Do variation potentials underpin systemic plant immunity?

Unexpected findings while investigating signalling mechanisms underpinning Systemic Acquired Resistance in *Arabidopis thaliana*

Murray Grant, BEE meeting, Scarman House, 29th March 2019

Food facts!

The UK imports 50% of its food …. *at least until 11pm today*

Crop production will need to increase 70% by 2050 to feed the world's population of ~9 billion (FAO).

(need more food in the next 40 years than in the last 10,000 years)

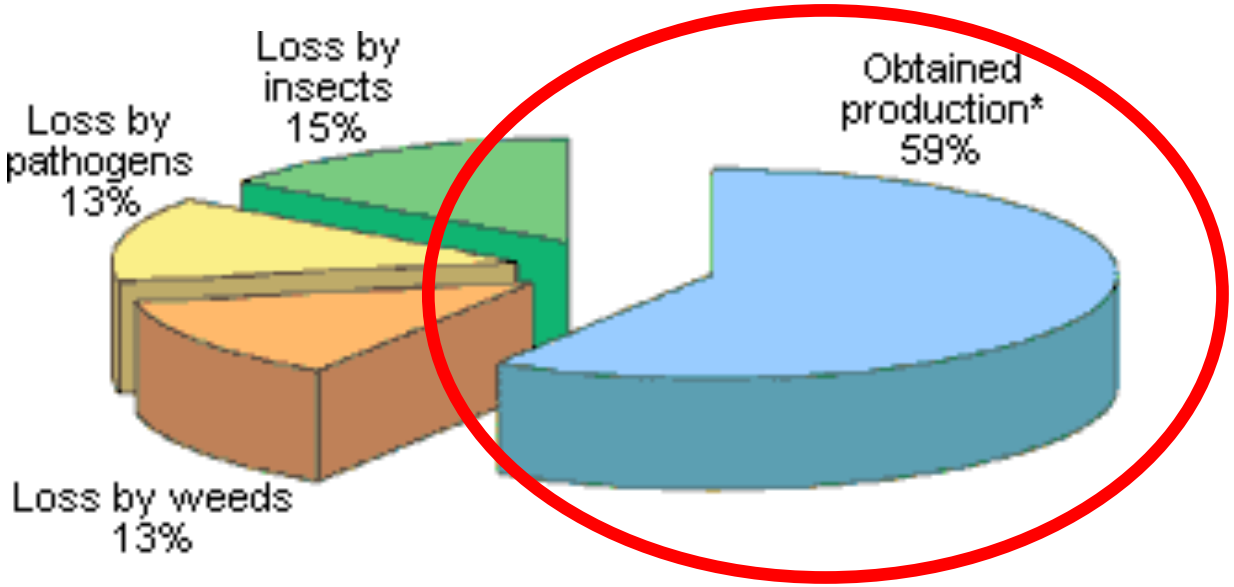
(Alexandratos and Bruinsma 2012)

Need to better understand fundamental plant processes

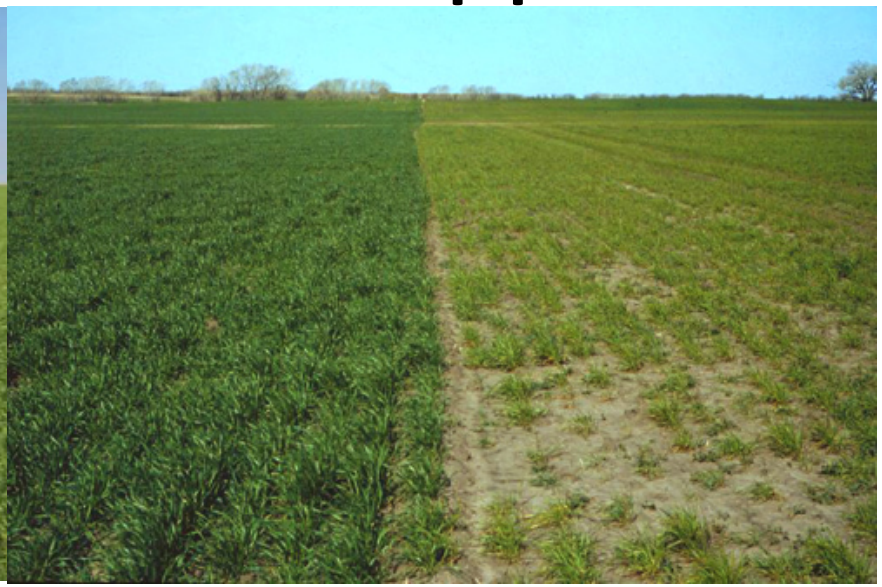
Need to be *more innovative* and be less risk adverse in our science

Can we generate/activate broad spectrum crop protection?

The importance of crop protection

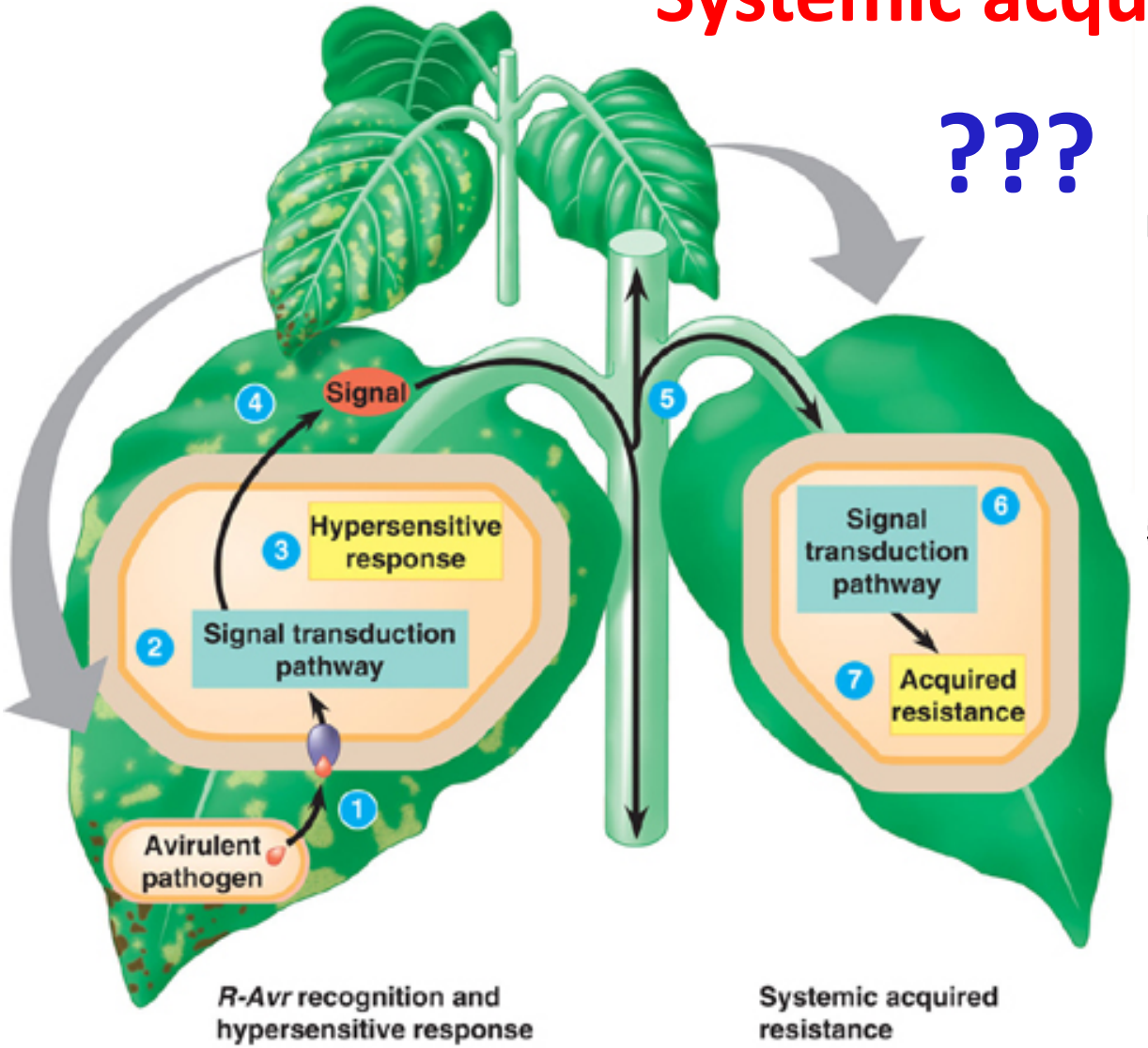


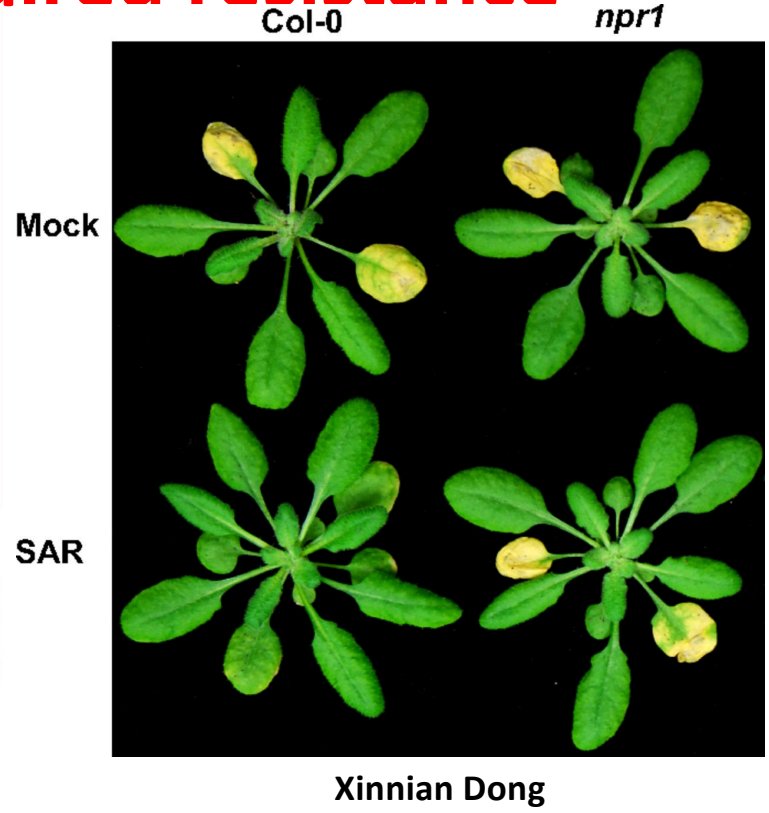
40% of the worlds food would not exist without crop protection



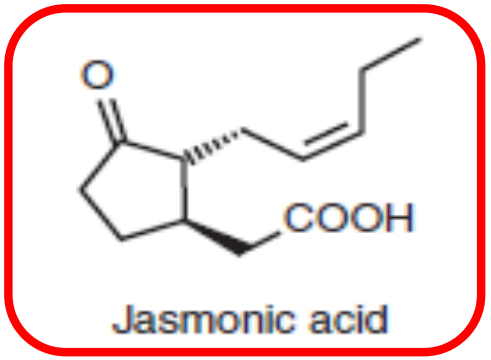
Plants have their own crop protection strategy

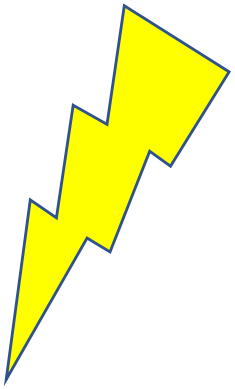
Systemic acquired resistance





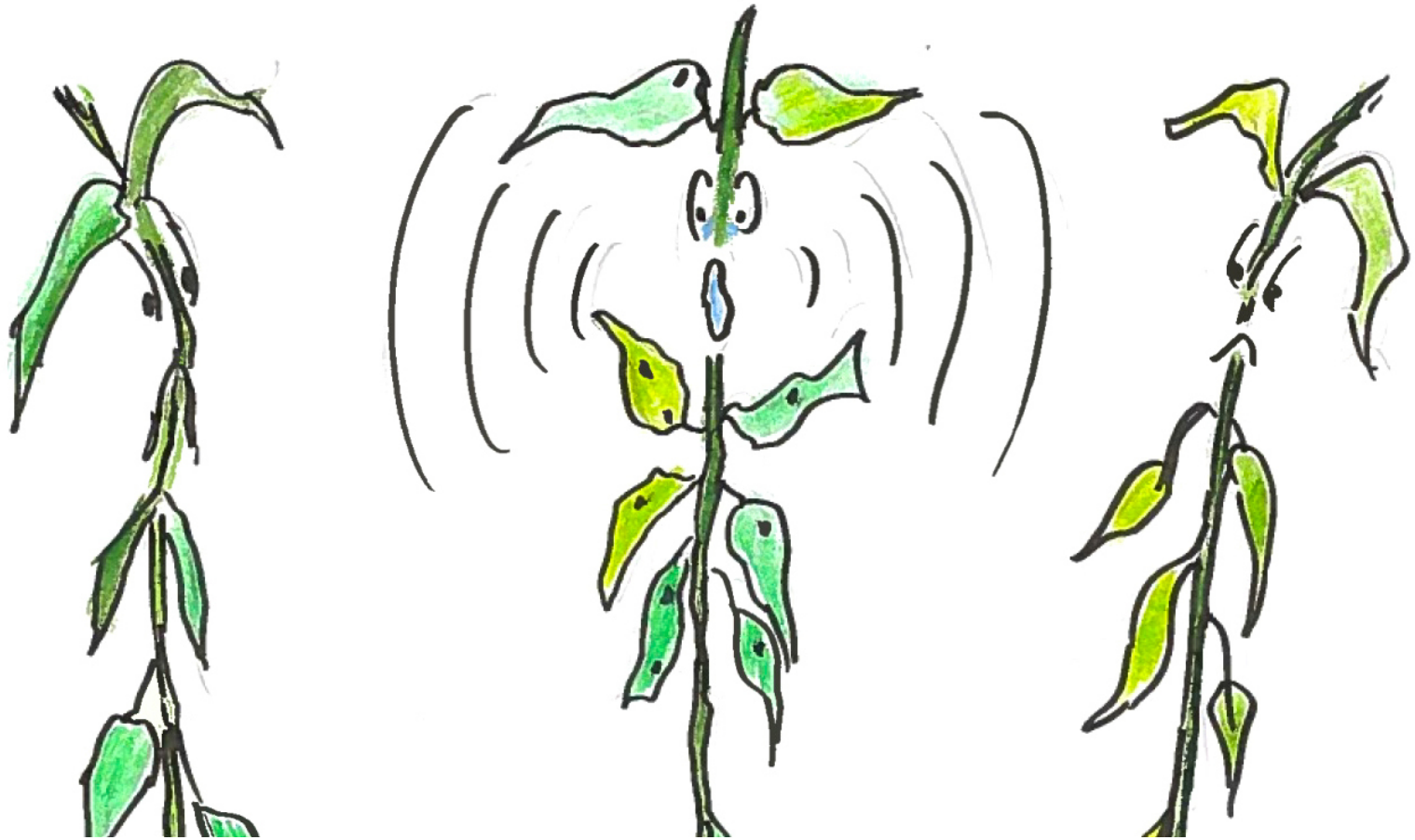
Xinnian Dong





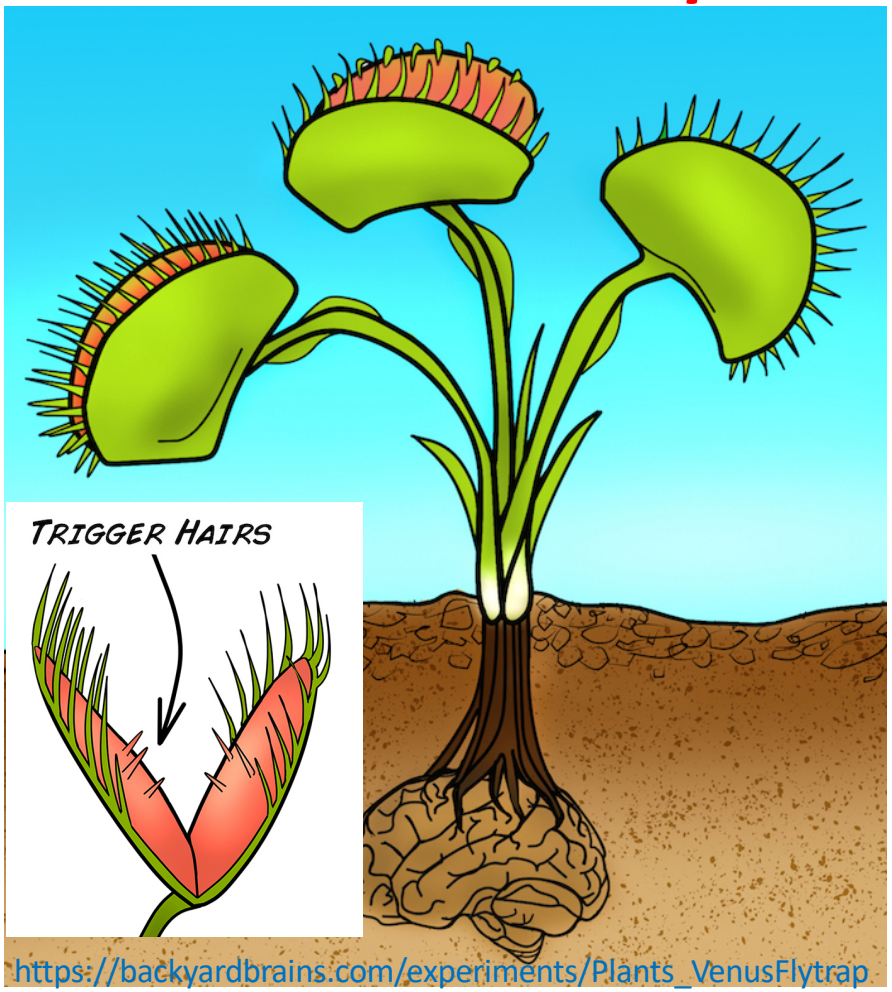
D.A. Dempsey and D.F. Klessig, Treads in Plant Sci., Sept 2012, Vol.17,No.9

Do plants talk?

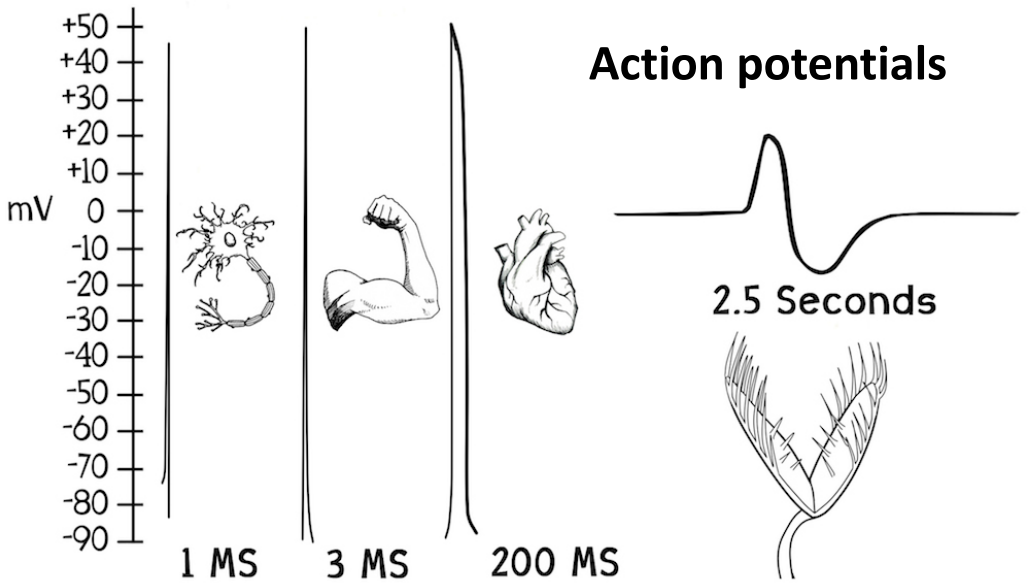


Intra – and inter plant chat

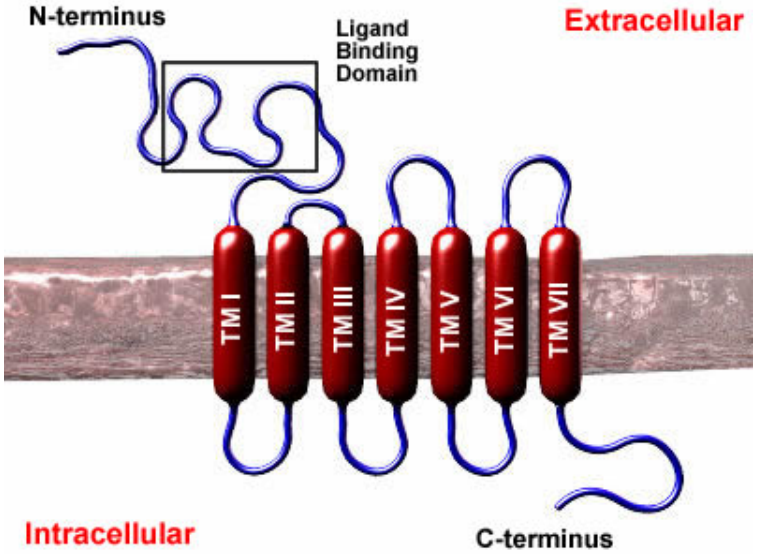
Do plants have brains?



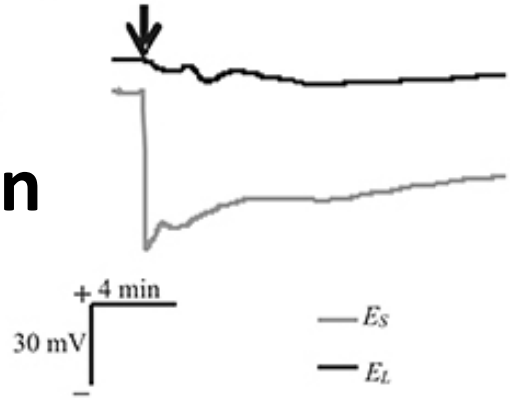
https://backyardbrains.com/experiments/Plants_VenusFlytrap



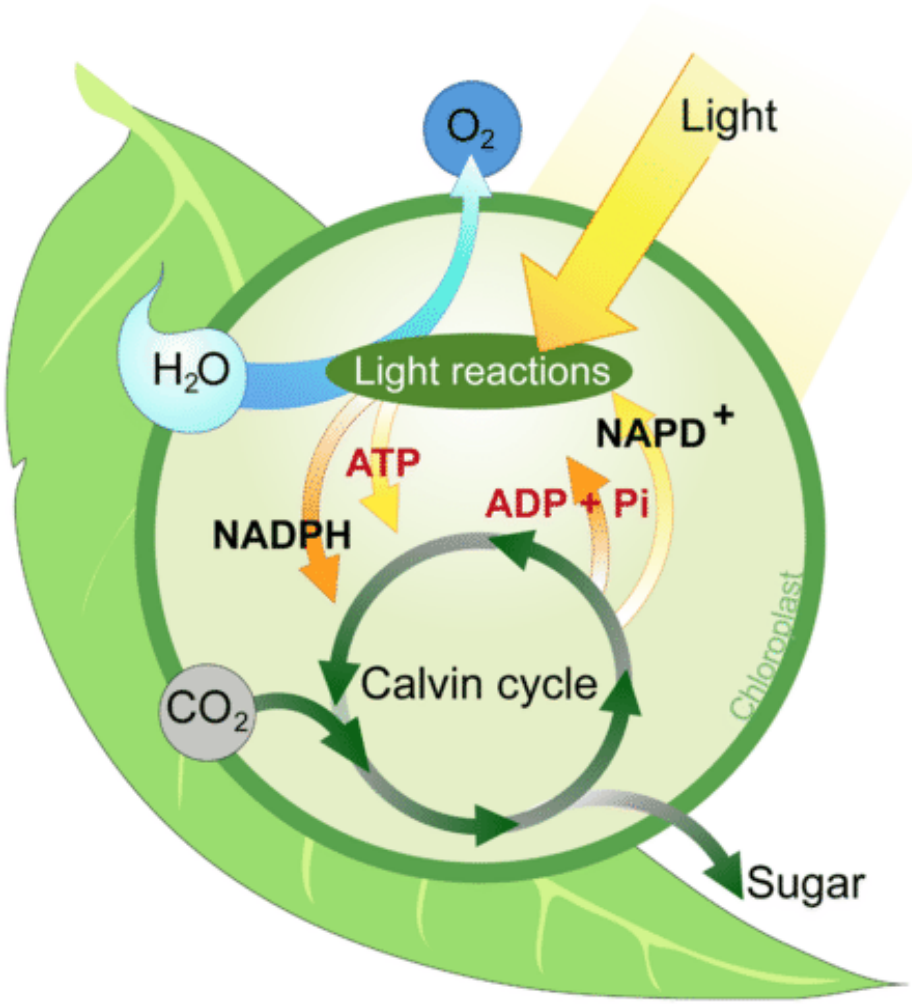
Plants have glutamate receptors



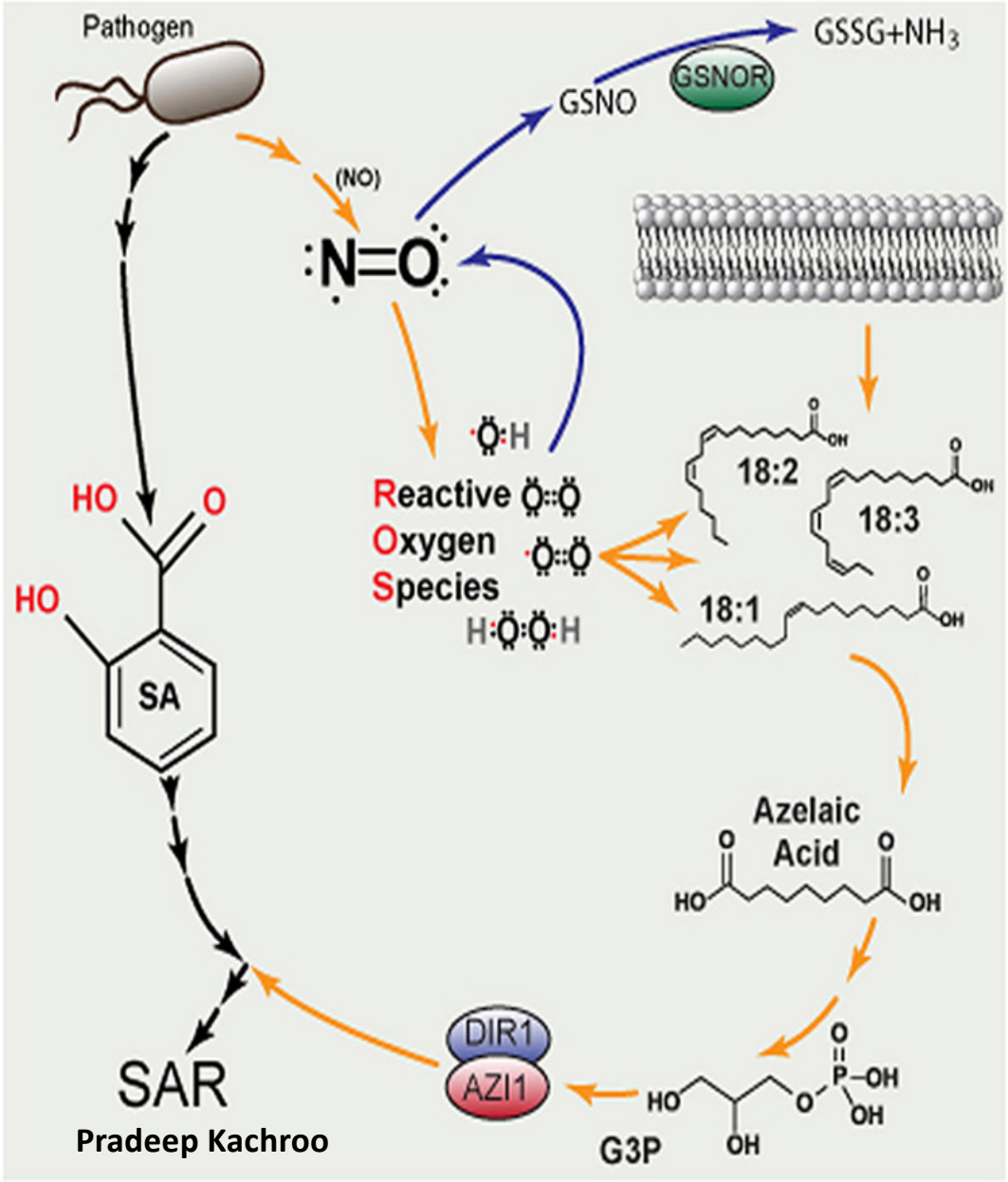
Plants primarily generate variation potentials



Emerging thinking about SAR mechanisms



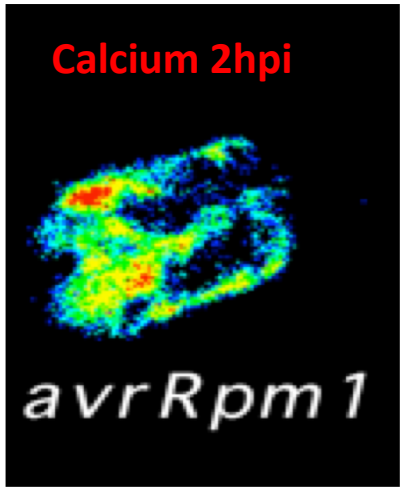
Jubal Harshaw, 2014

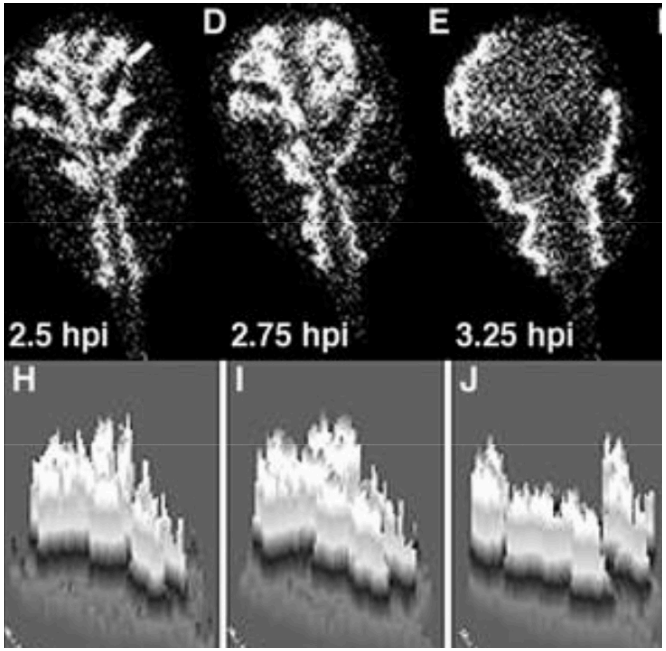


Effector triggered immunity: biophotons/bioelectrics

Natural bioluminescence caused by lipid peroxidation that occurs following successful gene-for-gene recognition (hypersensitive response)

Propagative ROS/NOS wave?



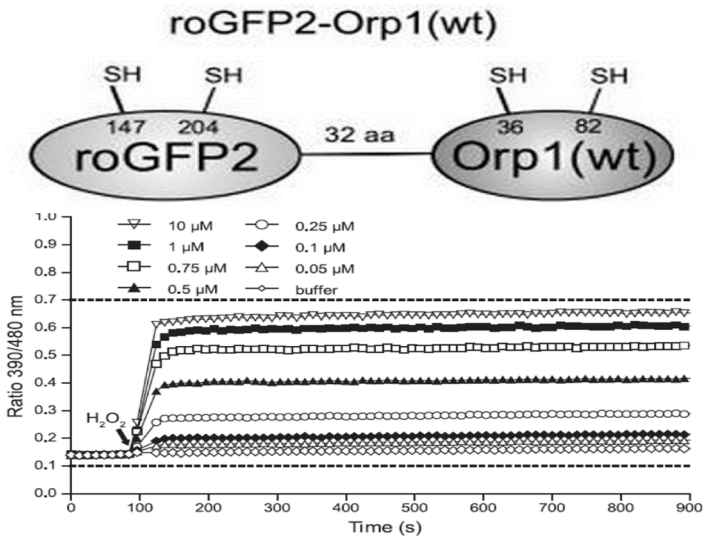


Bennett et al. 2005

avrRpm1 avrRPS4 avrRpt2

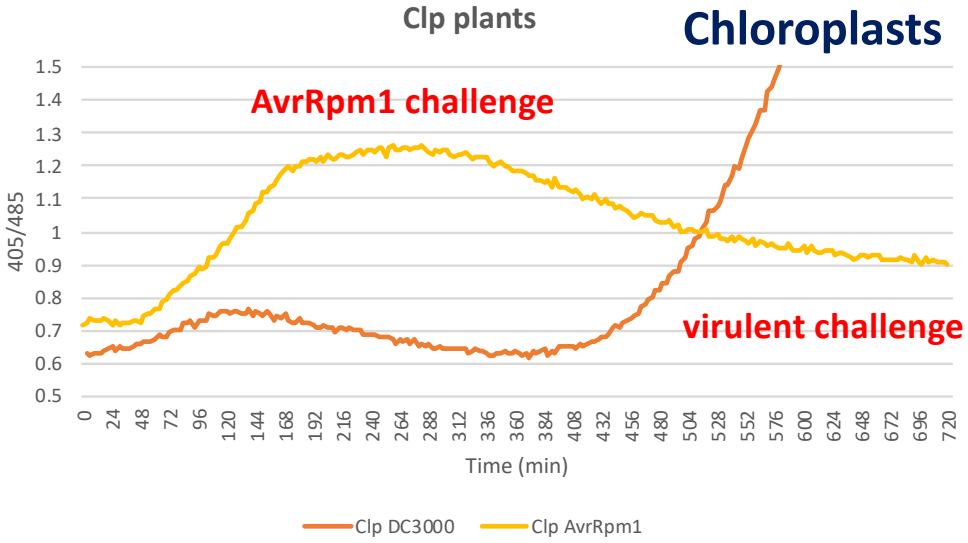
Imaging ETI – SAR trigger

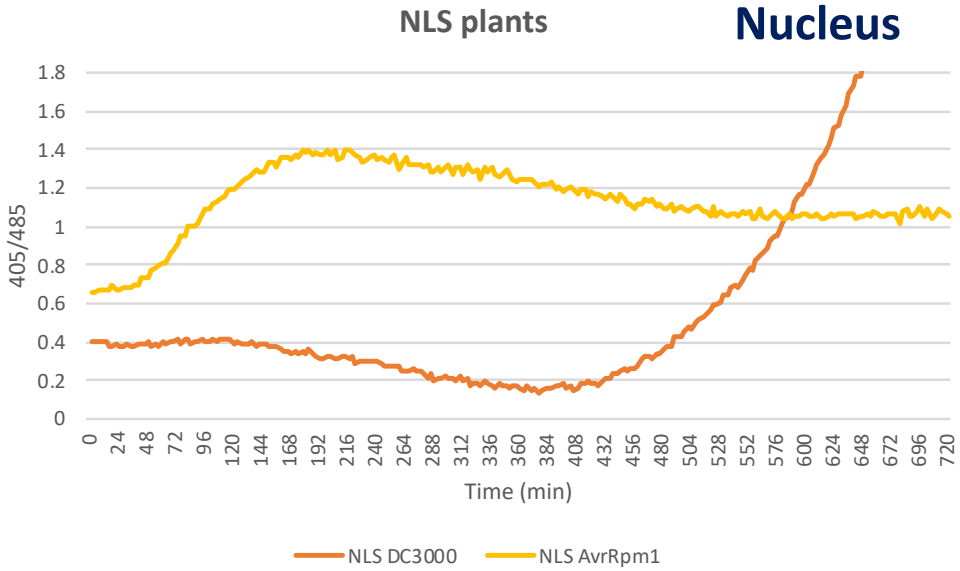
Genetically encoded receptors Orp1-GFP2 - measure H_2O_2



J. Biol. Chem.-2009-Gutscher-31532-40

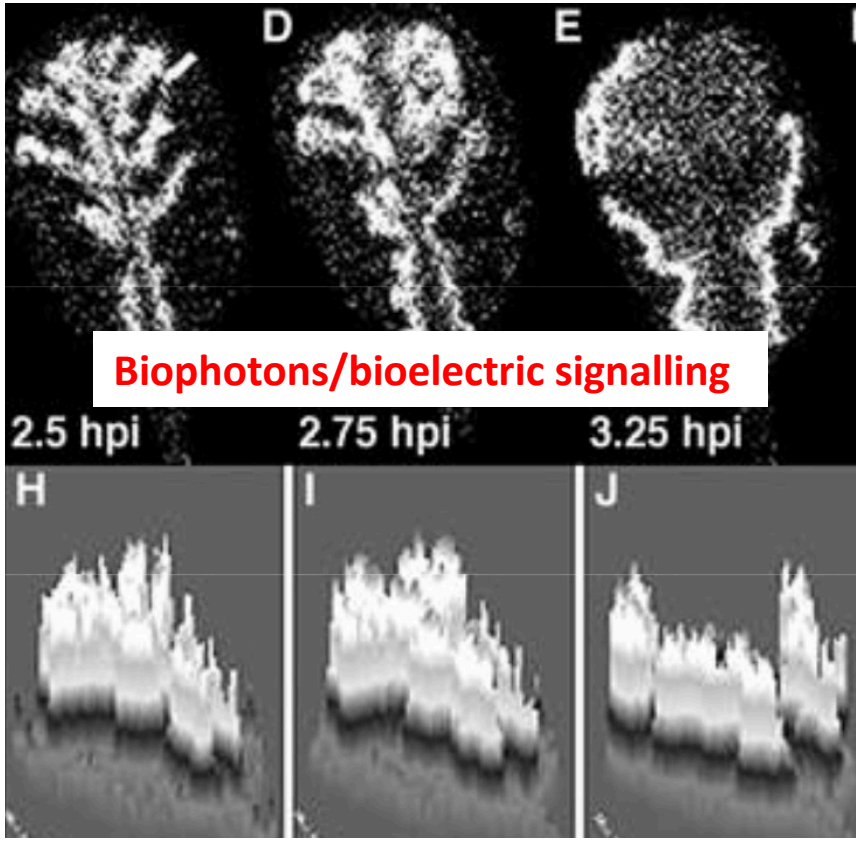
P. syringae treatment - ETI

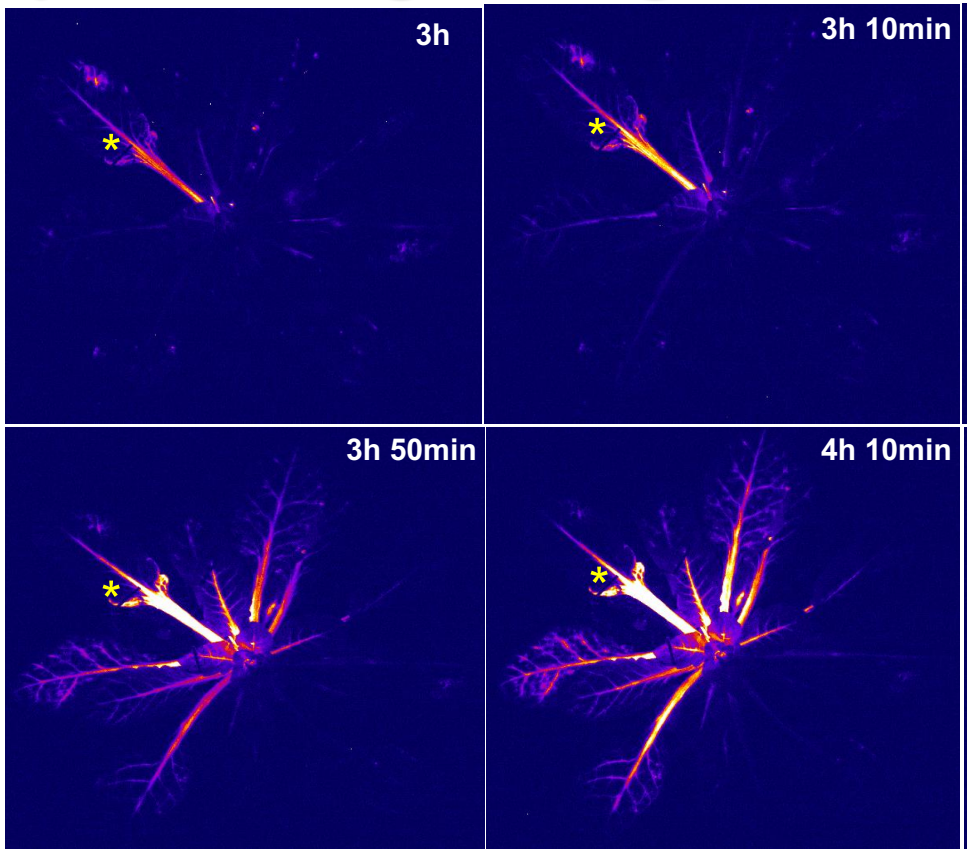


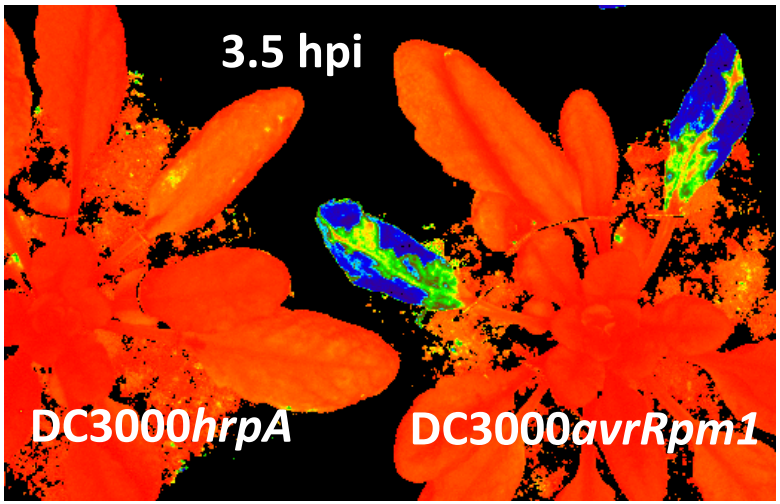


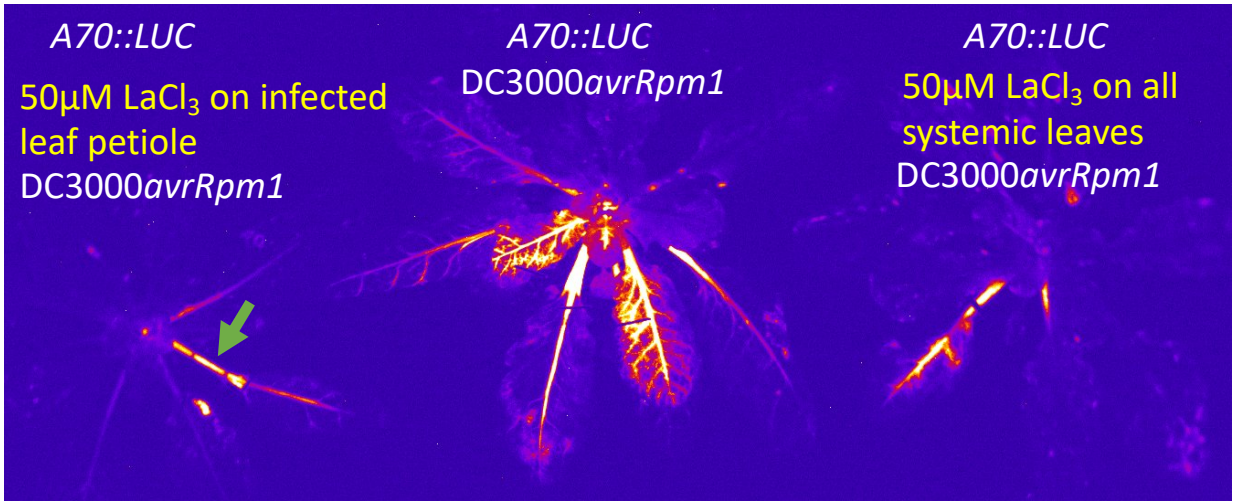
Run time is 720 mins = 12.5 hrs post infiltration

Imaging ETI mediated systemic signalling

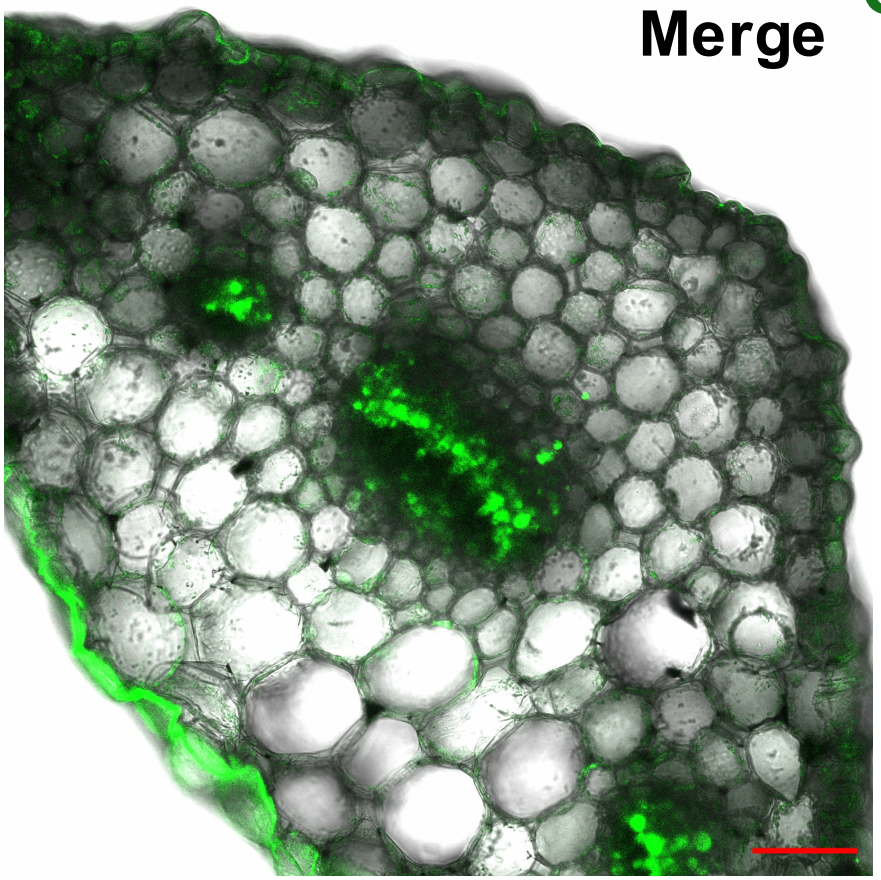


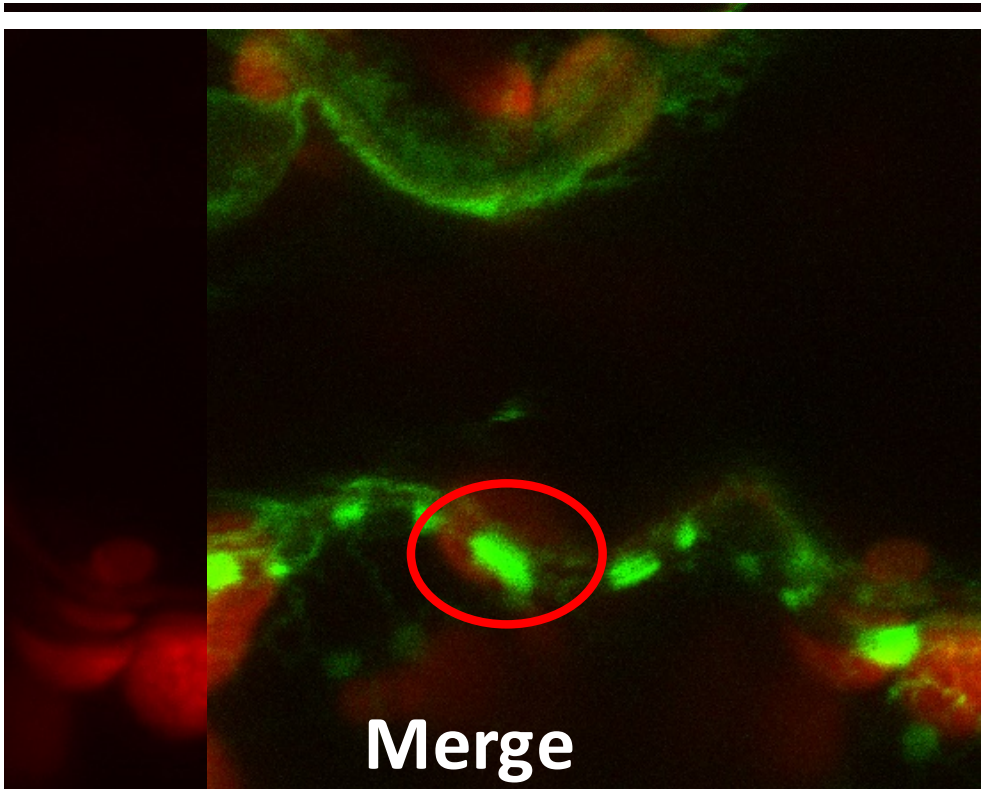






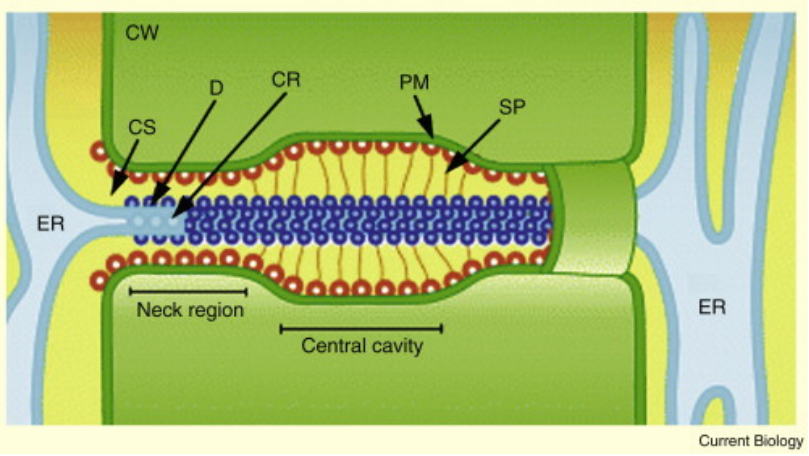
GFP-localisation



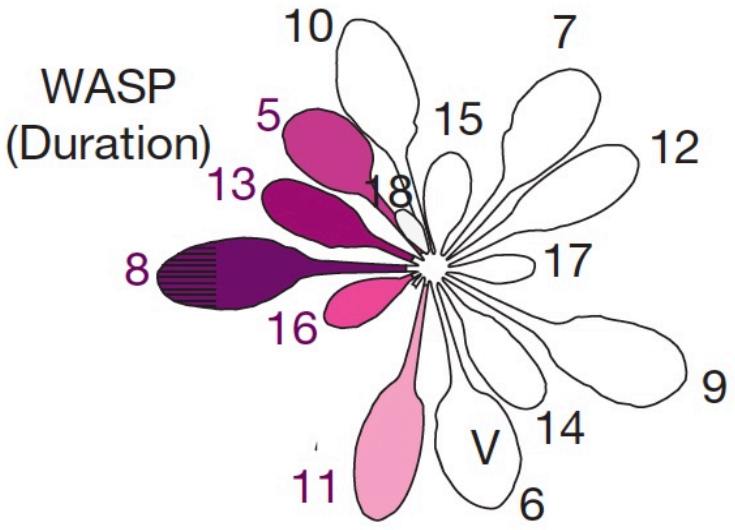


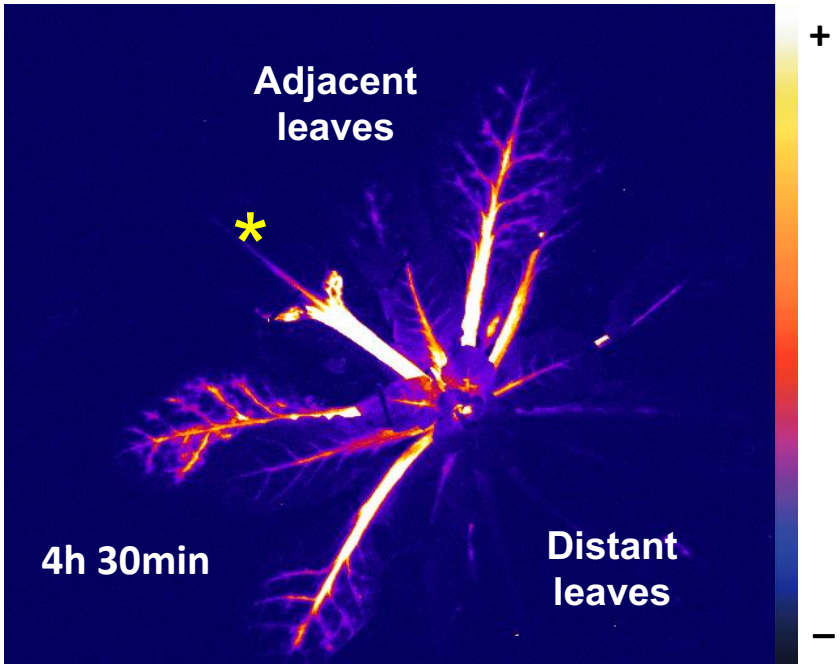
Plasmodesmata – suggests electrochemical signal travels symplastically through the plant cells

Maybe symplastic movement carries information?



Wound activated surface potentials





Wound response is JA based

ARTICLE

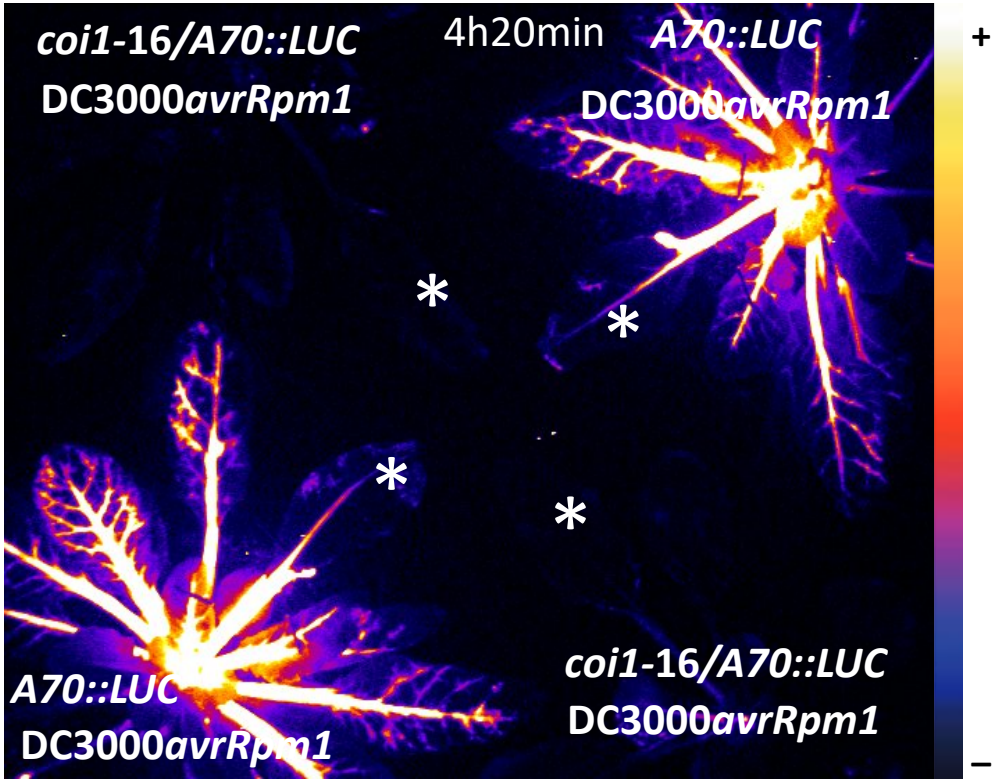
doi:10.1038/nature12478

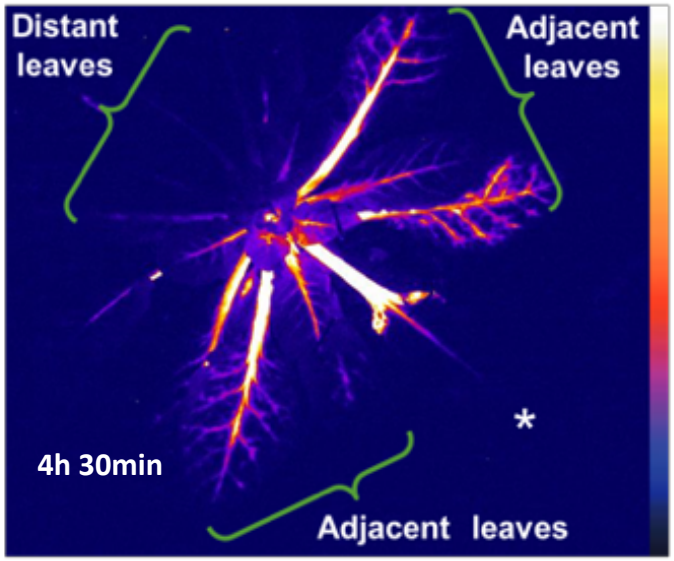
GLUTAMATE RECEPTOR–LIKE genes mediate leaf-to-leaf wound signalling

Seyed A. R. Mousavi[1], Adeline Chauvin[2], François Pascaud[3], Stephan Kellenberger[3] & Edward E. Farmer[1]

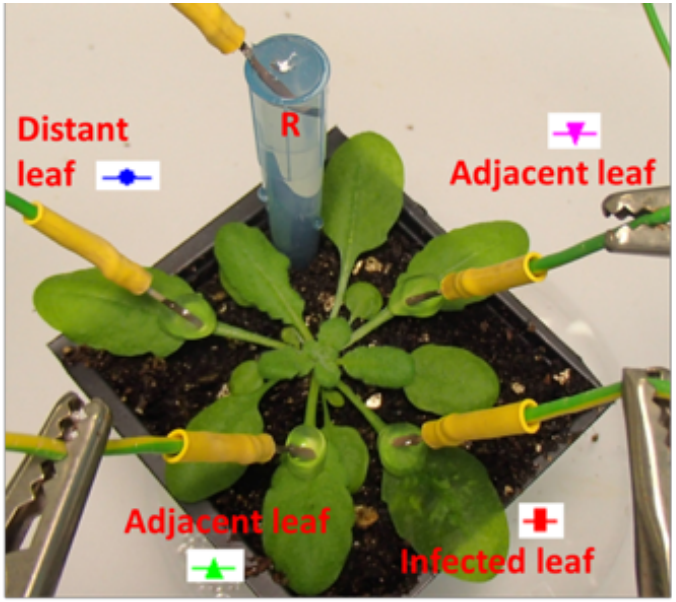
Wounded leaves communicate their damage status to one another through a poorly understood process of long-distance signalling. This stimulates the distal production of jasmonates, potent regulators of defence responses. Using non-invasive electrodes we mapped surface potential changes in *Arabidopsis thaliana* after wounding leaf eight and found that membrane depolarizations correlated with jasmonate signalling domains in undamaged leaves. Furthermore, current injection elicited jasmonoyl-isoleucine accumulation, resulting in a transcriptome enriched in RNAs encoding key jasmonate signalling regulators. From among 34 screened membrane protein mutant lines, mutations in several clade 3 *GLUTAMATE RECEPTOR–LIKE* genes (*GLRs 3.2*, *3.3* and *3.6*) attenuated wound-induced surface potential changes. Jasmonate-response gene expression in leaves distal to wounds was reduced in a *glr3.3 glr3.6* double mutant. This work provides a genetic basis for investigating mechanisms of long-distance wound signalling in plants and indicates that plant genes related to those important for synaptic activity in animals function in organ-to-organ wound signalling.

The jasmonate receptor mutant abolishes systemic signaling

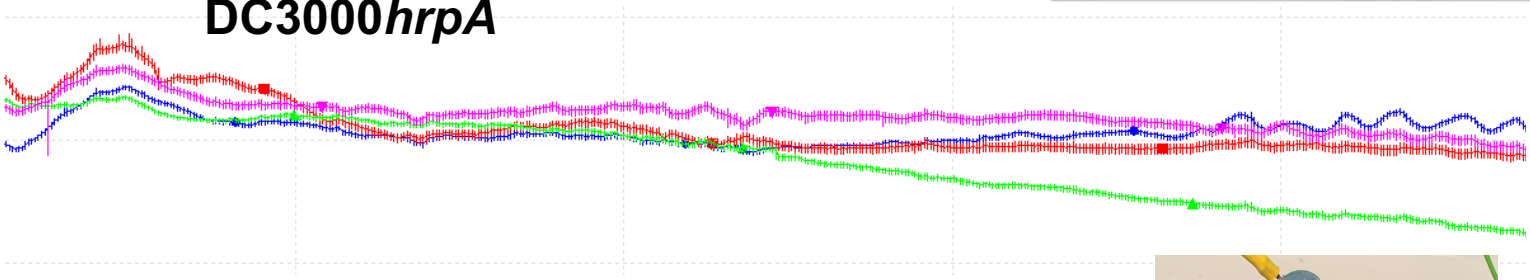




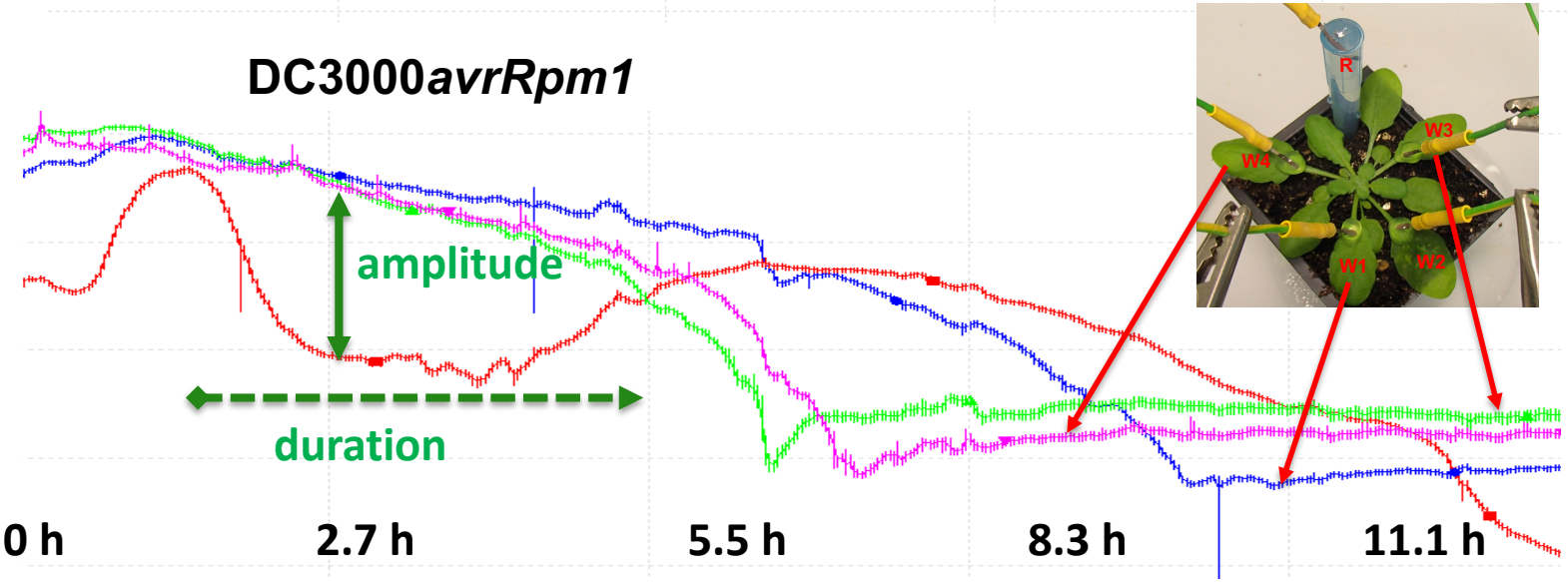
DASP?
Defense activated Surface potential



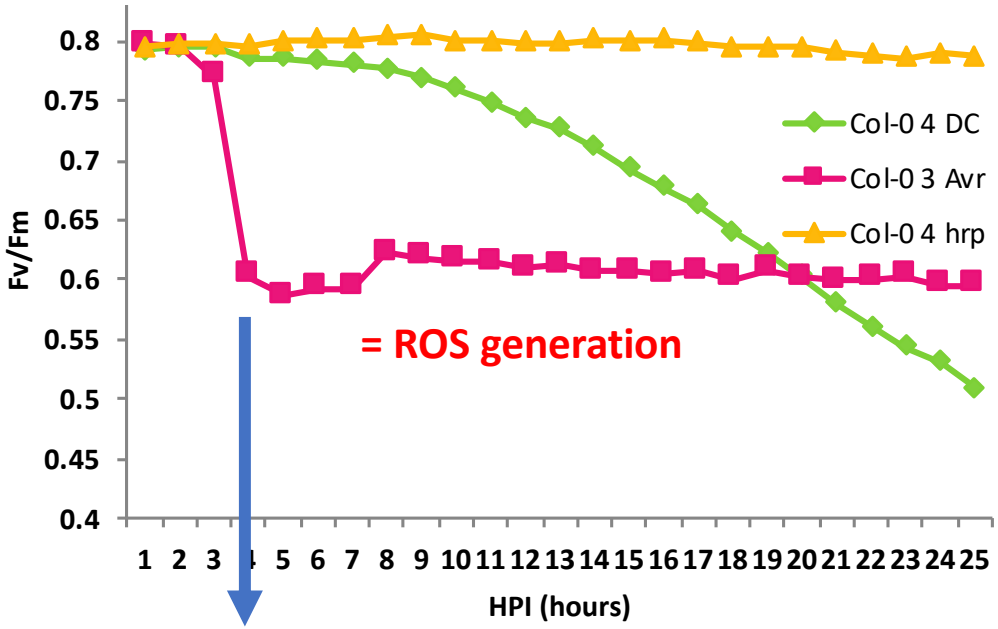
DC3000*hrpA*



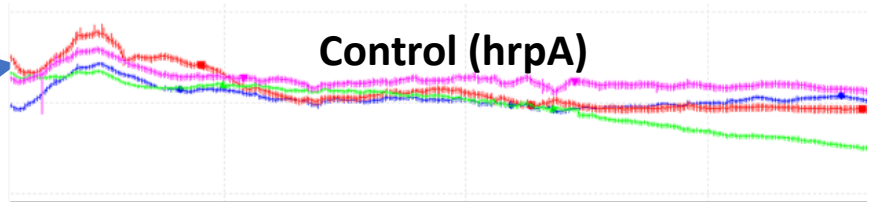
DC3000*avrRpm1*

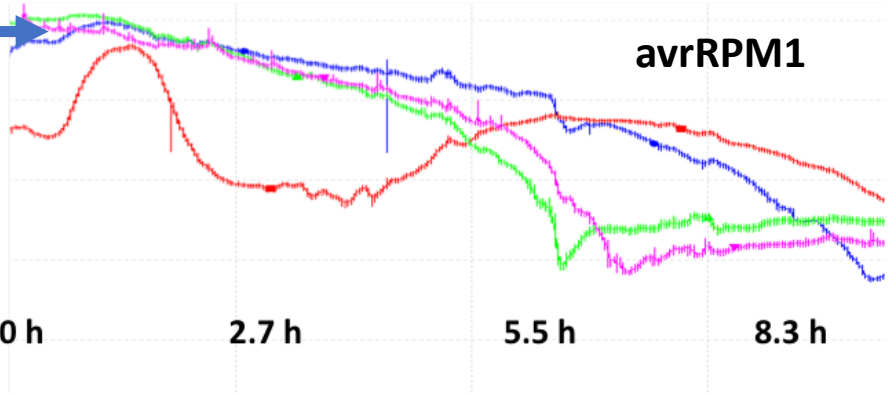


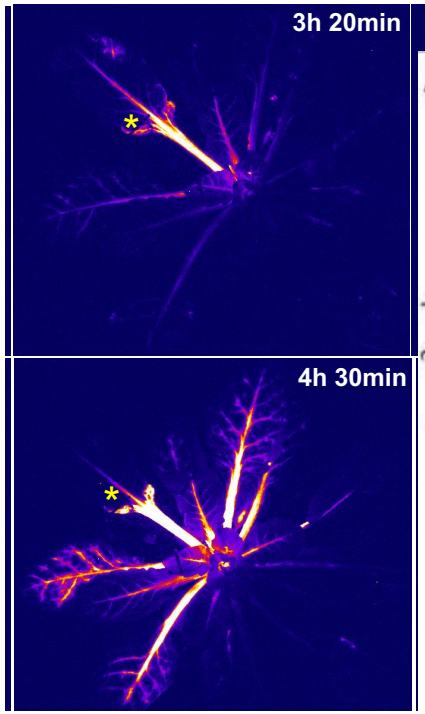
Chlorophyll fluorescence



Surface electric potentials







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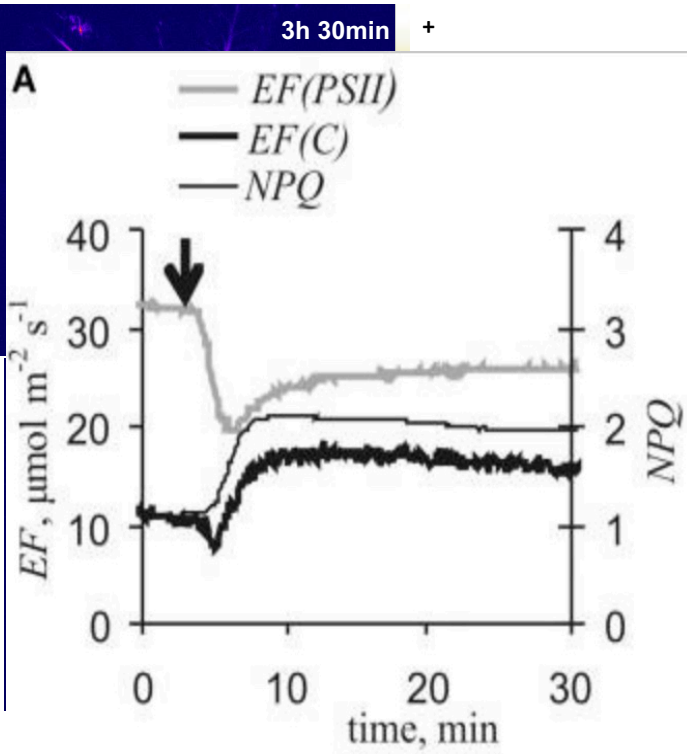

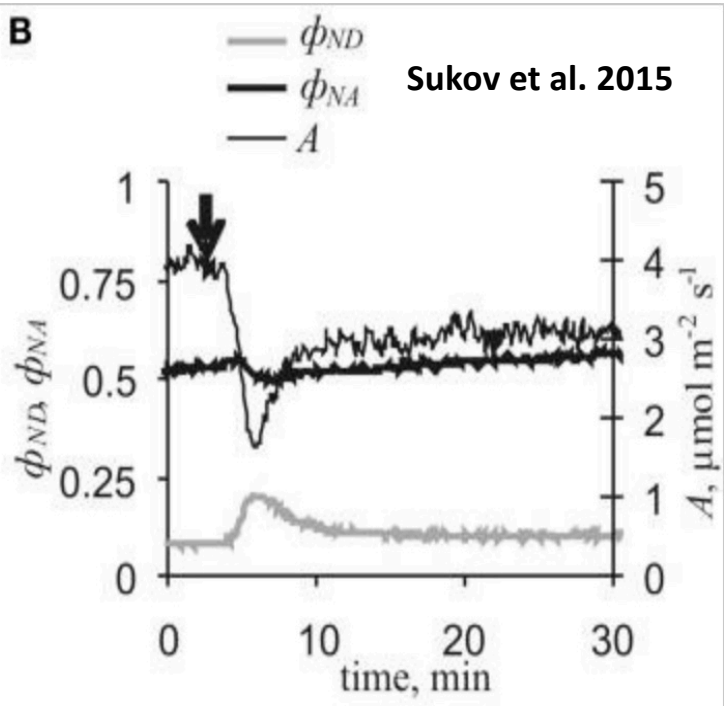

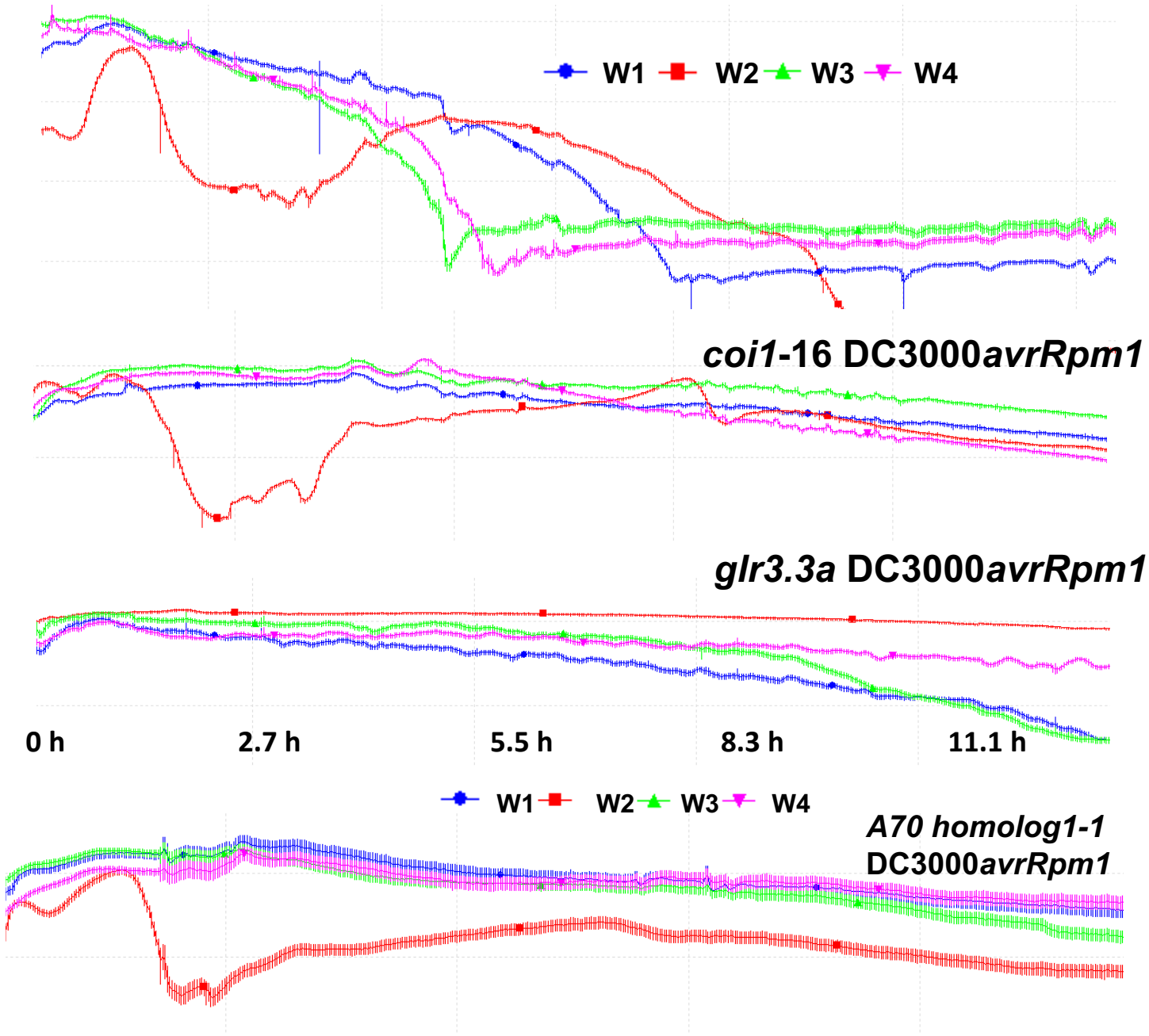

Glutamate receptors AND a jasmonate signal are required

ARTICLE 2013

doi:10.1038/nature12478

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WASP: wound activated surface potential changes

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injection elicit
jasmonate sign
GLUTAMATE
Jasmonate-res
work provides
that plant gene

RESEARCH

RESEA

BOTAN

Clu

RESEARCH ARTICLE

This week!

PLANT SCIENCE

PNAS

Damage on plants activates Ca^{2+}-dependent metacaspases for release of immunomodulatory peptides

2018

Tim Hander[1]*, Álvaro D. Fernández-Fernández[2,3]*, Robert P. Kumpf[2,3],

The identity of the cell files necessary for the leaf-to-leaf transmission of wound signals plants has been debated for decades. In

events leading to long-distance propagation of electrical signals. On other hand, evidence going back to the 1920s supports roles of

We hypothesise that:

Plant variation potentials reflect the sum of *complex physiochemical signal communication* in plants

Nearly all stress responses use VPs to communicate information that is decoded in distal tissues - contributions of ROS, Ca^{2+}, small molecules vary to specify the signal – this has been largely ignored to date

Can we:

Accurately measure these signals and their specific cellular origins?

Understand the signatures associated with specific stresses (amplitude & duration) and artificially generate these?

ARTICLE 2013

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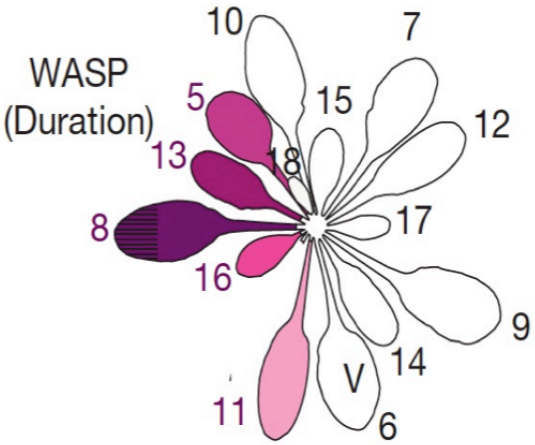
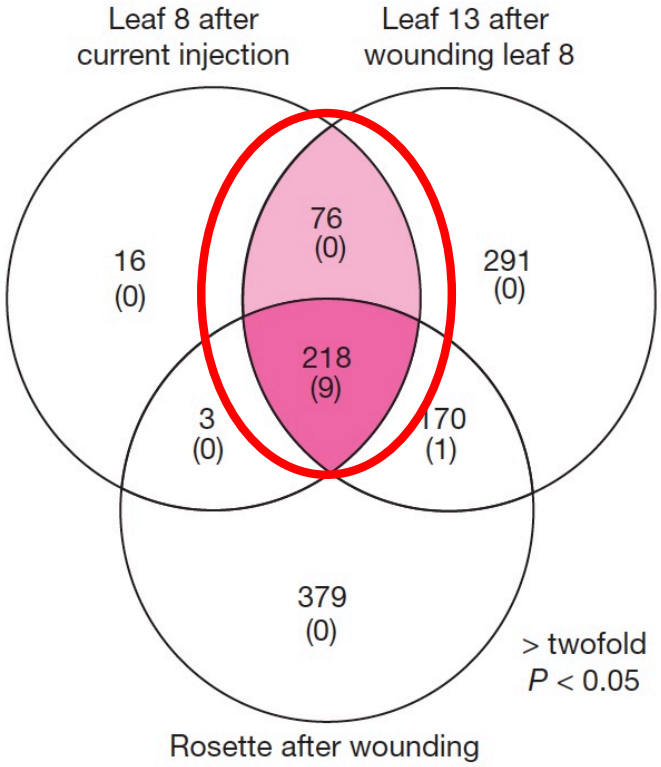


Current injection stimulates JAZ induction



Glutmate receptor dependent electrical signalling

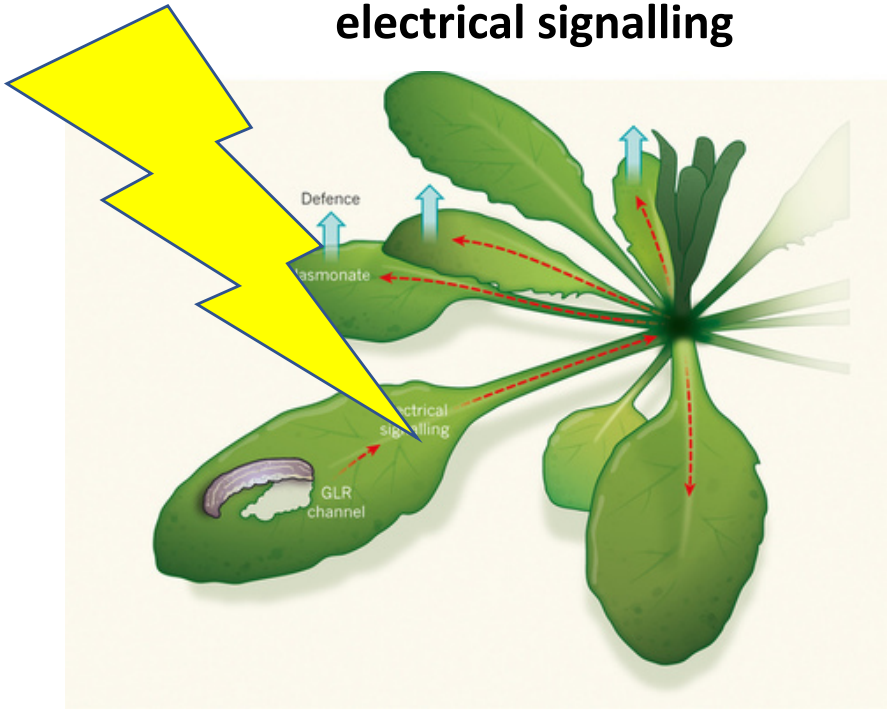
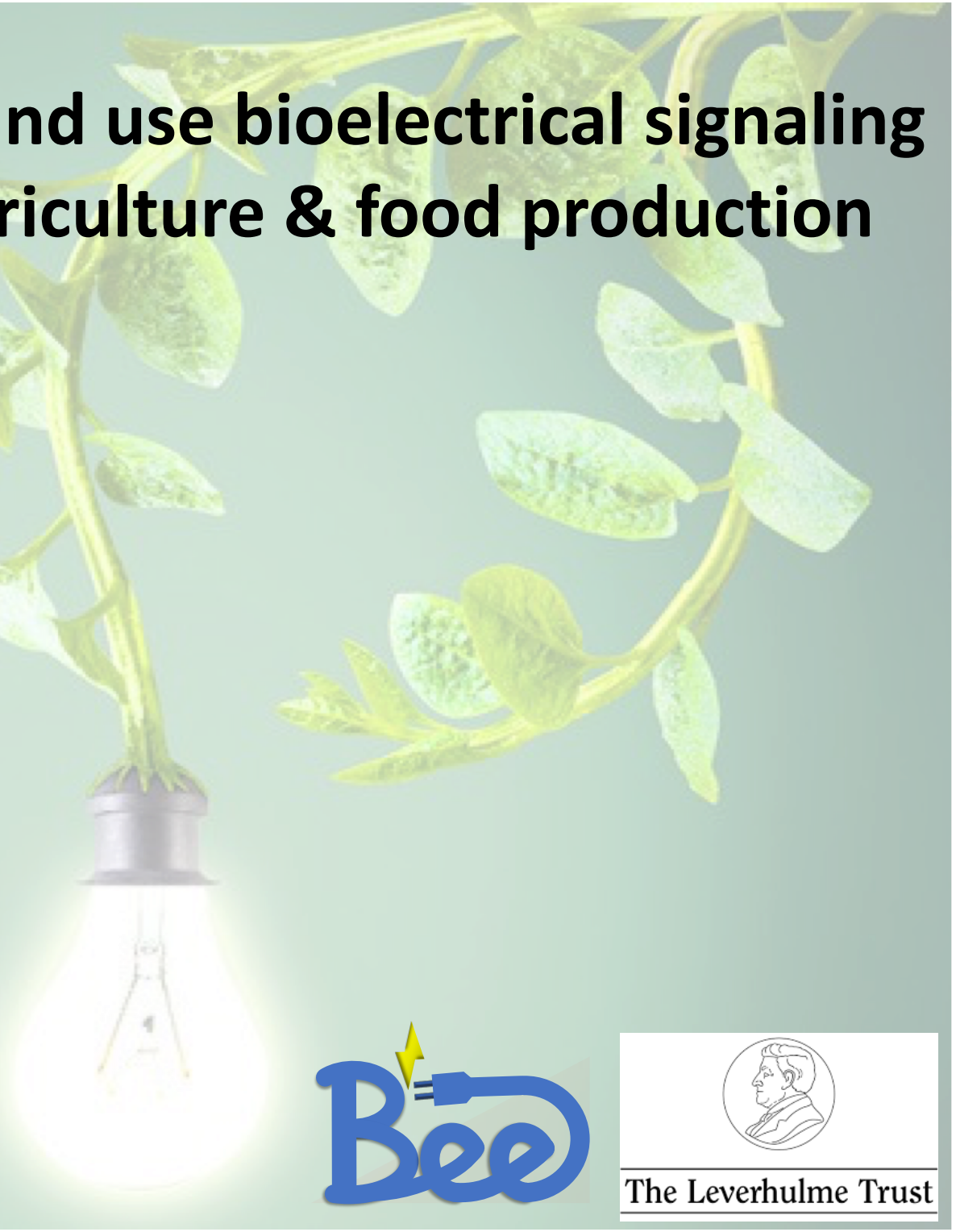


Figure 3 | Current injection and wounding stimulate the expression of a common *JAZ* gene-enriched subset of genes. Venn diagram for the number

Can we understand and use bioelectrical signaling in plants to make agriculture & food production more sustainable?



BBSRC bioscience for the future

Bee

The Leverhulme Trust

The future - a solar powered zapper robot?

Cheap!

Potential (☺) for broad spectrum tunable protection (insects, pathogens)

No fungicide/pesticide residue

Environmentally friendly

Acknowledgments

The Leverhulme Trust

PRESTA — Plant Responses to Environmental STress in Arabidopsis

WARWICK

WARWICK
THE UNIVERSITY OF WARWICK

Trupti Gaikwad
Susan Breen

UNIVERSITY OF EXETER

Marta de Torres Zabala
Nick Smirnoff
Peter Winlove
Stephen Green
David Horsell

University of Essex

Tracy Lawson

University of Plymouth

George Littlejohn

MPI Golm

Michi Tillich

Bee

BBSRC
20 Years of Pioneering
Great British Bioscience