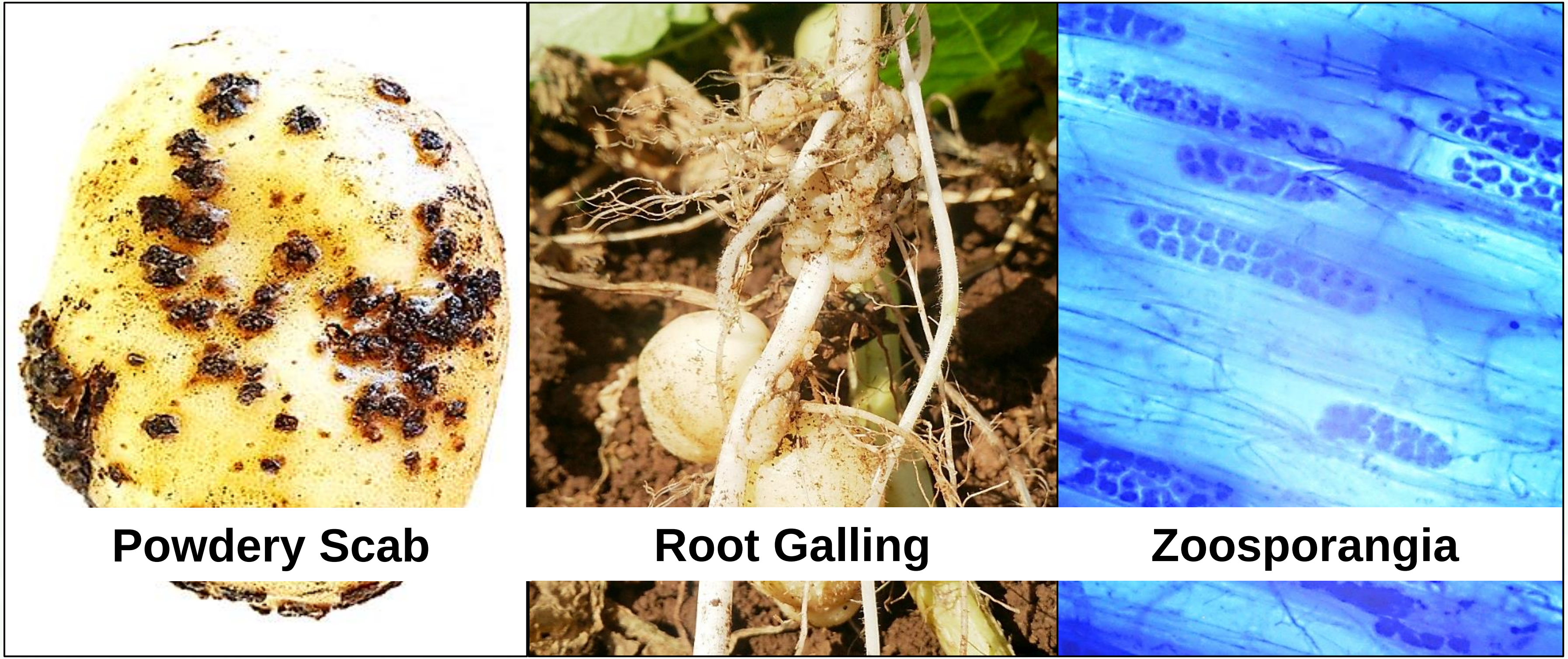
Hort Innovation

Powdery Scab



Estimated Australian losses - AUD$13.4 M p.a.

Wilson CR (2016). Acta Hort. 1123: DOI 10.17660/ActaHortic.2016.1123.2

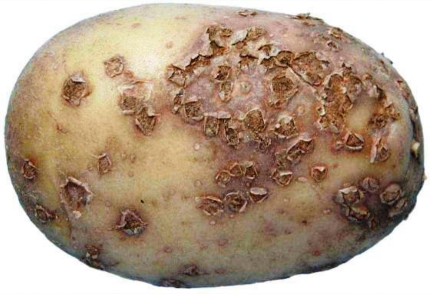
Adversely impacts root function & plant growth

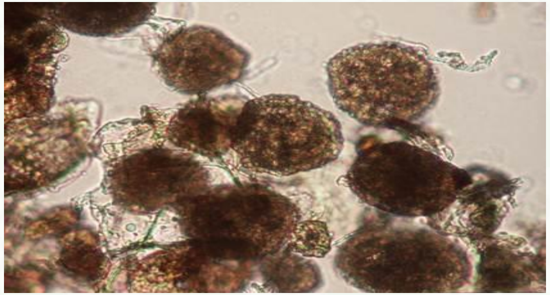
Susceptible potato cv. Iwa

The pathogen survives in soil for a long time

The pathogen produces robust conglomerates of resting spores that persist for decades in a dormant state in the soil or on infected tubers

These form in both root galls and tuber scabs and are released into the soil





Potato infection cycle

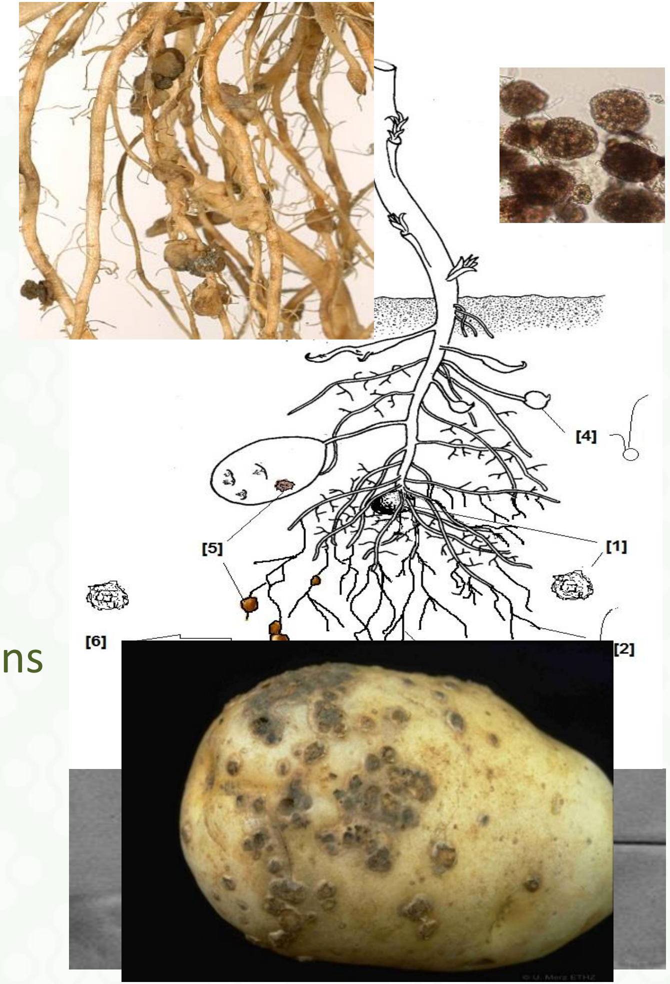
Resting spores germinate releasing primary zoospores

The short-lived zoospores move to roots, bind onto the root surface and infect

These produce secondary zoospores that re-infect roots in a cyclic manner

Root galls form later in mature roots

Young tubers are infected by zoospores producing scab lesions filled with resting spores which are released into the soil



Host Resistance

Resistance is a critical component of powdery scab management
Here we have focussed on resistance to initial root infection

Resistance to root attachment by pathogen zoospores

How are resistant and susceptible cultivars different?
Can we remove “susceptibility”?

New controls targeting root binding

Target root surface proteins

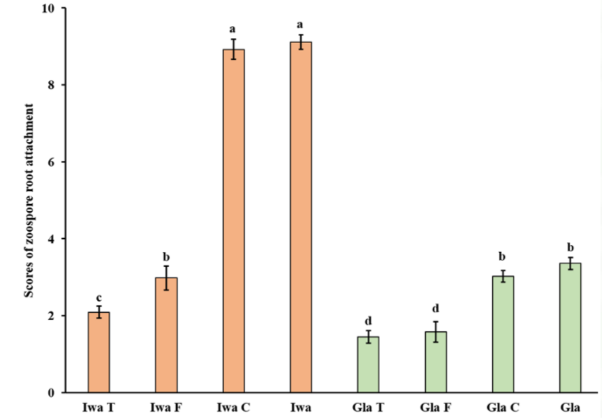
- Trypsin shaving technique
- Strip only surface exposed proteins

Disrupting root binding

- Enzymes reduced zoospore attachment suggesting removal of glycosylated protein receptor

Proteomic analyses

- Comparison of root surfaces of resistant and susceptible varieties identified putative receptors



Non-trypsin treated Iwa root hairs incubated with Spongospora zoospores

Yu et al. 2023 *Proteomes* 11.1 (2023): 7
Yu et al. 2023 *Molecules* 27.18 (2022): 6024

What next

Target putative zoospore receptors to generate highly resistant varieties

- Test putative gene targets for their role in zoospore binding – and then
- Remove these receptors through conventional breeding, somaclonal selection or CRISPR gene editing to generate extreme resistance

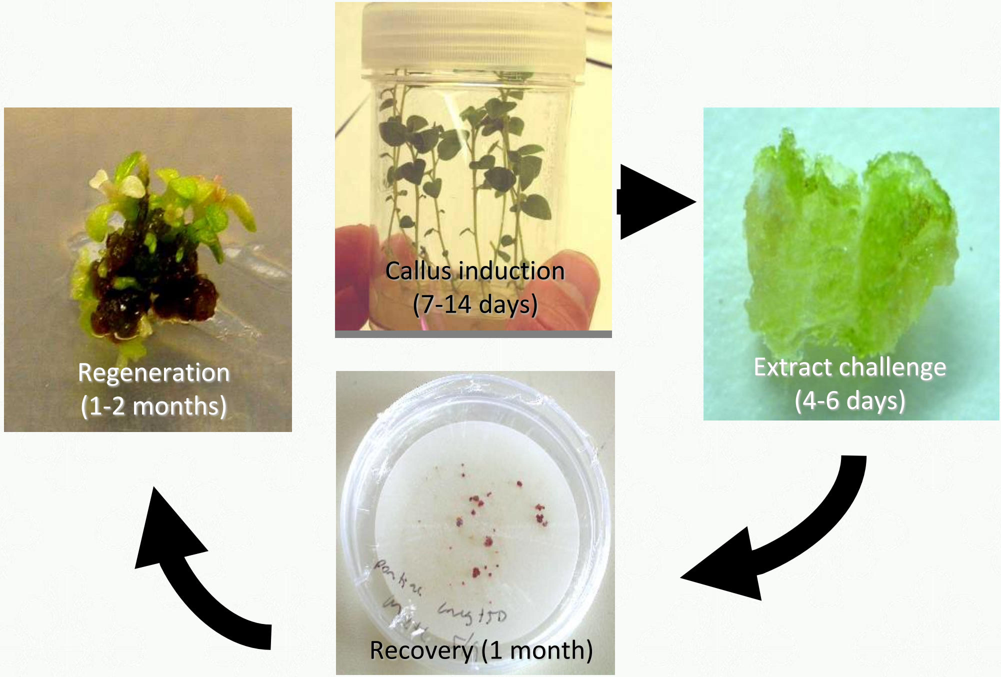
Somaclonal breeding

Somaclonal cell selection techniques can enhance disease resistance without loss of important agronomic traits

Somaclonal cell selection technique

In tissue culture we isolate callus cells which we treat with root gall extract or other pathogen toxins.

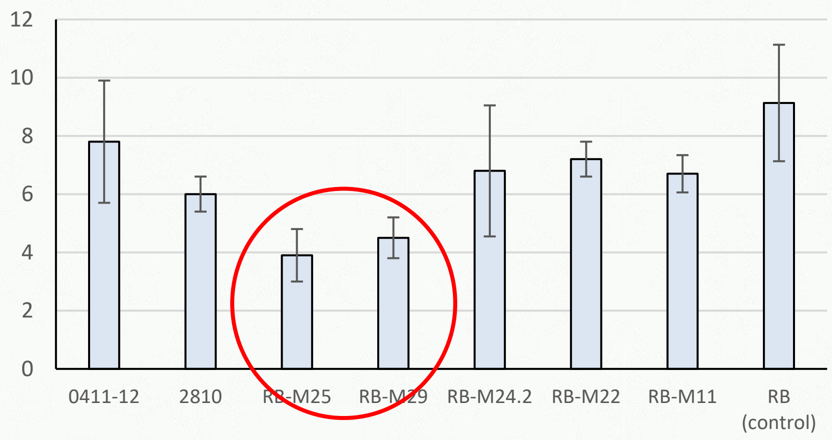
We then screen for resistance to zoospore root attachment

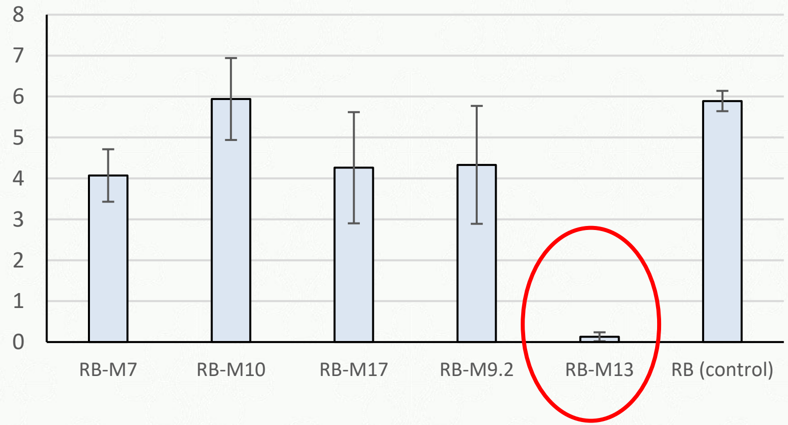


We screened the regenerants using a zoospore root attachment assay

Host resistance to powdery scab

Several lines showed significantly reduced zoospore binding (up to 45-fold)



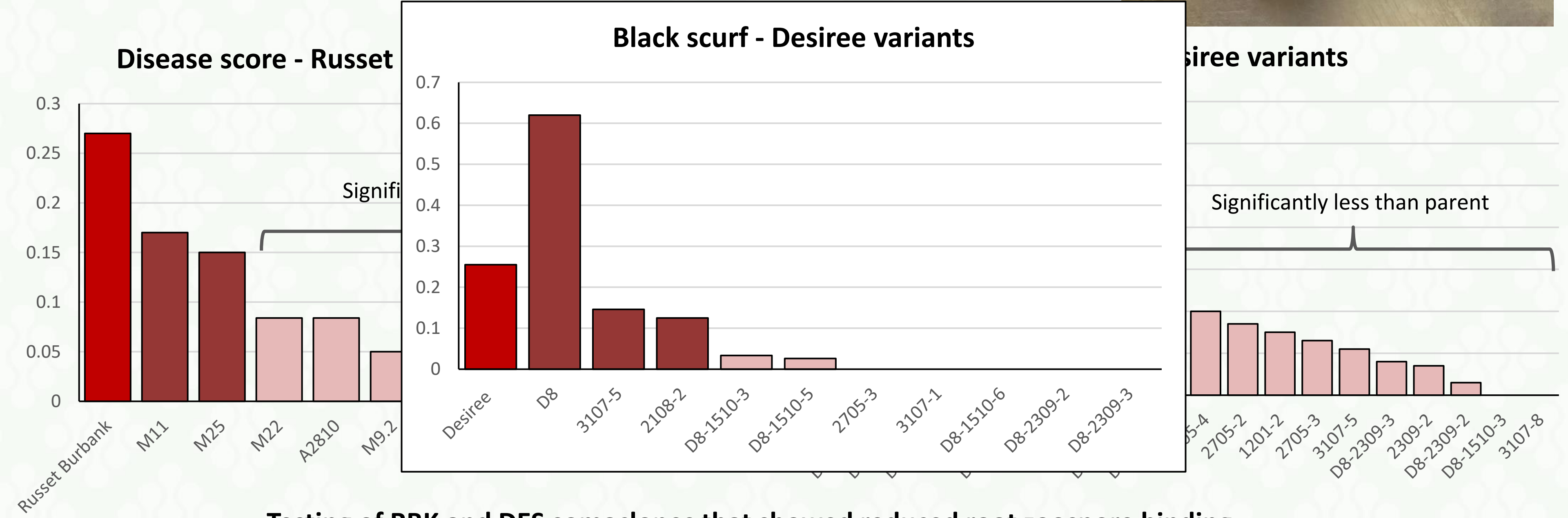


Screening of Russet Burbank variants against unselected parent (control).

New resistant varieties

Glasshouse screening

- Those showing reduced zoospore attachment generally also showed less disease in glasshouse challenge



Testing of RBK and DES somaclones that showed reduced root zoospore binding

What next

Somaclonal variants have enhanced resistance to powdery scab

- Agronomic testing of the disease resistant lines
- Generation of further resistant lines (of diverse commercial cultivars)
- Analysis of the physiological and genetic basis of enhanced resistance (to powdery scab and other diseases)
- Utilise the technology for yield (and other) trait enhancement

Altering the soil chemical ecology

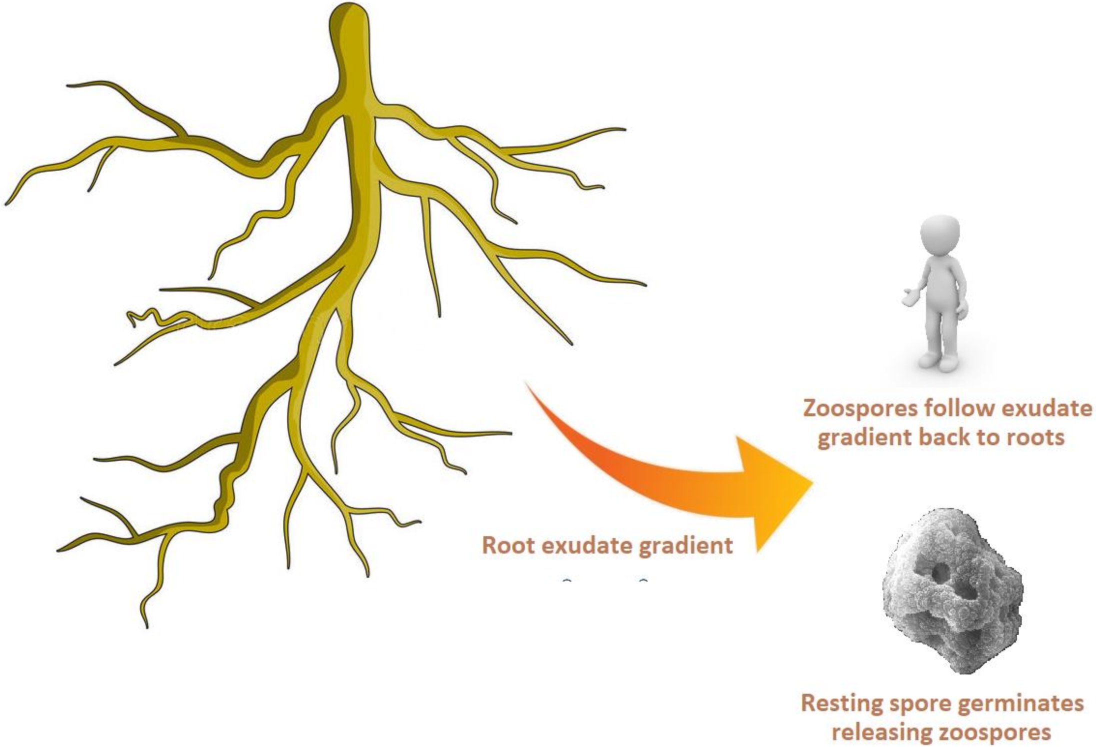
Pathogens and plants have chemical conversations
how can we use this to reduce disease?

Host & pathogen have chemical conversations

Resting spores are stimulated to germinate by **root exudates**
(resting spores wait for a host plant)

Zoospores are then attracted to roots by **root exudates**
(short-lived spores efficiently find roots)

Very efficient of the pathogen



Balendres et al. (2016) J. Agric. & Food Chem. 64: 7466-74
Amponsah et al (2023) Phytopathology doi.org/10.1094/PHYTO-04-21-0176-R

Identifying individual exudate compounds

We have analysed potato root exudates and found:

- Stimulants of resting spore germination
- Attractants of zoospores
- Inhibitors of zoospores
- Interestingly, these seem to be associated with cultivar resistance

Chemotaxis attractants & Germination stimulants
Tyramine
Glutamine
Proline
Pinatol
Trehalose
Raffinose
Asparagine
Serine
Chemotaxis inhibitors
Spermine
Choline

Balendres et al. (2016) J. Agric. & Food Chem. 64: 7466-74
Amponsah et al (2023) Phytopathology doi.org/10.1094/PHYTO-04-21-0176-R

Can we disrupt the chemical signals from plant to pathogen?

A new understanding of how the pathogen and potato plant communicate has given us new strategies to combat disease

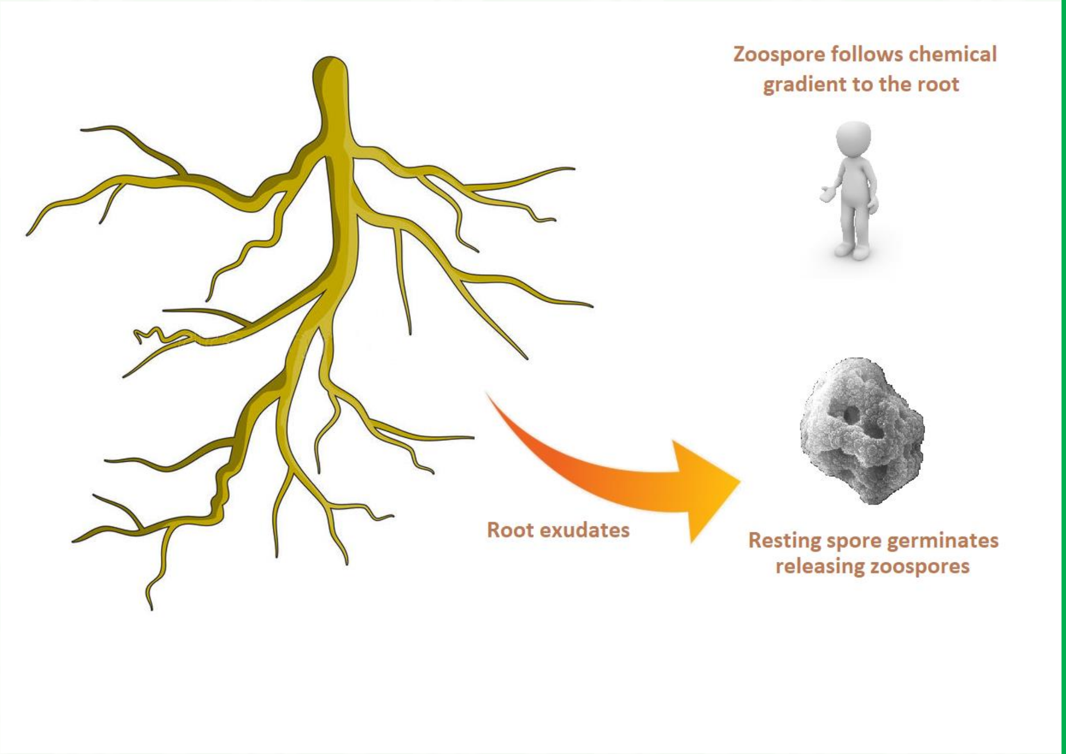
Germinate to exterminate

Can we use this information to deplete soil inoculum

‘Germinate to Exterminate’

Deplete soil inoculum before planting

Resting spores persist for 10^{+} years but zoospores survive for only a few hours

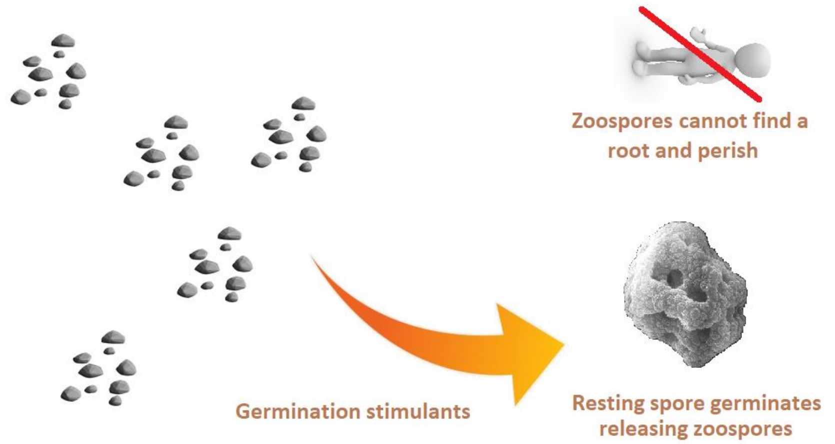


'Germinate to Exterminate'

Deplete soil inoculum before planting

Resting spores persist for 10^{+} years but zoospores survive for only a few hours

If we stimulate germination in absence of a host - the pathogen will die



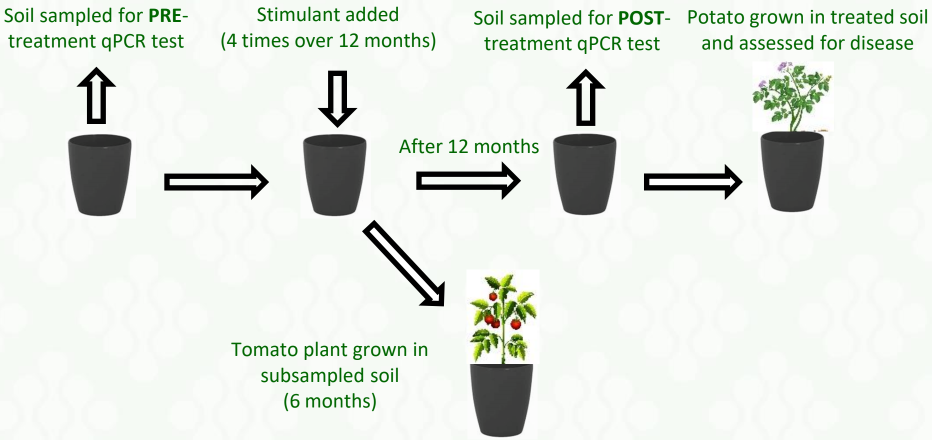
Similar approaches suggested in the management of:

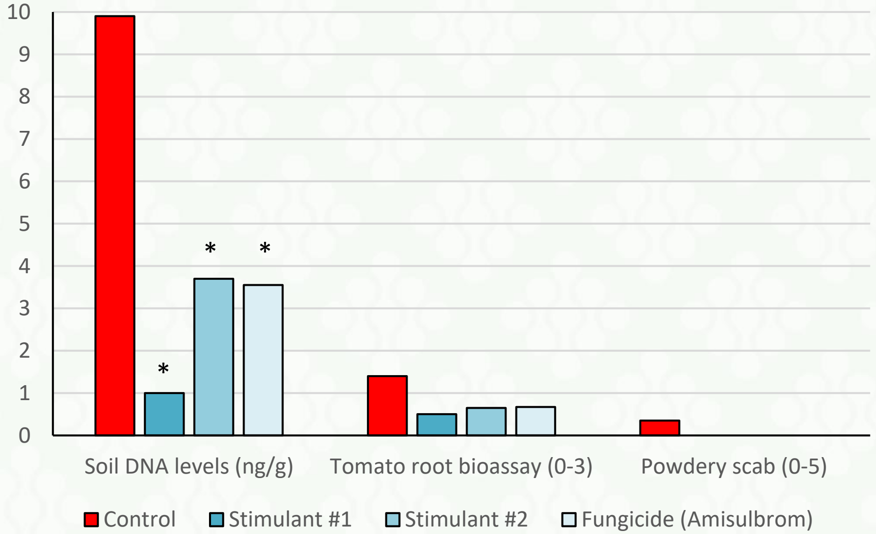
- Clubroot of brassicas (Mattey and Dixon, 2015)
- White rot of onion (Davis *et al.* 2007)

‘Germinate to Exterminate’

In pot trials:

Germination stimulants (or fungicide treatments) applied four times to soil successfully depleted pathogen inoculum levels





Glasshouse Experiment: Soil – Sandy loam

Balendres et al. (2017) Plant Pathology 67: 902-908

‘Germinate to Exterminate’

In field plot trials:

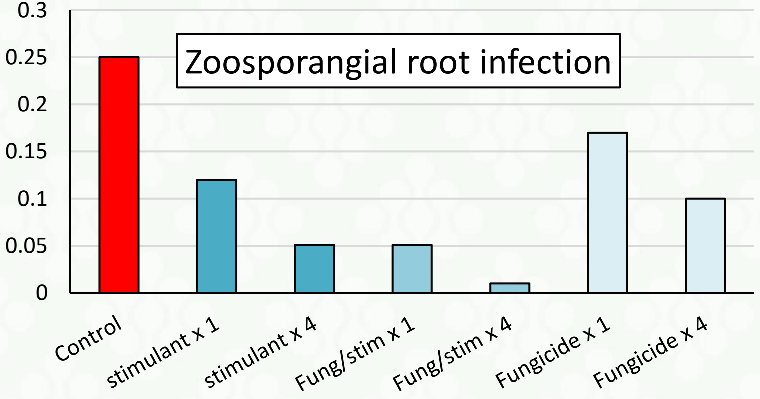
Germination stimulant and fungicide (fluazinam) applied once or four times 12 month prior to planting with cv. Kennebec

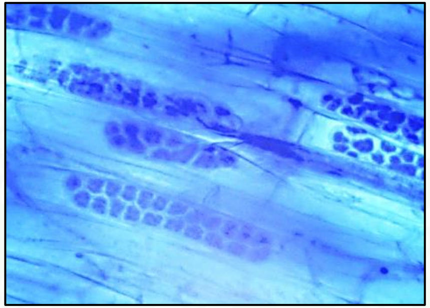
'Germinate to Exterminate'

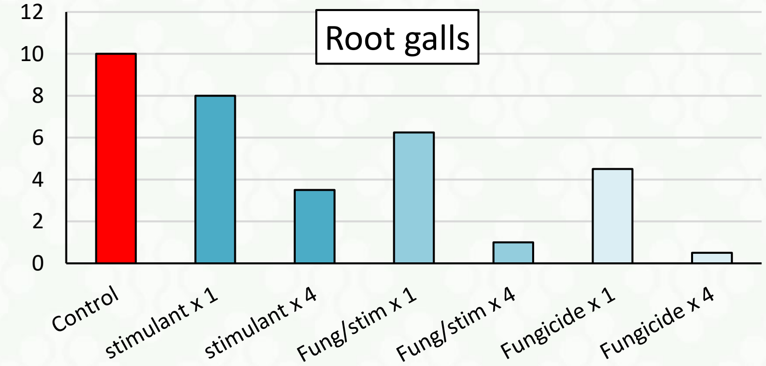
In field plot trials:

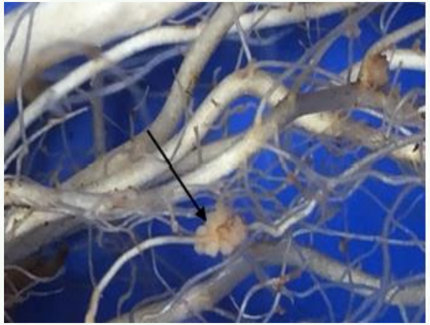
Most treatments showed promise.

Especially multiple and combined stimulant/fungicide treatments









What next

Further work to determine:

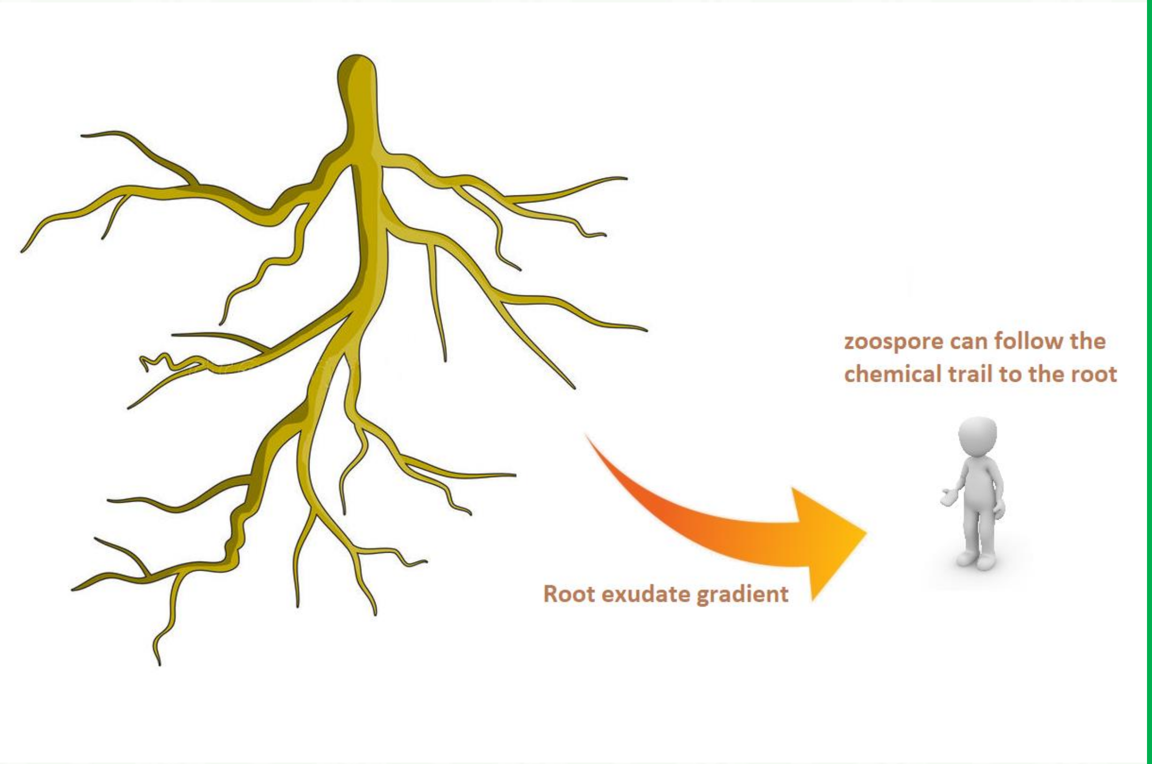
- Best materials
- Best formulations
- Best rates and frequency of application
- Optimal integration with current practices

Diffuse to Confuse

Can we use this information to avoid root infection

'Diffuse to Confuse'

Confuse the zoospores

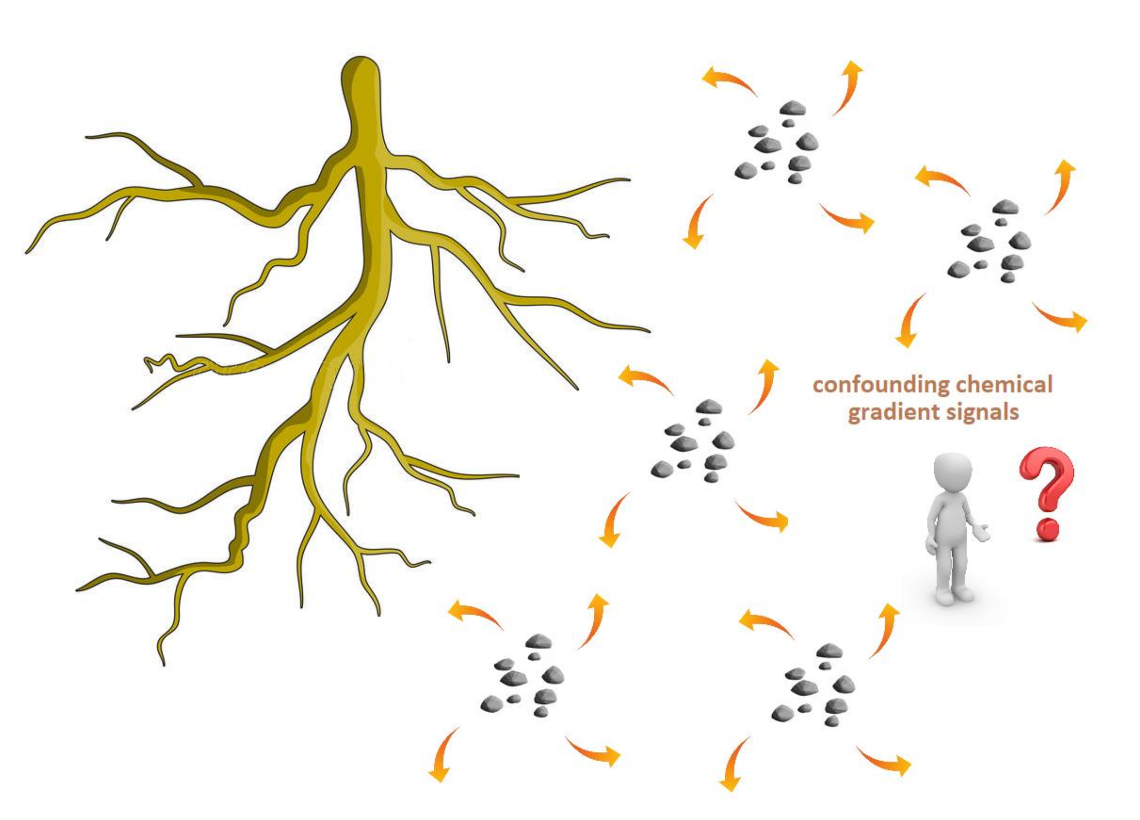


'Diffuse to Confuse'

Confuse the zoospores

What if we add decoy compounds into cropping soil to draw the zoospores away from roots

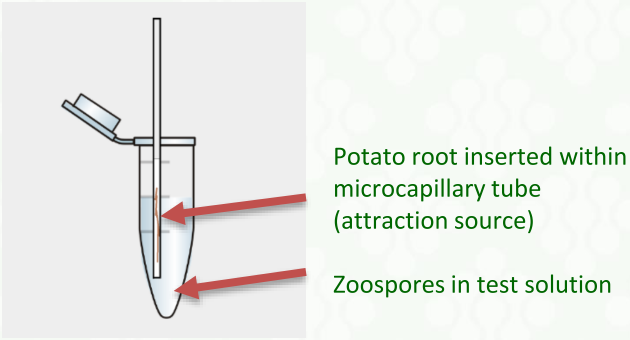
(just like the pheromone traps in orchards work against coddling moth!)

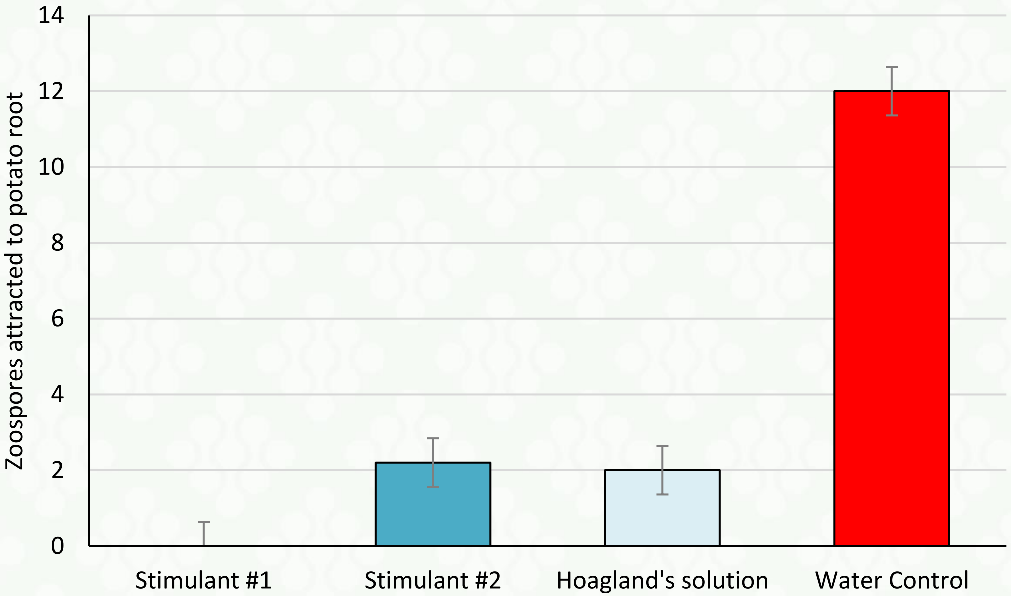


'Diffuse to Confuse'

In *in vitro* testing:

Stimulants successfully impaired chemotaxis toward potato root





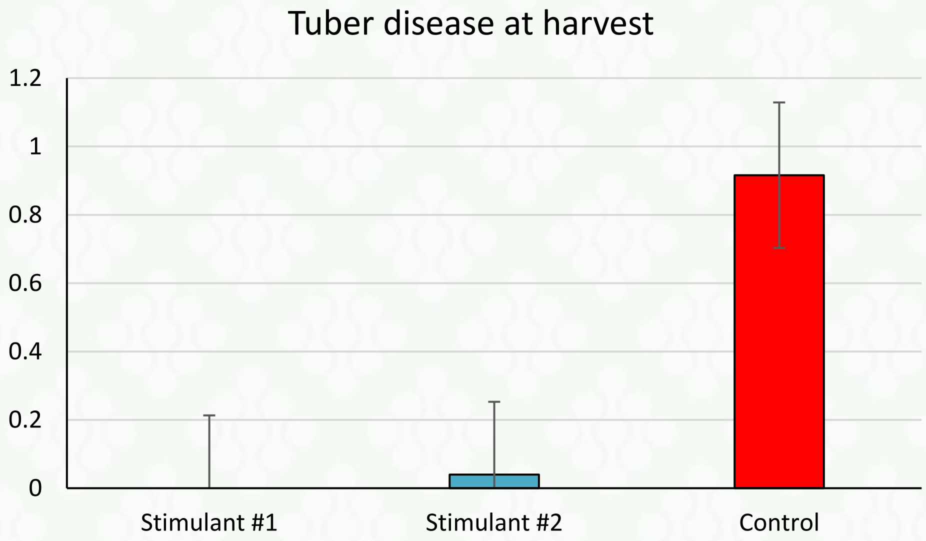
'Diffuse to Confuse'

In pot trials:

Stimulants applied at high rates at planting successfully reduced tuber disease

Stimulant added, mixed through soil & potato tuber planted

Assess harvest tubers for disease



Glasshouse Experiment: Soil – Sandy loam

'Diffuse to Confuse'

Control

Stimulant

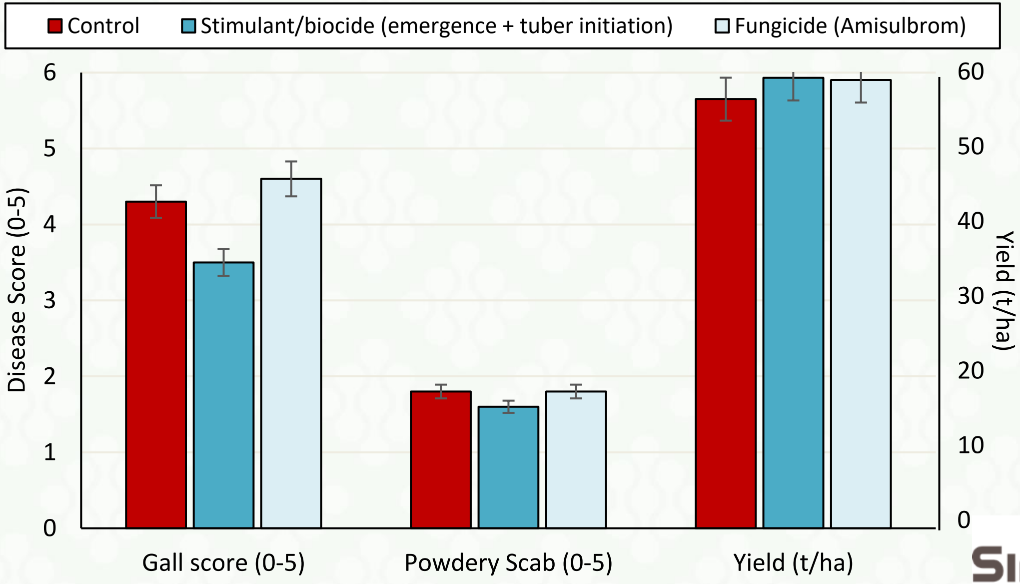
Fungicide

In a field trial:

Stimulant/biocide treatment applied twice to soil at low rates provided significant suppression of disease

- 22.5% less galling
- 11.1% less tuber lesions

Tuber yields increased by 9.5%



Simplot AUSTRALIA

What next

Further work to determine:

- Best materials
- Best formulations
- Best rates and frequency of application
- Optimal integration with current practices

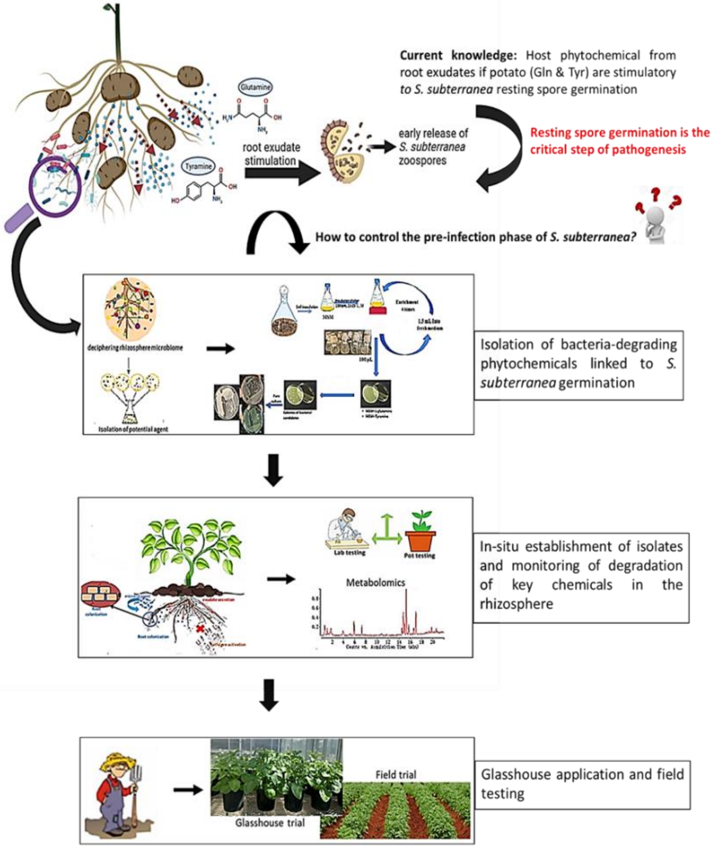
Bacterial rhizosphere amendments

Can we alter the rhizosphere chemistry using biological approaches?

How can we alter natural exudation patterns?

Root exudate depleting rhizosphere bacteria

Can we use rhizosphere bacteria to degrade the stimulants in the rhizosphere and stop pathogen germination and infection?

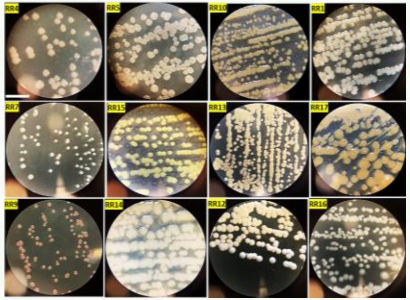


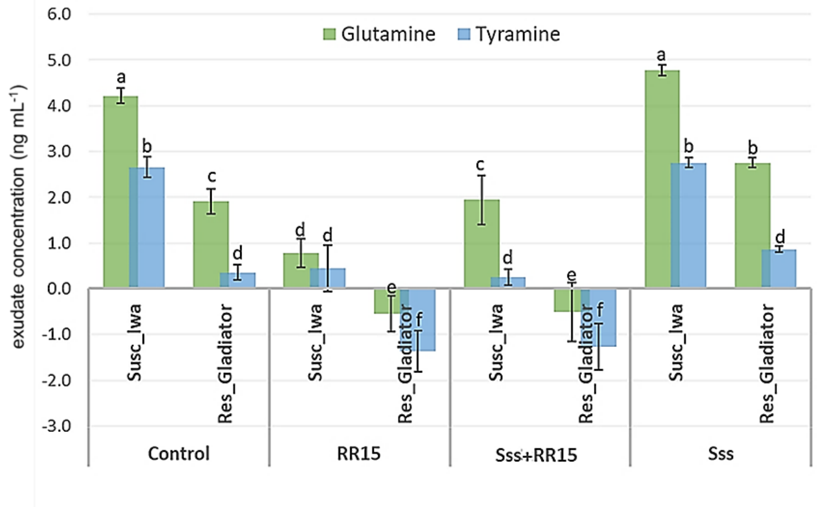
Root exudate depleting rhizosphere bacteria

We have isolated bacteria from the potato root rhizosphere that:

- Inhabit and persist in the rhizosphere
- Efficiently degrade key pathogen stimulant compounds present within root exudates

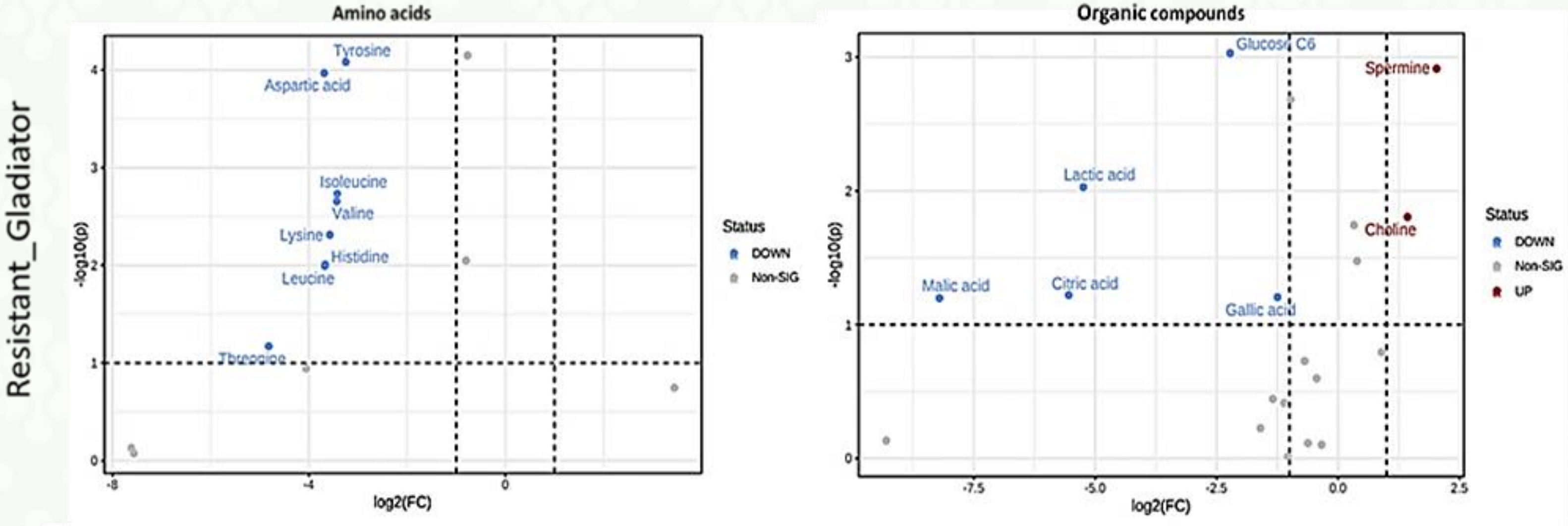
Trials have shown adding the bacteria to potato plants can markedly change root exudate chemical composition





Root exudate depleting rhizosphere bacteria

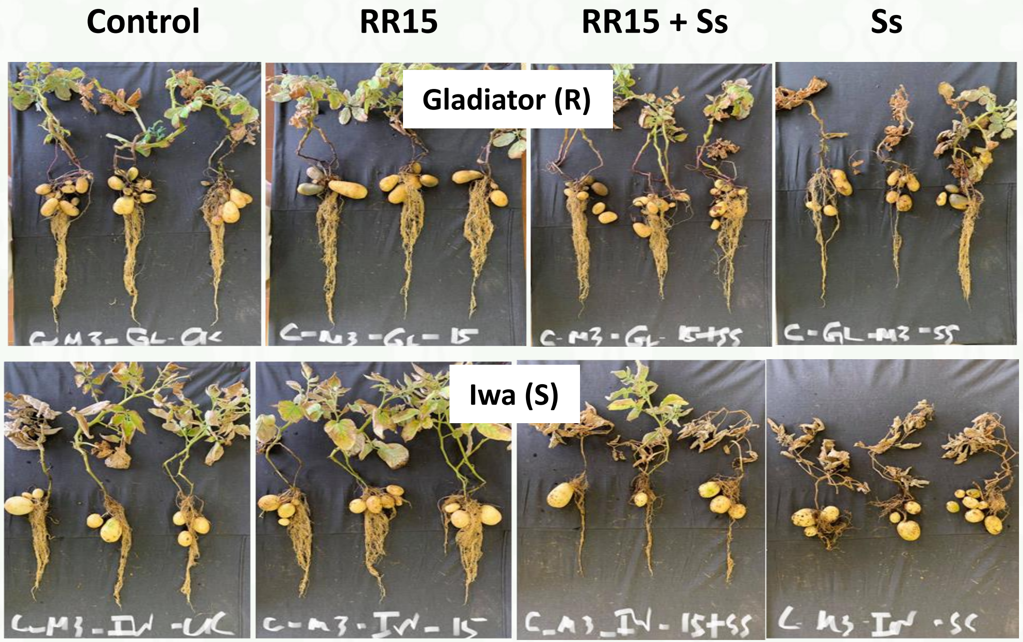
We see not only are the target stimulants decreased, but also inhibitor molecules increased

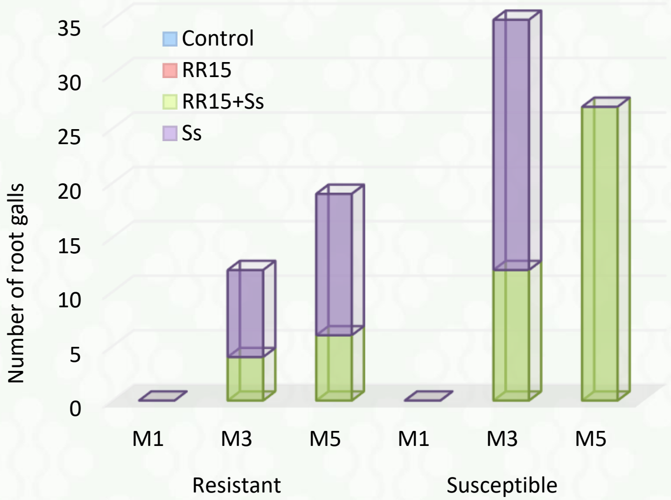


Reduces disease

In pot trials:

Bacterial inoculant successfully reduced root galls numbers and impact on root damage



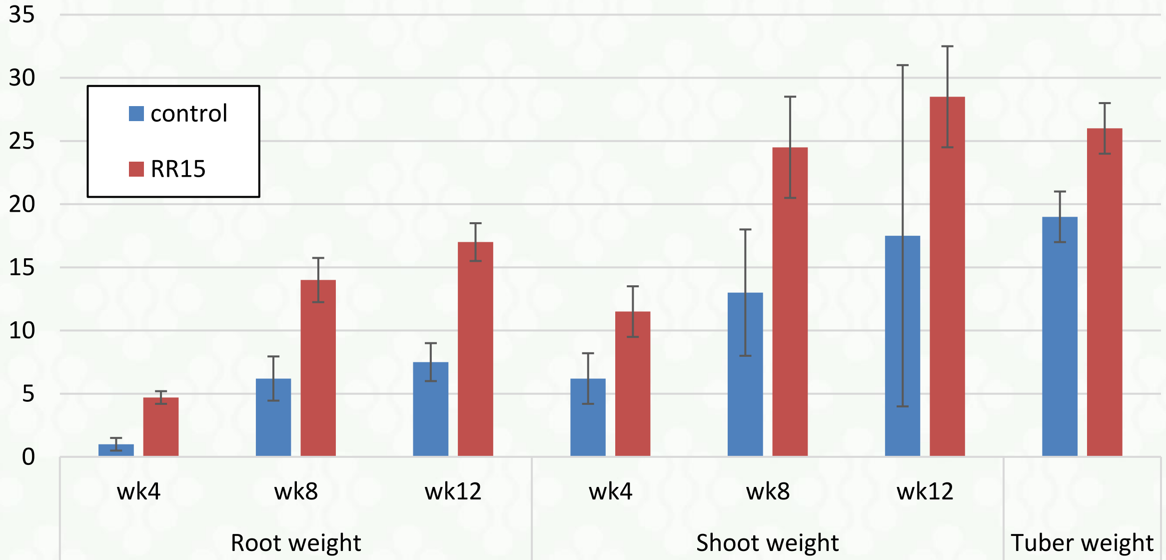


Boosts potato growth

In pot trials:

Bacterial inoculants also increased both potato root growth and tuber yields

Control **RR15**



Boosts potato growth

In field trial:

These are tuber numbers and weights from 5 plants (with 5 replicates) of cv. Russet Burbank

- Total tuber weight increased with treatment – **12.3% increase**
- Marketable yields (excluding chats <75g) also increased with treatment – **16.8% increase**
- Ideal weight (250-850g) also greater with treatment – **40.3% increase**

	Mean tuber count	Mean Total wt (g)	Mean Ave wt (g)/tuber	Mean Mkt wt (>75g)	Mean Mkt wt count	Mean Ideal wt (250-850)	Mean Ideal wt count
Treated	57.6	9920.4	175	9428.6	43.5	3772	11.3
Control	67.4	8691.3	132.3	7849.3	46.4	2250.5	7.2

What next

Rhizosphere inoculant product

- Product formulation
- Commercial testing and release


Thats a lot to
take in

Summary – new management strategies

Resistance to root infection

- Screen varieties for root infection resistance and generate resistant variants (Somaclones, CRISPR etc)

Manipulation of soil chemical ecology

- Germinate-to-exterminate
- Diffuse-to-confuse
- Rhizosphere bacteria altering exudate profiles

Summary – new management strategies

These are not necessarily silver bullets

- Best practice of maintaining soil health, volunteer control, irrigation management, soil testing, using certified seed and resistant varieties, and registered fungicides will still be important.

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