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Shaping a Path Forward: Innovative environmentally friendly methods to manage diseases of field crops

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Plant disease can cause devastating disasters

Irish Potato Famine (1845-1852)

Tom Sullivan of County Kerry comtemplates the extent of the blight.

Pictorial Times - 1846

Pereira et al.

http://www.historyplace.com/worldhistory/famine/begins.htm

Plant disease and global food security

Pictures cited from http://ecology110armine2011sp.wordpress.com/2011/05/09/population-growth-and-its-impacts/

Importance of Wheat to Canada

- **Total Farm Cash Receipts (2015,$ thousands):**
  $59,430,885
- **Farm Crops Cash Receipts:**
  $ 31,638,922

- **Wheat Cash Receipts:**
  $5,082,352
  9% of total / 16% of crops

- **Contribution from 2011 to 2015:**
  7-10% of total receipts (Ave: 8%)
  14-17% of crop receipts (Ave: 16%)

Source: Statistics Canada

Severe Fusarium infection on wheat

Malting Craft Houses & the Millennials

Fusarium in Barley – Affects all of us!!!

From field to Glass

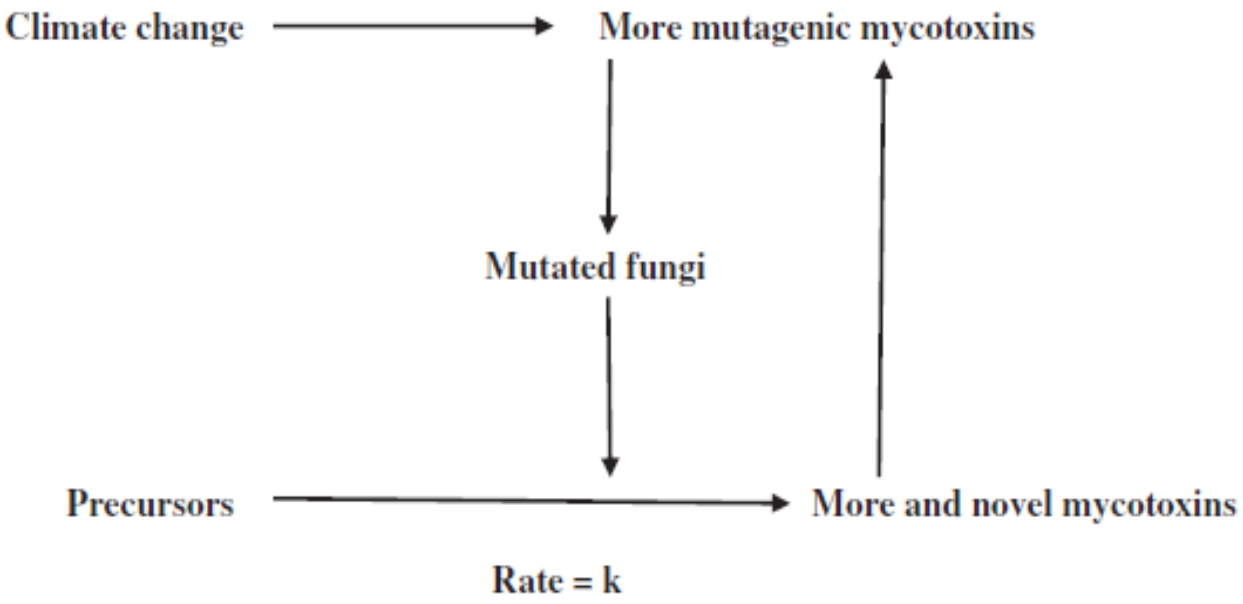
Even small changes in climate can have significant effects on ecosystems:

- Will affect food production, security and safety

- Influences primary plant production systems which may result in changes in mycotoxin contamination in plants

Fungal toxins and Climate Change

The climate change mycotoxin cycle



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R.R.M. Paterson, N. Lima / Food Research International 44 (2011) 2555–2566

Canola

- **A 27 billion dollar crop!! A Canadian discovery.**

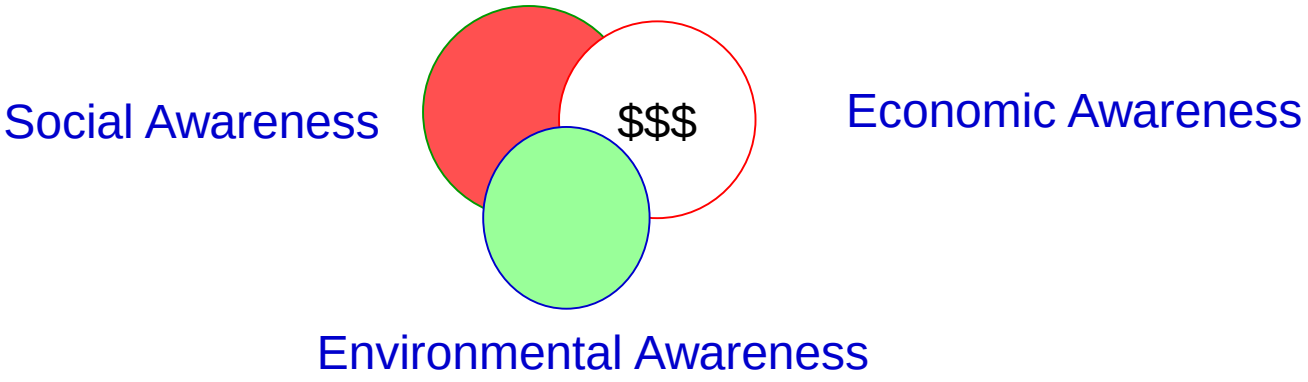
Blackleg - What is it?

- What is it?
  - Caused by the fungus *Leptosphaeria maculans*

Cropping systems in the new millennium

- Cropping practices are changing in the new millennium due to environmental concerns.

- How do we adopt these new techniques and practices, improve the quality of our environment that we *live in*, and at the same time benefit from farming?



How do we manage diseases?

- **Option 1**: fungicides and it is the most popular!

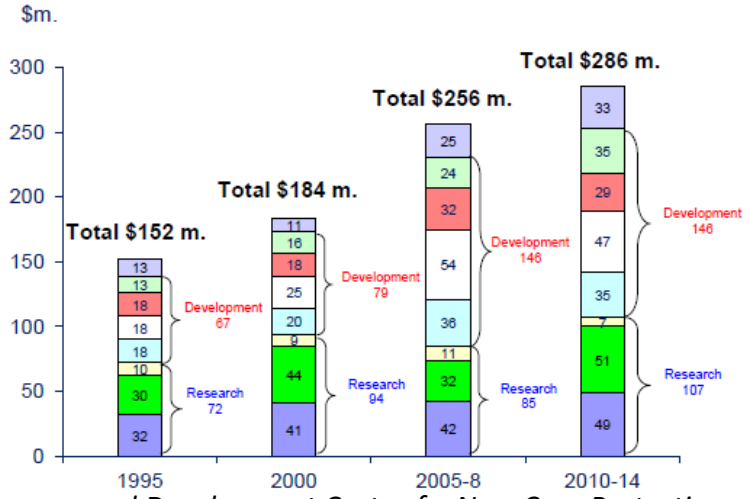
Global agrochemical market growth by product sector 2004

$ million	2004	2003	Growth 2004/2003 %
Herbicides	14660	13400	9.4
Insecticides	7690	6649	15.7
Fungicides	7330	5746	27.6
Others	1045	915	14.2
Total	**30725**	**26710**	**15.0**

The Future of Chemical Fungicides

- Sustainable agriculture for the future will likely require highly potent, single molecule fungicides.
- However, the development of new modes of action, required to overcome resistance to existing products and the removal of others from the market, remains a challenge to the industry for a number of reasons:

1. Increasing cost of bringing a product to market- currently >$280 million
2. Increasing regulatory safety margins
3. Increasing cost of production



Discovery and Development Costs of a New Crop Protection Product (Phillips McDougall , March 2016)

As a result, the preservation of existing chemical fungicides through integration with cultural practices and existing/novel alternative technologies is paramount.

Table 6. Children with parent-reported birth defects and paternal pesticide use.[a]

Exposure category	Total no. applicators with children		No. applicators with children who have birth defects		OR	95% CI
	n	%	*n*	%		
Herb/insect/fume	39	7.28	6	15.38	2.27	0.85–6.08
Herb/insect/fung	182	33.96	21	11.54	1.70	0.79–3.66
Herb/insect	73	13.62	9	12.33	1.82	0.74–4.46
Other[b]	58	10.82	5	8.62	1.27	0.43–3.73
All four	66	12.31	5	7.58	1.12	0.38–3.29
Herb only	118	22.01	8	6.78	Referent	

Abbreviations: fume, fumigants; fung, fungicide; herb, herbicide; insect, insecticide. [a]Pesticide applicator exposure groups were defined by pesticide class use. In these comparisons, applicators who used herbicides but not other products were assigned to the referent group. The number of applicators who have children with and without birth defects are reported in the table according to exposure group. Approximately 15% of applicators who apply herbicides, insecticides, and fumigants have children with birth anomalies. More detailed analysis (see text) of specific fumigant use shows that applications of the fumigant phosphine were associated with a significant increase in adverse birth, developmental, and neurobehavioral sequelae (OR = 2.5; CI 1.22–5.05). [b]Any pesticide combination not listed.

Specific Problems with Fungicides

- Pathogens become resistant over time developing "Super races"
- Environmentally hazardous
- Could destroy non-target organisms (beneficials)

Option 2: Environmentally-friendly control

- Breeding for disease resistance
- Rotation with non-host crops
- Biological Control using beneficial organisms
- Improving the microbiome – with beneficials
- Novel techniques – path to moving forward

(1) Plant Resistance

- **Use of plant resistance is one of the most attractive approaches to suppressing plant disease.**
  - **1. Requires no action by the farmer during the growing season.**
  - **2. Is not disruptive to the environment.**
  - **3. Is generally compatible with other disease management techniques.**
  - **4. Most often (*not always*) singularly sufficient to suppress disease to tolerable levels.**

Single R-gene containing Topas NIL Topas WT

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Field trial at Carman 2014

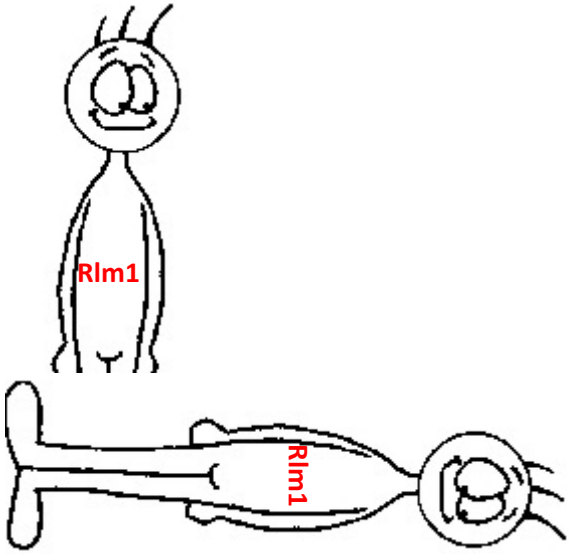
What are the Types of Resistance we have?

- **Resistance**
  - **Two types**:
    1. **Single gene – major resistance**
    2. **Many genes with minor resistance**
       - many genes each with small impact

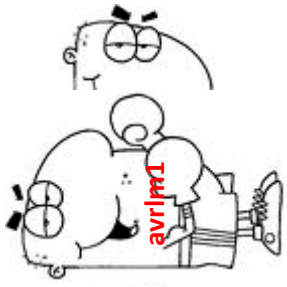
Pathogenicity Gene

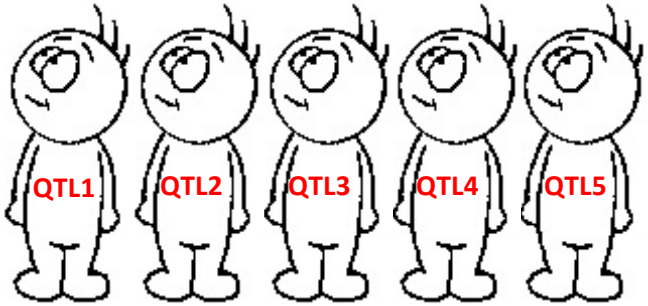
Host Gene

Qualitative Resistance



Quantitative Resistance

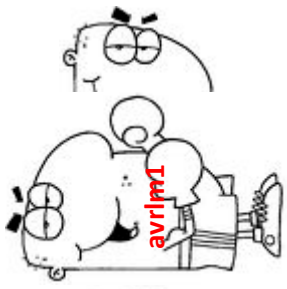


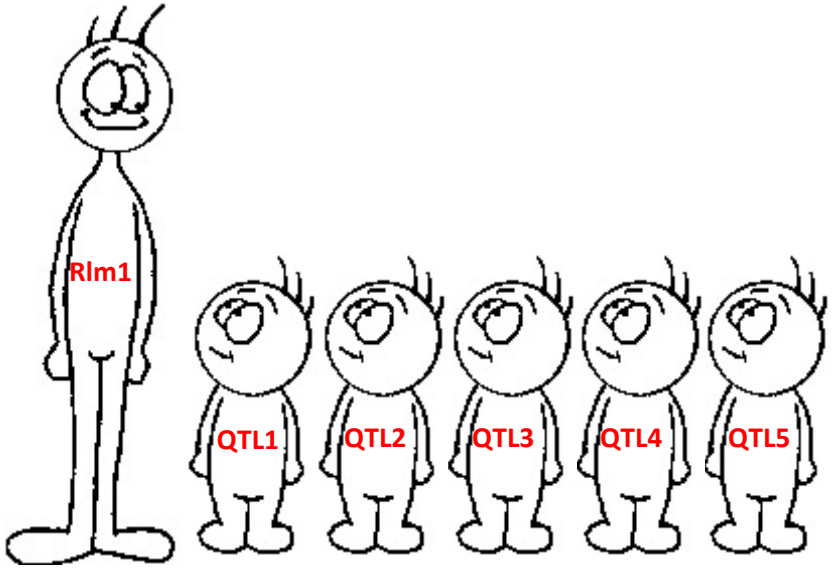


Pathogenicity Gene

Host Gene

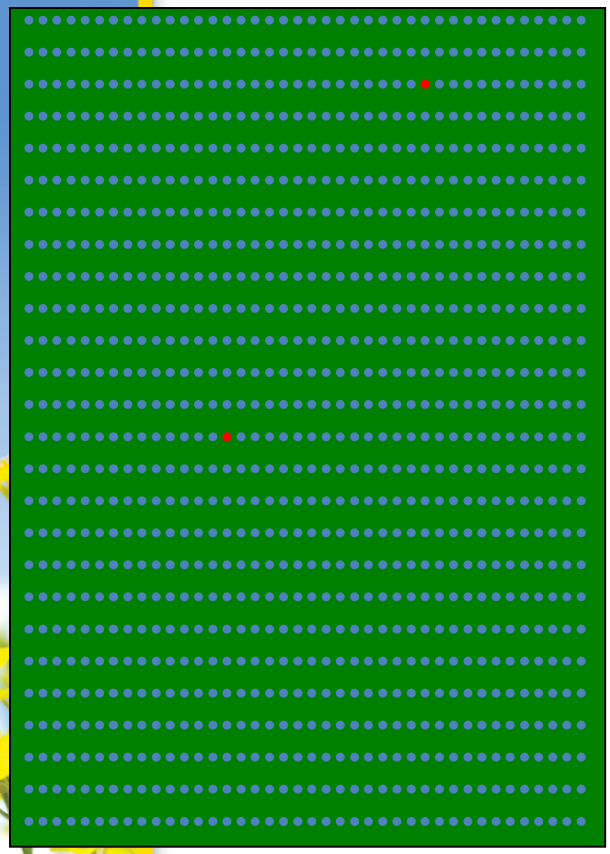
Quantitative Resistance



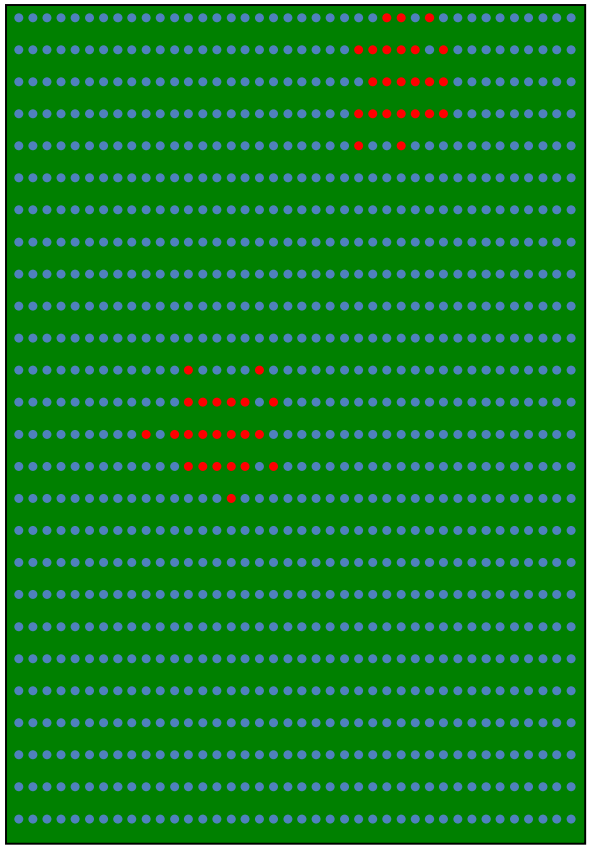


(2) Crop Rotation

Frequent canola production on a field may result in selection for virulent races of pathogens



Canola field – year 1



Same canola field same variety / gene – year 2?

Same canola field same variety /gene – year 3?

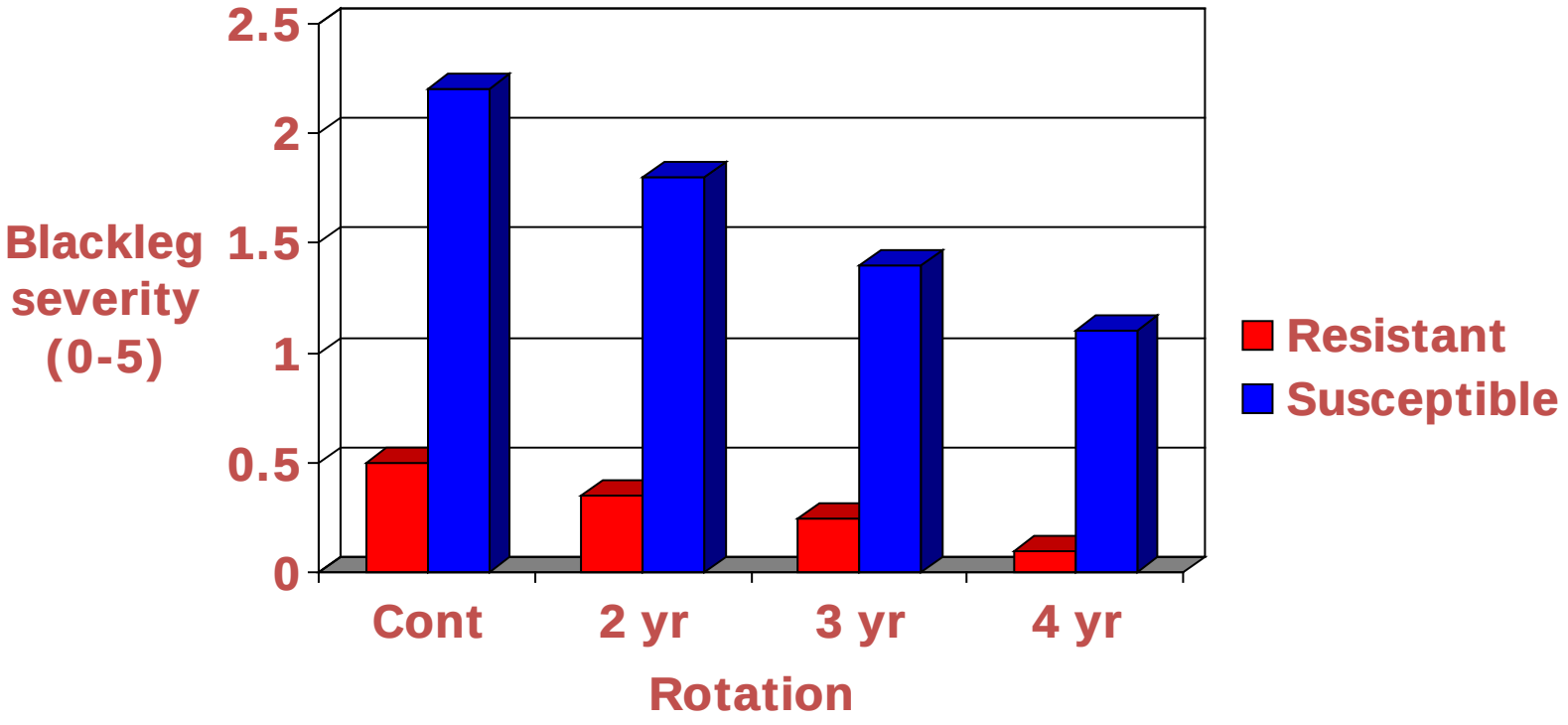
Slide from Dr. Randy Kutcher

Message of hope: Easy fix
(1) Rotation with non-hosts

- **Rotate canola with non-host crops for Blackleg.**
  - **Wheat**
  - **Soybean**
  - **Sunflower**
  - **Barley**
  - **Flax**
  - **Corn**
  - **Oats**

Do Rotations with non-hosts help?

- Crop Rotations
  - Getting tighter
  - Increase risk for disease development



Influence of rotation length on blackleg
[12 site-years at Scott and Melfort, SK 2000-05]

(3) Biological Control

Why biological control?

- To control diseases in an environmentally safe way
- An alternative to chemical applications

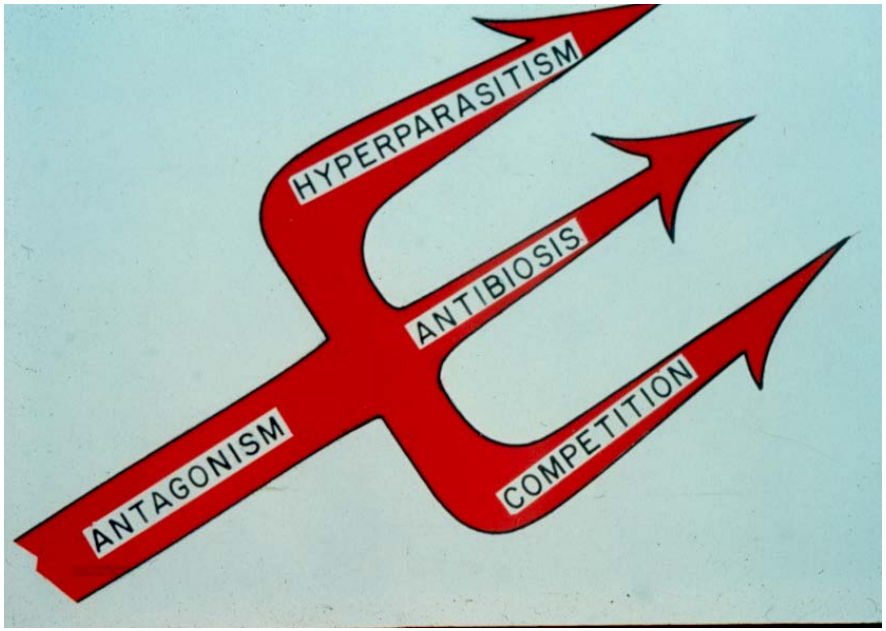
❖ Use naturally-occurring microorganisms

What is biological control?

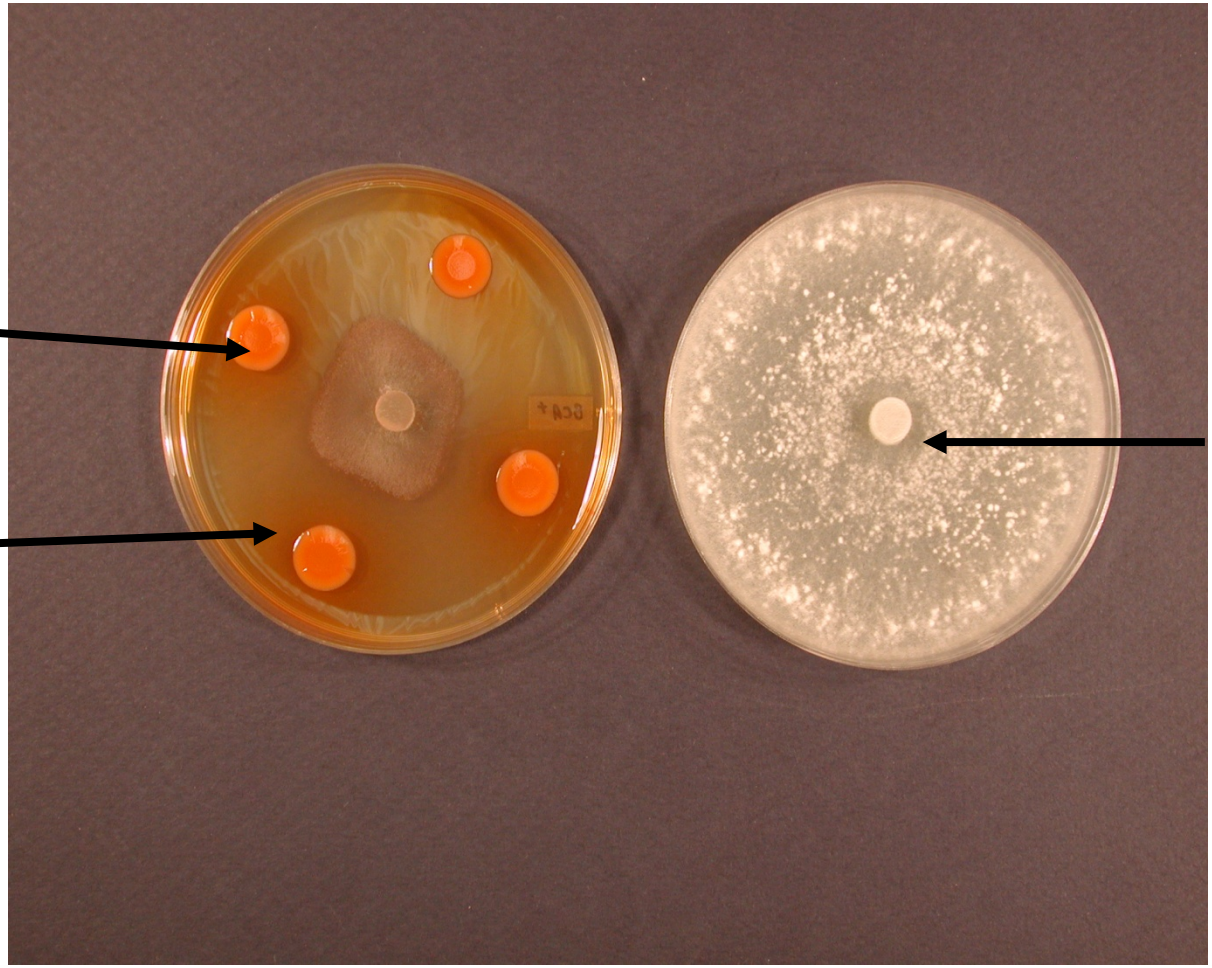
- Biological control is the inhibition of growth, infection or reproduction of one organism using another organism (Dilantha Fernando)

4 mechanisms

Direct parasitism
Competition
Direct antibiotic effects
Indirect antibiotic effects



Inhibition of *Sclerotinia* by *P. chlororaphis* PA-23

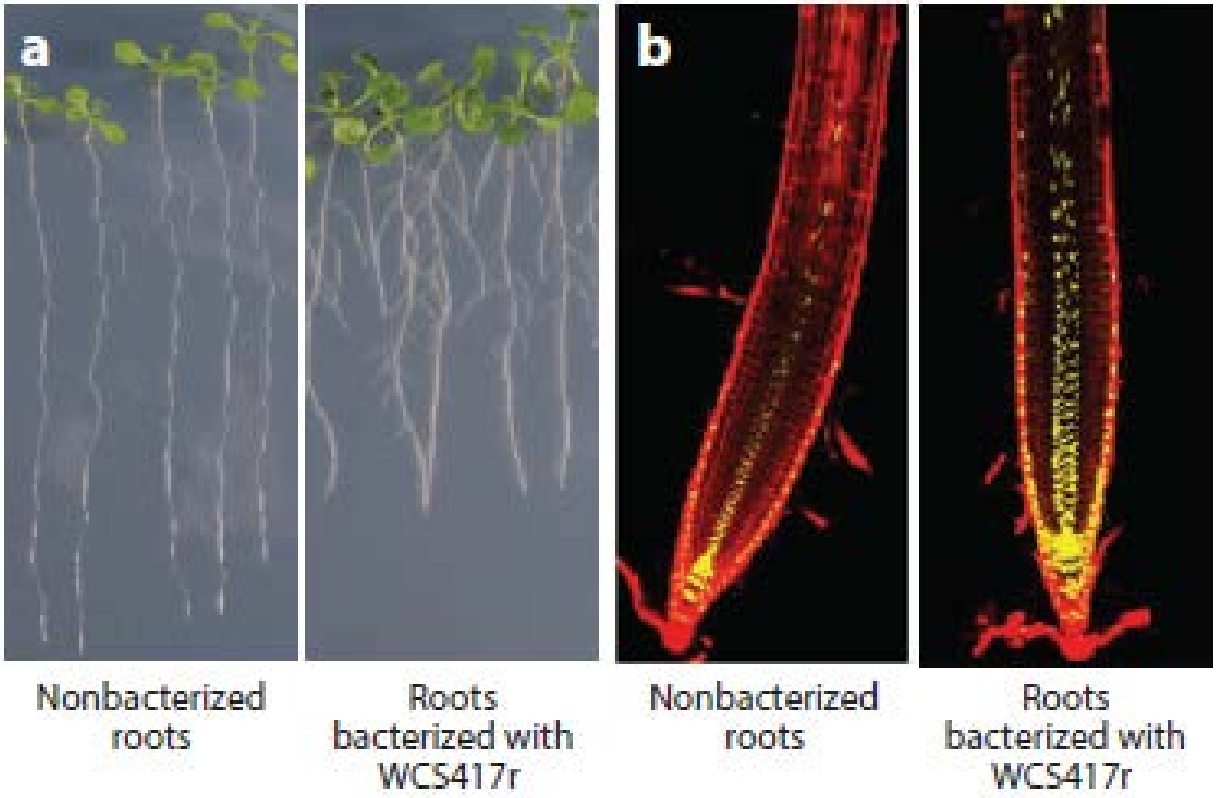


P. chlororaphis (PA23) vs. stem rot of canola

(4) Beneficials in the microbiome

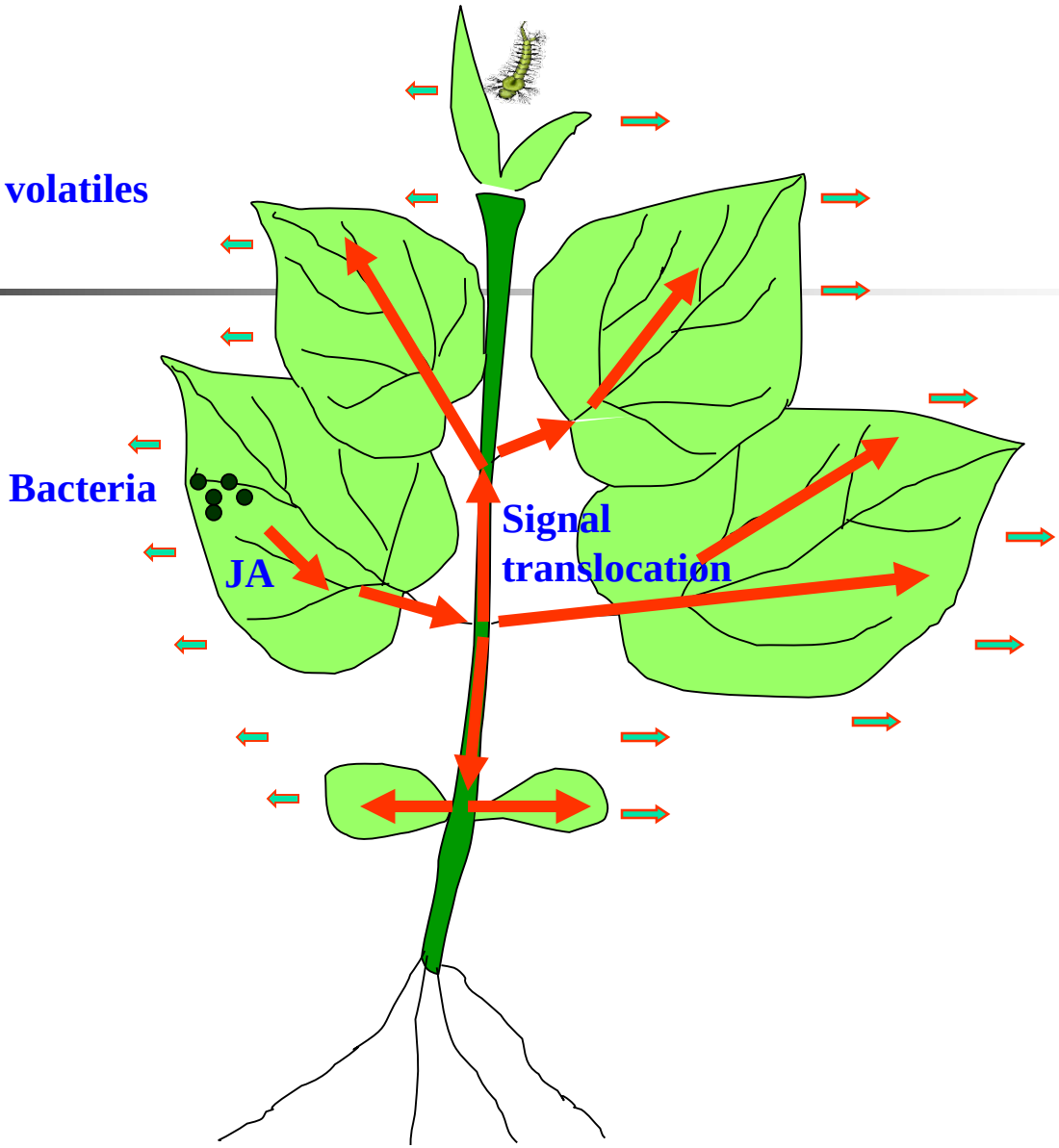
- Soils have millions of beneficial microorganisms (like the probiotics in your yoghurt).

Plant growth-promoting effects of *P. fluorescens* WCS417r



Pieterse et al. (2014) Annu. Rev. Phytopathol. 52:347-75

Green volatiles

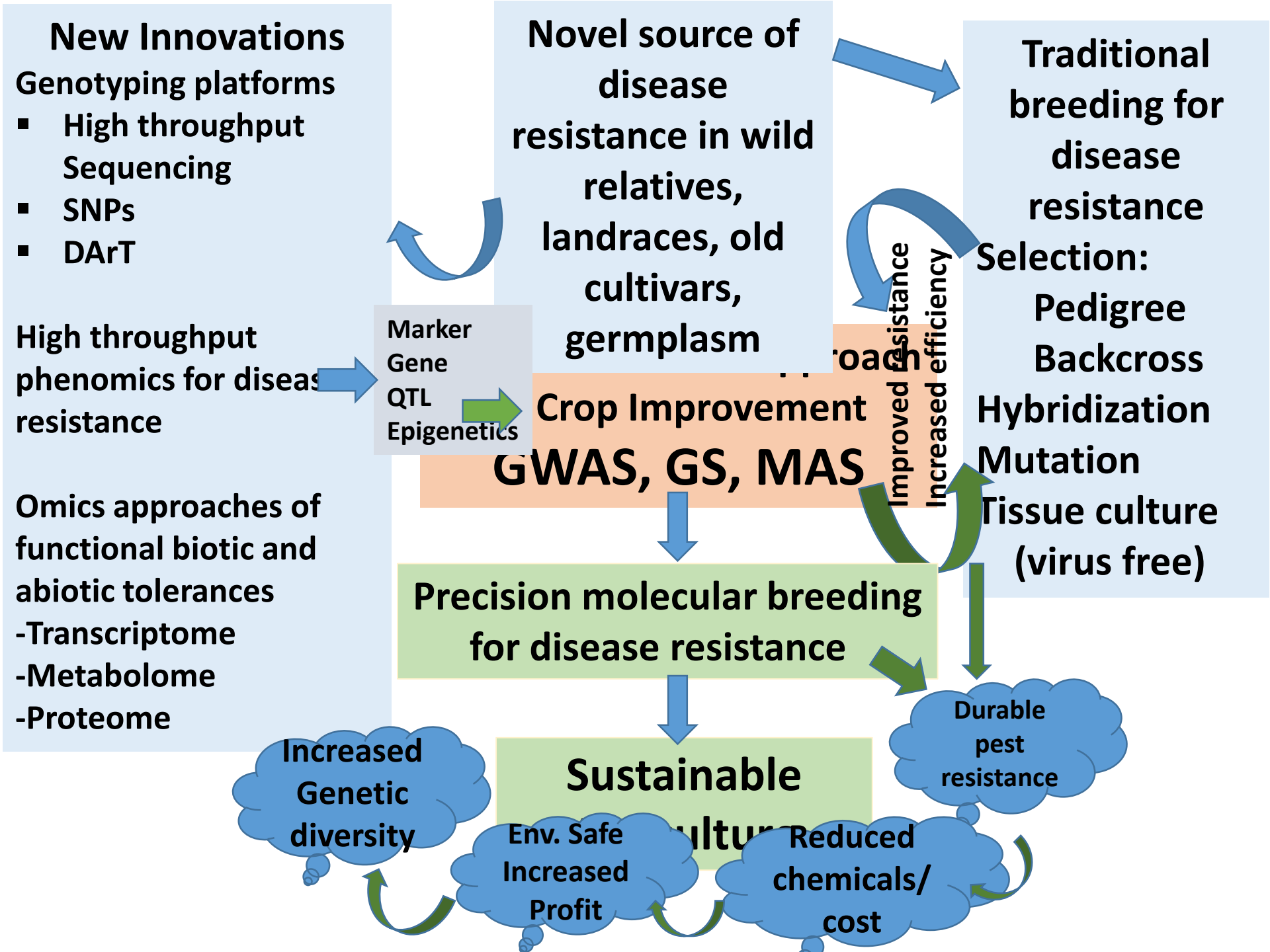


Plant Growth Promoting Activity of PA23


HiStick2
THE POWER OF "2"
HiStick N/T
One Step
SoilGard
SERENADE
KODIAK
Messenger

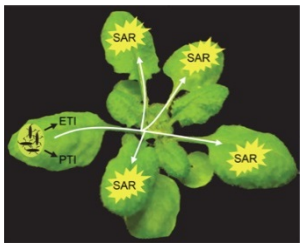
(5) Novel Techniques

- Genome wide association studies (GWAS)
- Genomic selection (GS)
- Marker assisted selection (MAS)
- Gene editing
- Salicylic acid priming (SA)


New Innovations
Genotyping platforms
High throughput Sequencing
SNPs
DArT
High throughput phenomics for disease resistance
Omics approaches of functional biotic and abiotic tolerances
-Transcriptome
-Metabolome
-Proteome
Novel source of disease resistance in wild relatives, landraces, old cultivars, germplasm
Marker
Gene
QTL
Epigenetics
Crop Improvement
GWAS, GS, MAS
Improved Resistance
Increased efficiency
Traditional breeding for disease resistance
Selection:
Pedigree
Backcross
Hybridization
Mutation
Tissue culture
(virus free)
Precision molecular breeding for disease resistance
Increased Genetic diversity
Sustainable
Durable pest resistance
Env. Safe
Increased Profit
Reduced chemicals/ cost

Roles of salicylic acid (SA)

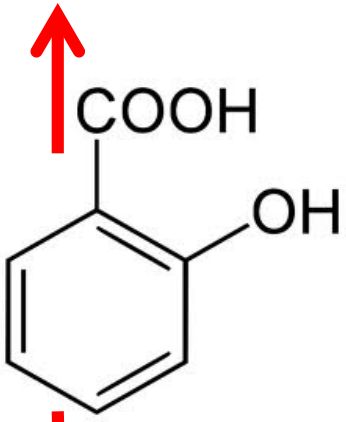
Drought



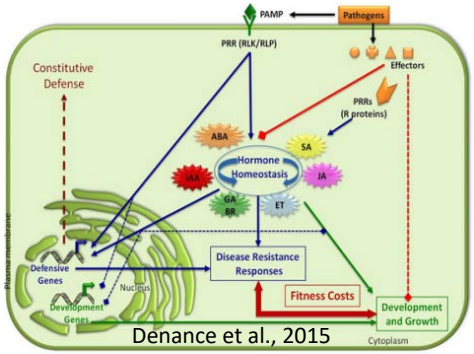
Disease resistance

Growth and Development

Salinity



Heat



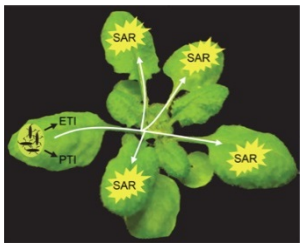
Denance et al., 2015

Phytohormone cross-talk

Seed production

Salicylic acid priming

Drought

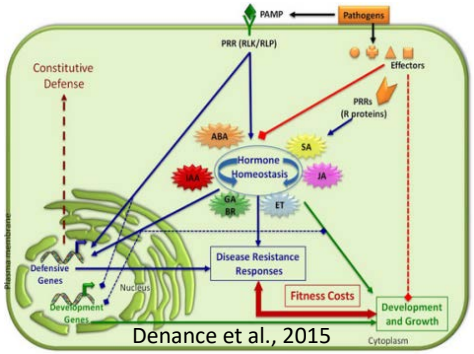


Disease resistance

Growth and Development

Salinity

Heat



Denance et al., 2015

Phytohormone cross-talk

Seed production

Gene Editing

- *Genome editing* is a way of making specific changes to the DNA of a cell or organism.

- *Gene editing* (or *genome editing*) is the insertion, deletion or replacement of DNA at a specific site in the *genome* of an organism or cell.


Photo courtesy
of H. Brun

ENSURE SUSTAINABLE

PRODUCTION

MARKET ACCESS

STRENGTHEN CANADIAN AGRICULTURE AND OUR FARMERS

BE PROUD

Thank you very much