Late blight control today and tomorrow

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STØTTET AF

Kartoffelafgiftsfonden

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Contents

- *The pathogen: Phytophthora infestans*
- Adaptation & populations
- Host resistance

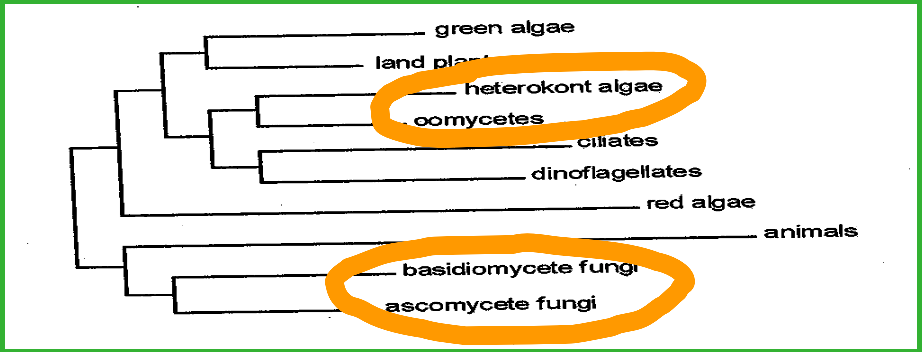
- Potato late blight control, now and in the future

- Pitfalls for future potato late blight control

Potato Late Blight

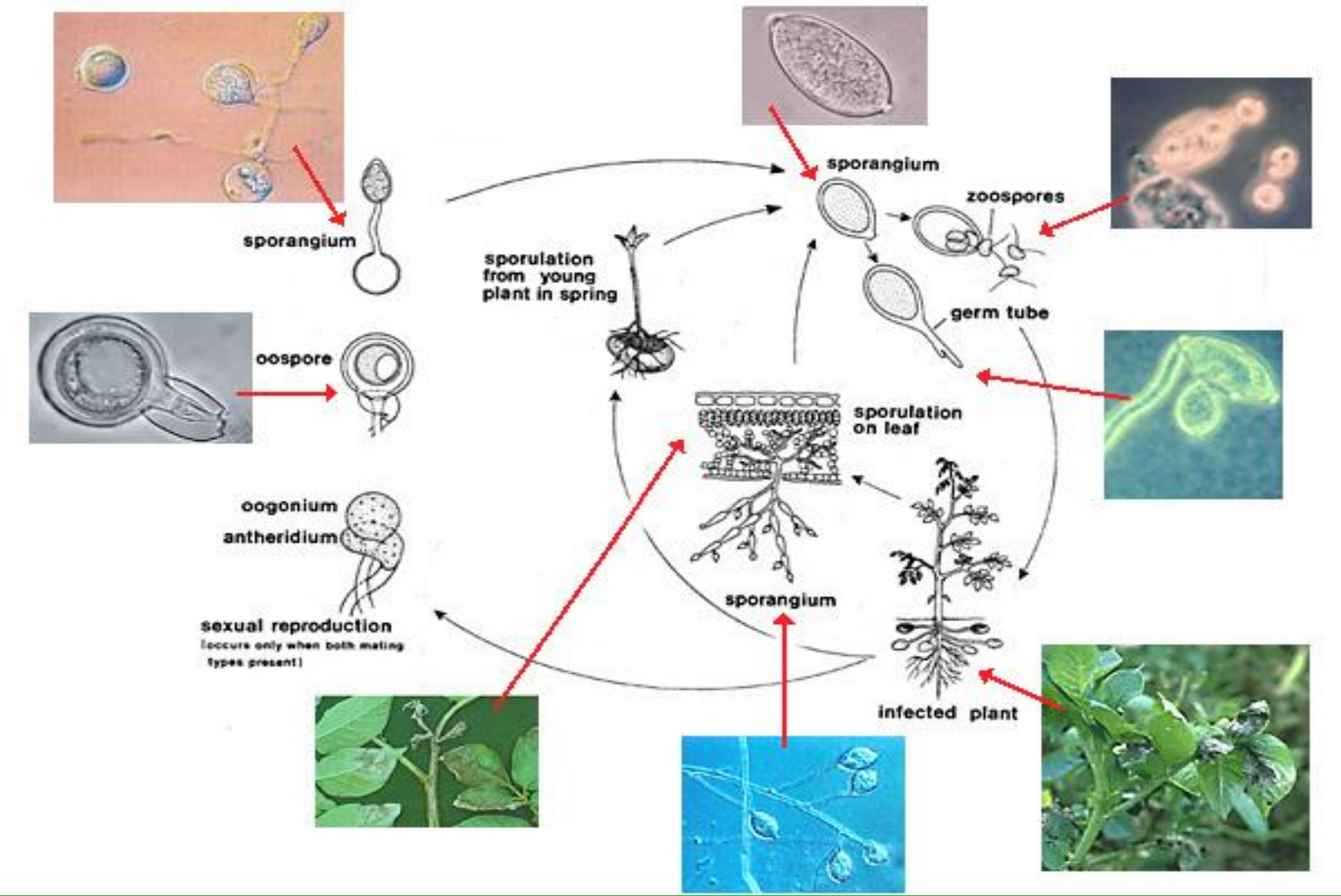
Phytophthora infestans

- *Phytophthora infestans* :
  - Looks and behaves like a fungus ..
    (hyphae, expanding circular colonies, spores, ..)
  - Oomycete
  - Biotrophic
  - Heterothallic (two mating types: A1 and A2)
  - Diploid / triploid



Phylogenetic tree (van de Peer and de Wachter, 1997)

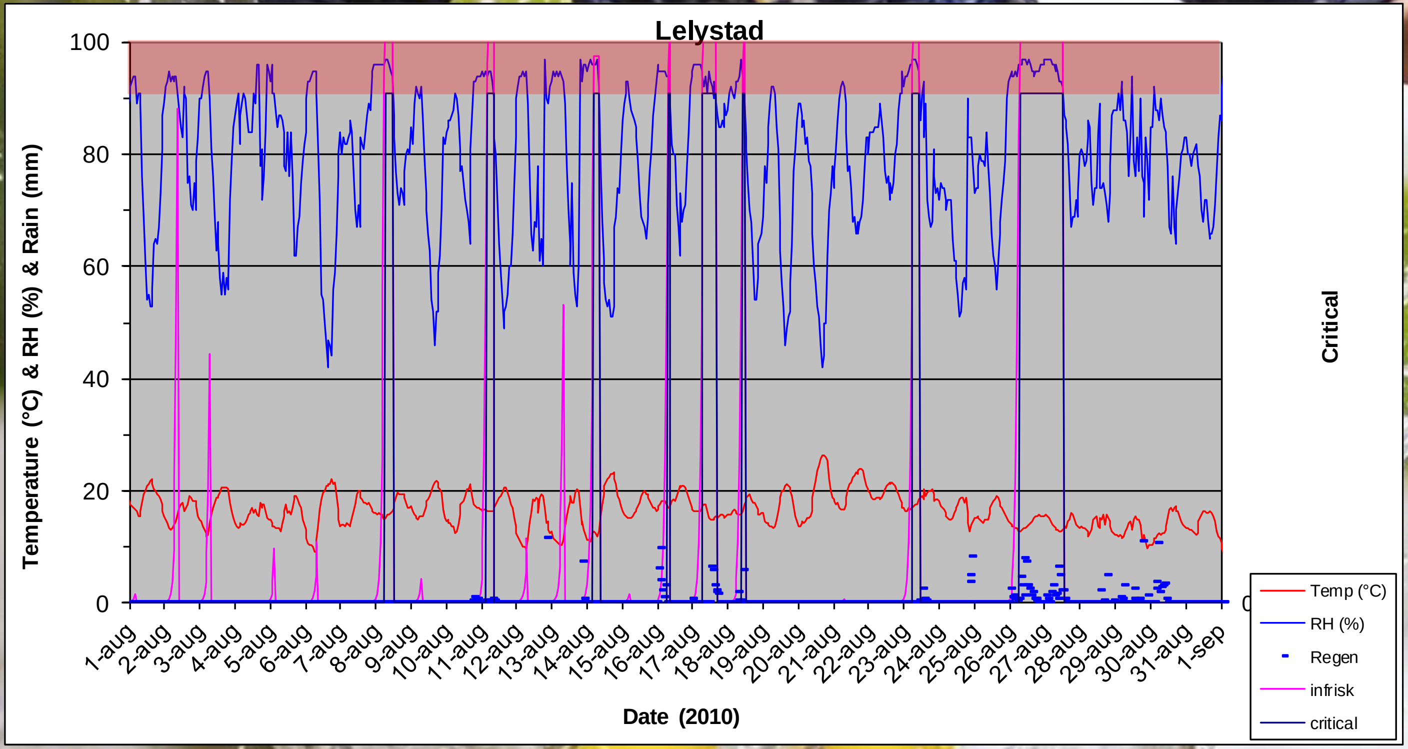
P. infestans disease cycle

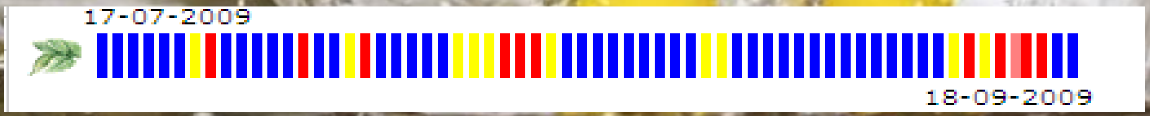


Annual costs associated to potato Late Blight

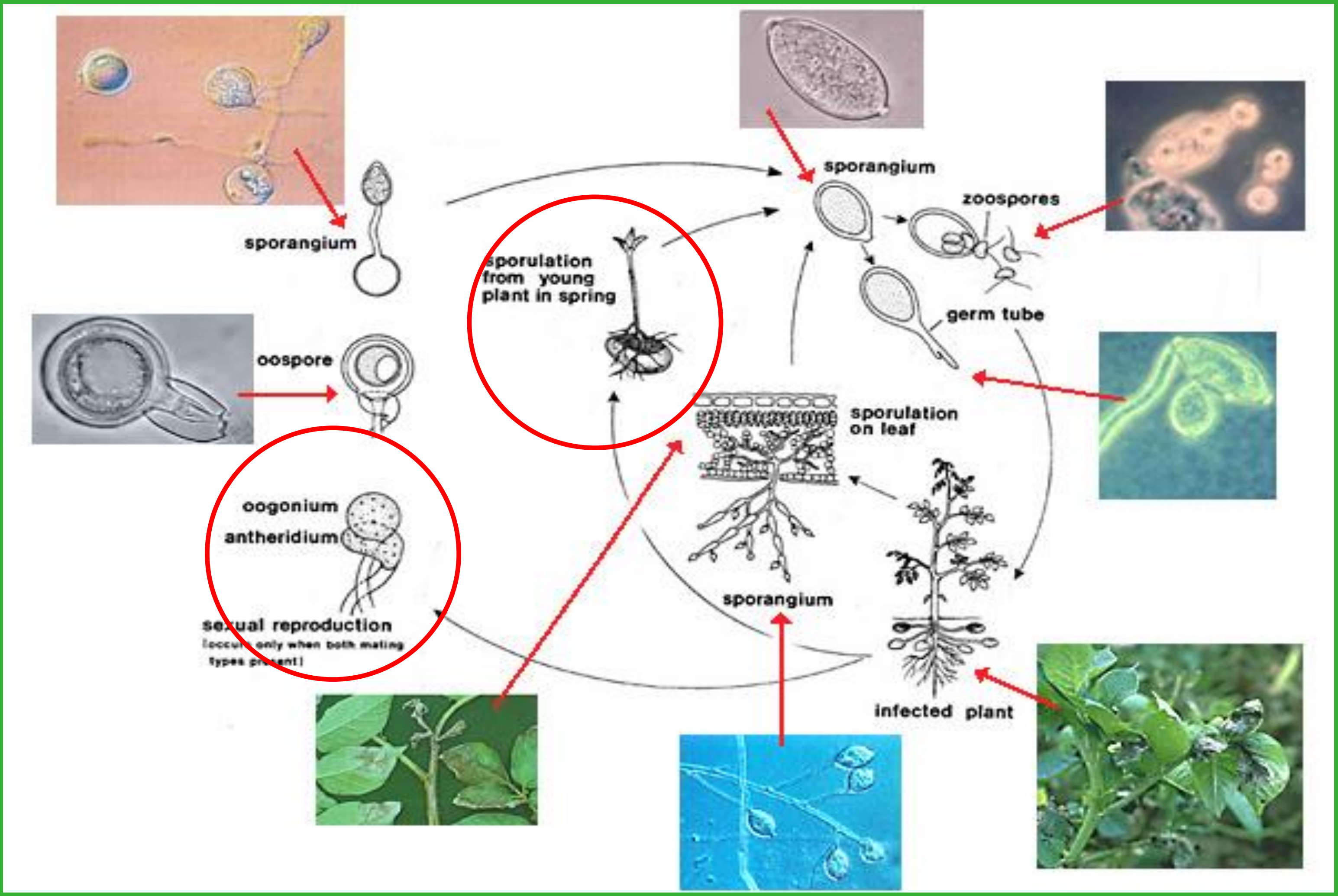
- Cost of Potato Late Blight control (Haverkort et al 2008):
  - The Netherlands (€150 million/year):
    - Fungicides €60 million (1421 ton a.i.)
    - Spraying etc: €60 million
    - Losses: €30 million
  - Globally: $3 billion annually (including losses)
- Cost on Tomato: similar

Late blight: a "rain disease"?

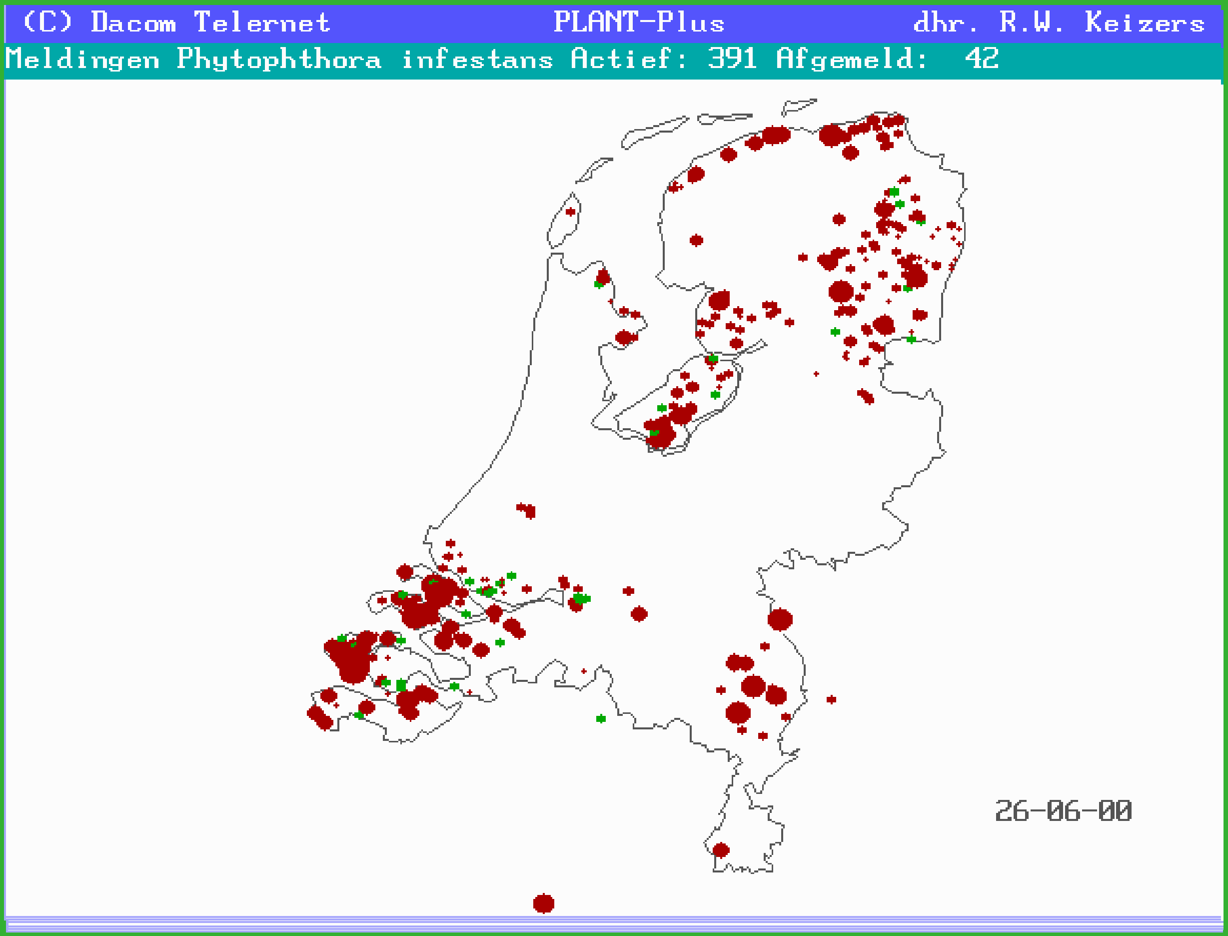




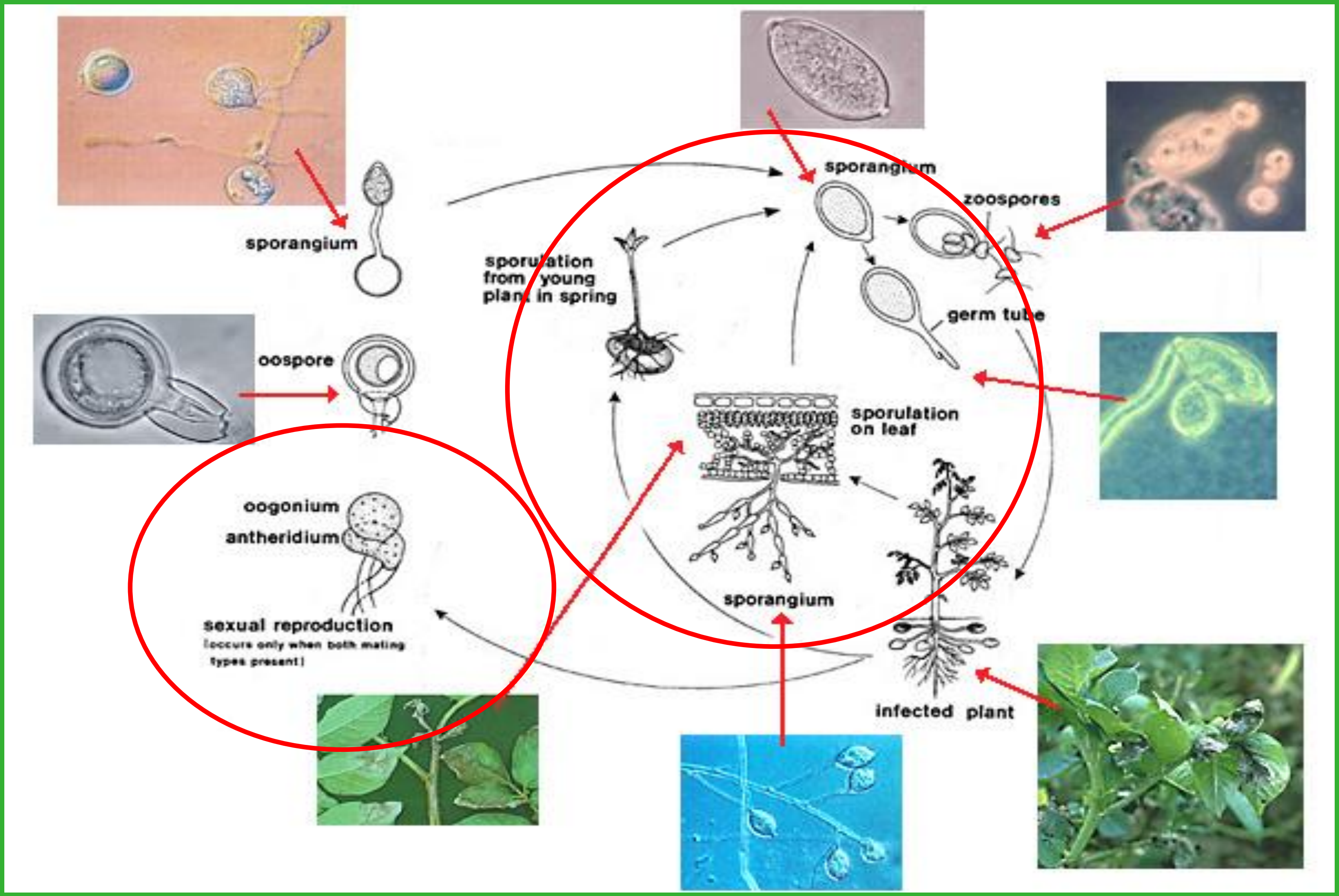
P. infestans: Primary sources



Late blight outbreak 2000

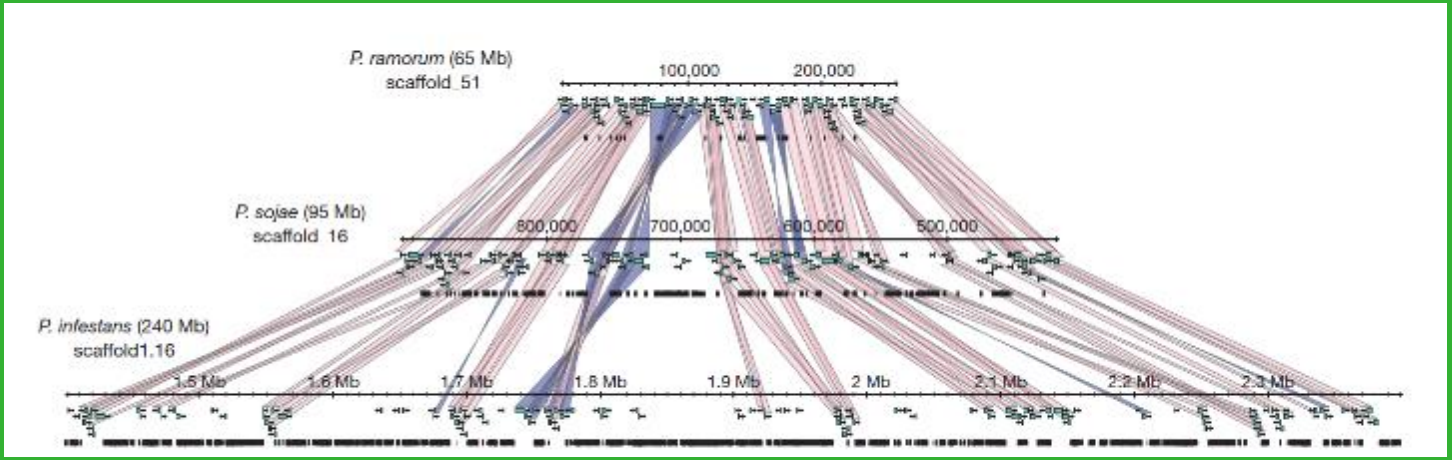


P. infestans: genetic variation & adaptation



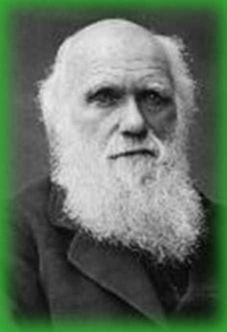
Phytophthora infestans

- Genome ~ 240 Mbase
  (extremely large within the genus Phytophthora)
- “2 speed genome”
  - House keeping genes (conserved)
  - Infection related genes (extremely “flexible”)



Haas & Kamoun et al., 2009

Adaptation by *P. infestans:* Mutation & Selection



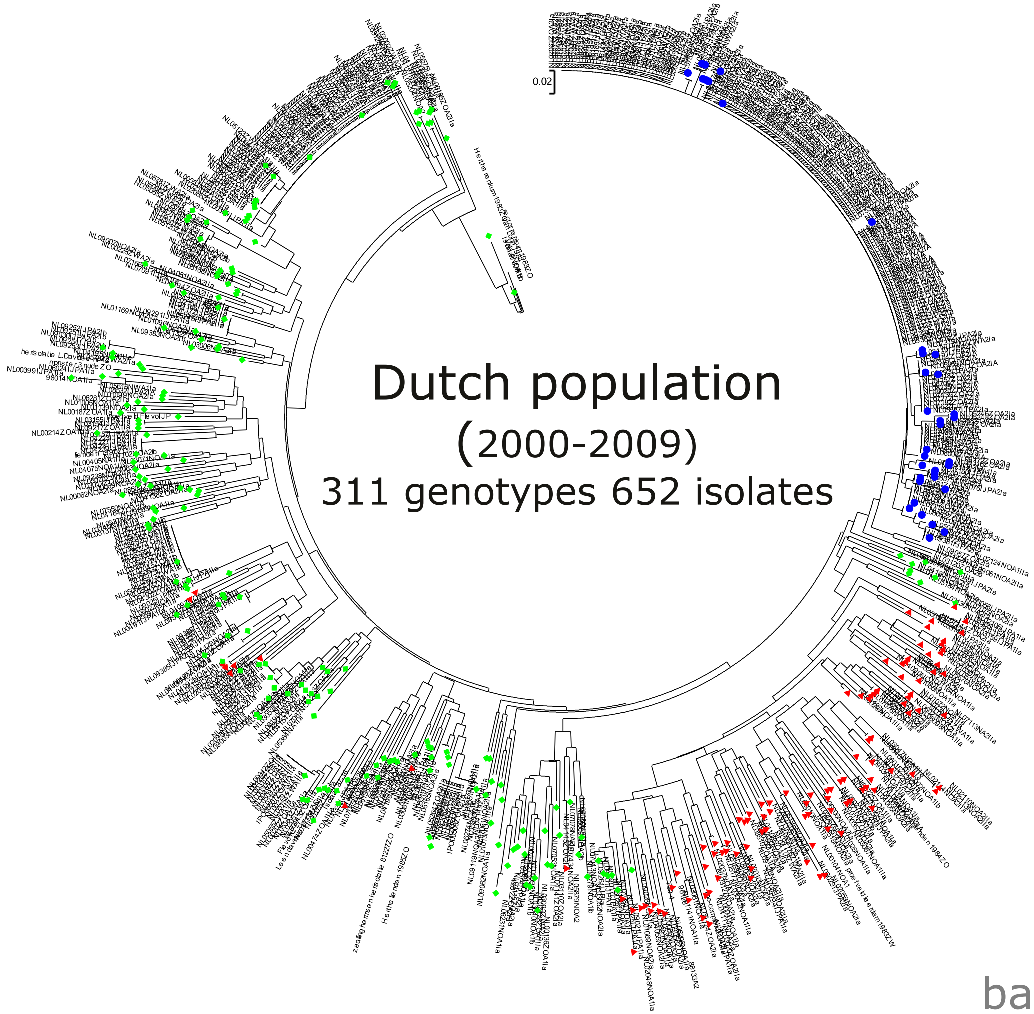
4×10^{12}
sporangia / ha

Infected crop

Resistant / Sprayed crop

The Dutch *P. infestans* population 2000 - 2009

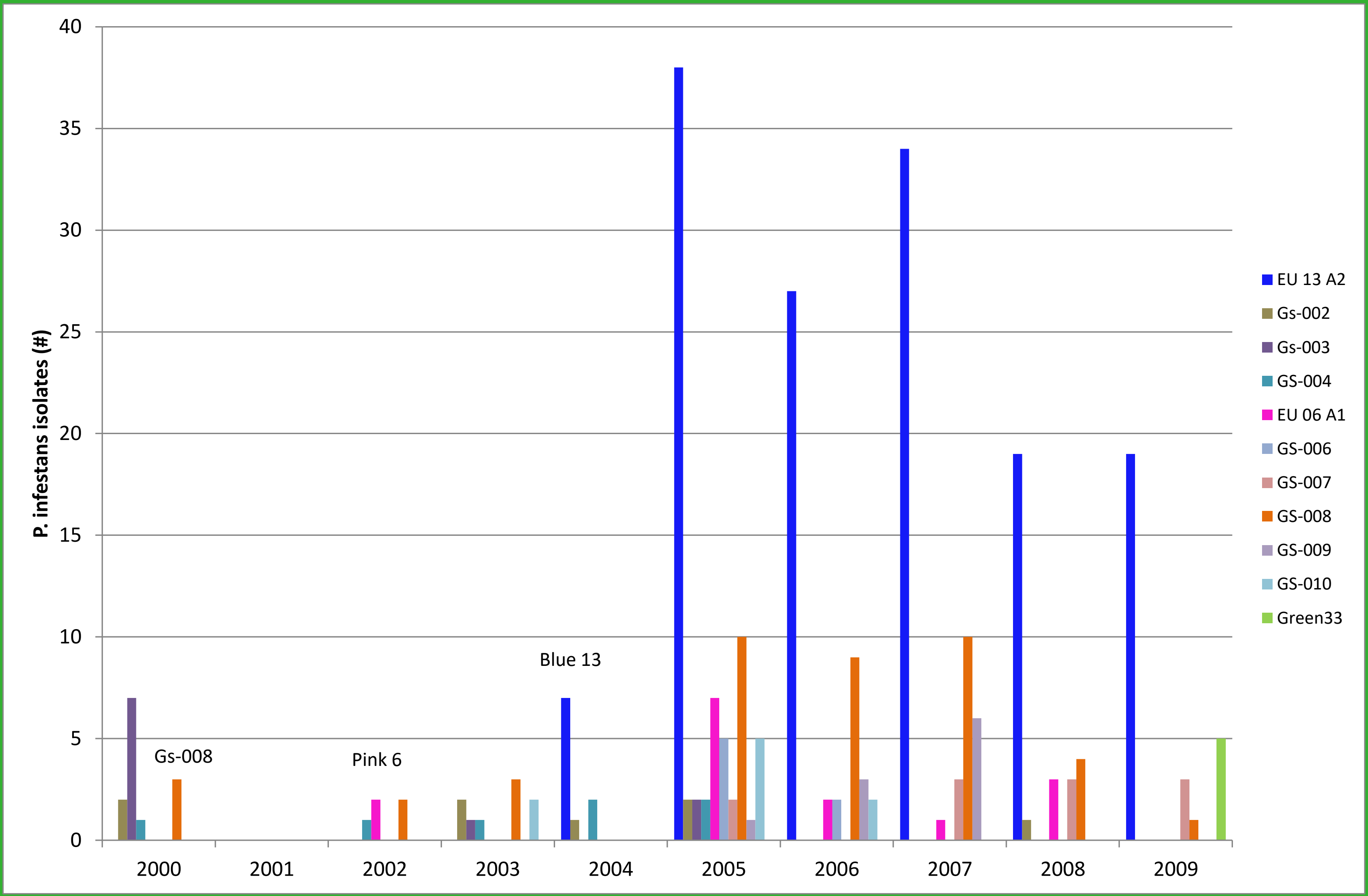
Dutch population splits in 3 parts



Blue = Group 1
Red = Group 2
Green = Group 3

3 groups were distinguished based on “PCA” & “STRUCTURE”

Dynamics of dominant clonal lines 2000 - 2009



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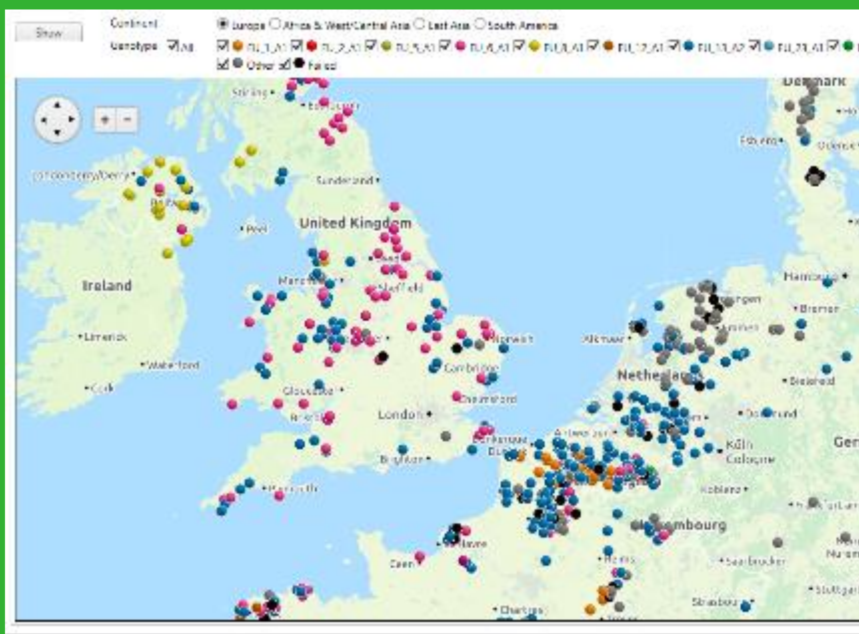
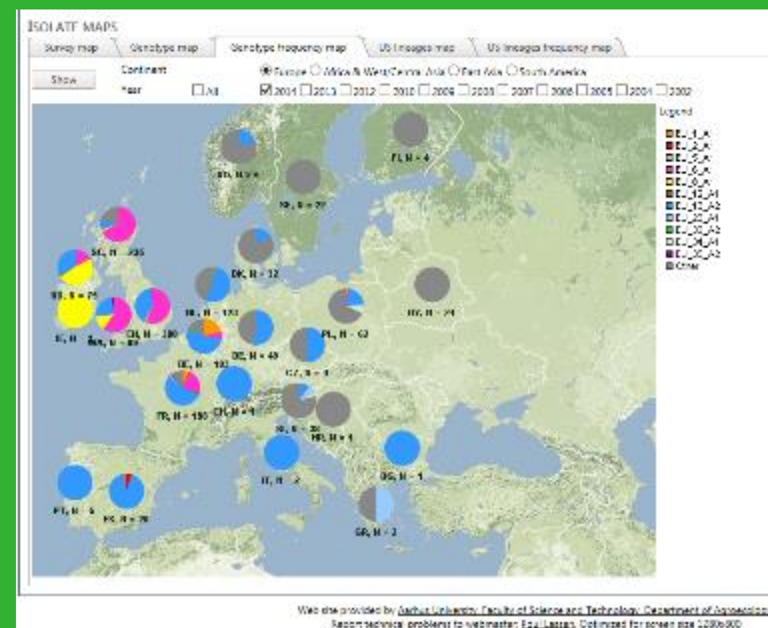
EU Population 2014





Consequences of population change: The virulence spectrum of Blue13

Data: David Cooke & Alison Lees (SCRI)

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The Scottish Government

POTATO COUNCIL

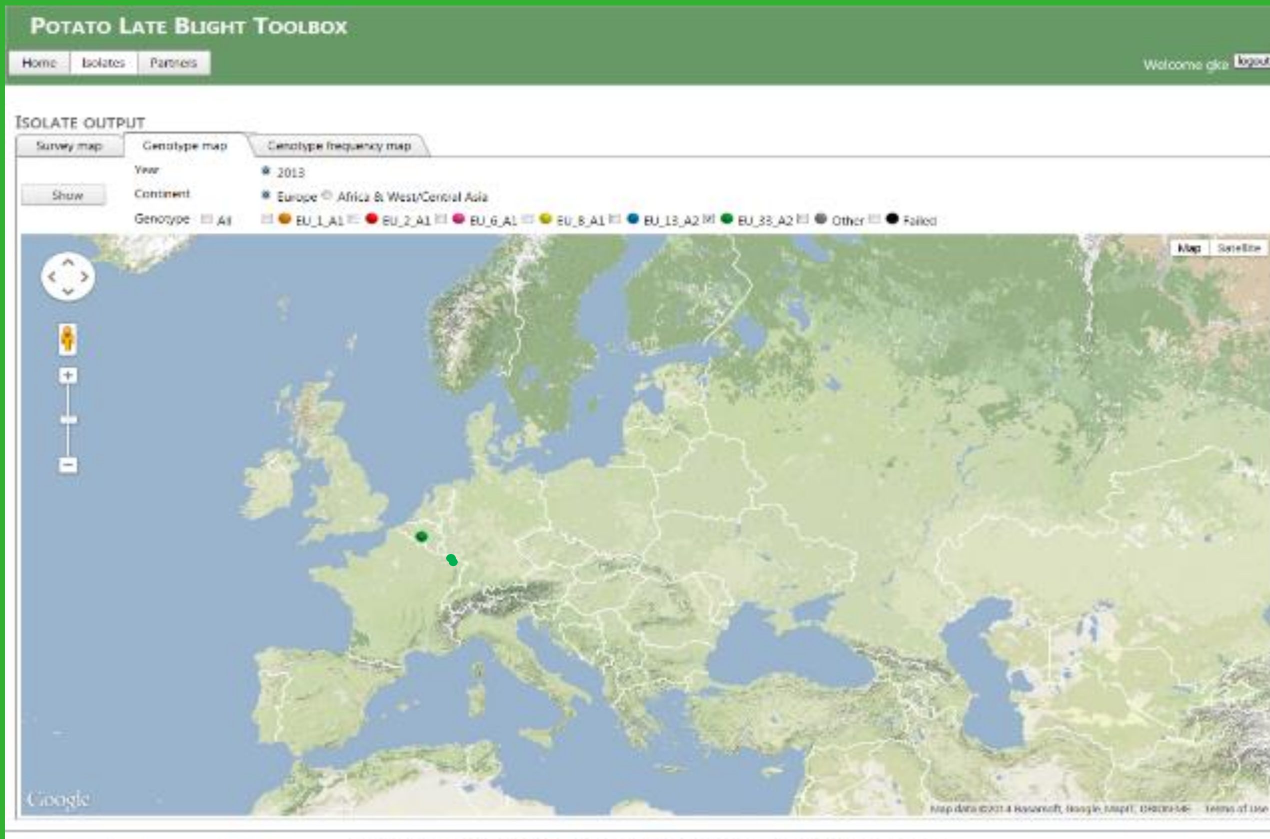
scri living technology

Consequences of population change: Resistance to fluazinam

Green33 in the Netherlands

- Green33
  - NL2010: 20%
  - NL2011: 22%
  - NL2012: 6%

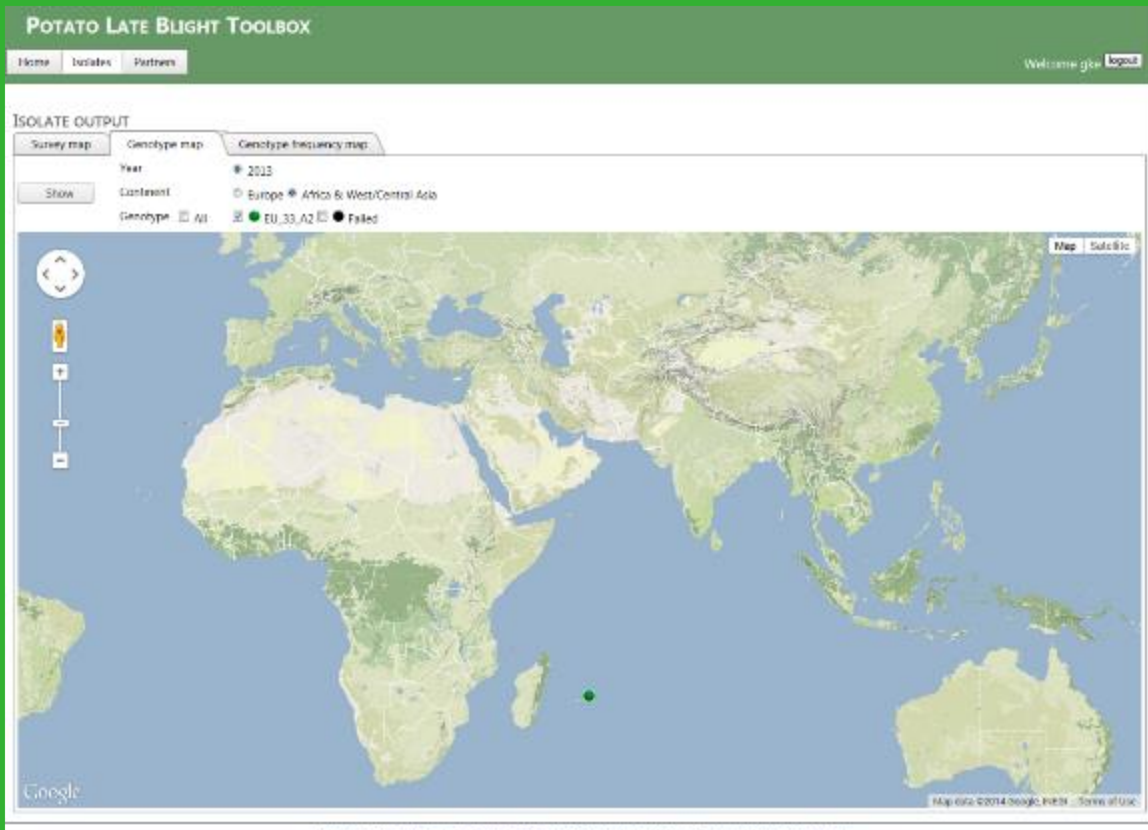
Green33 in 2013



EuroBlight

A potato late blight network for Europe

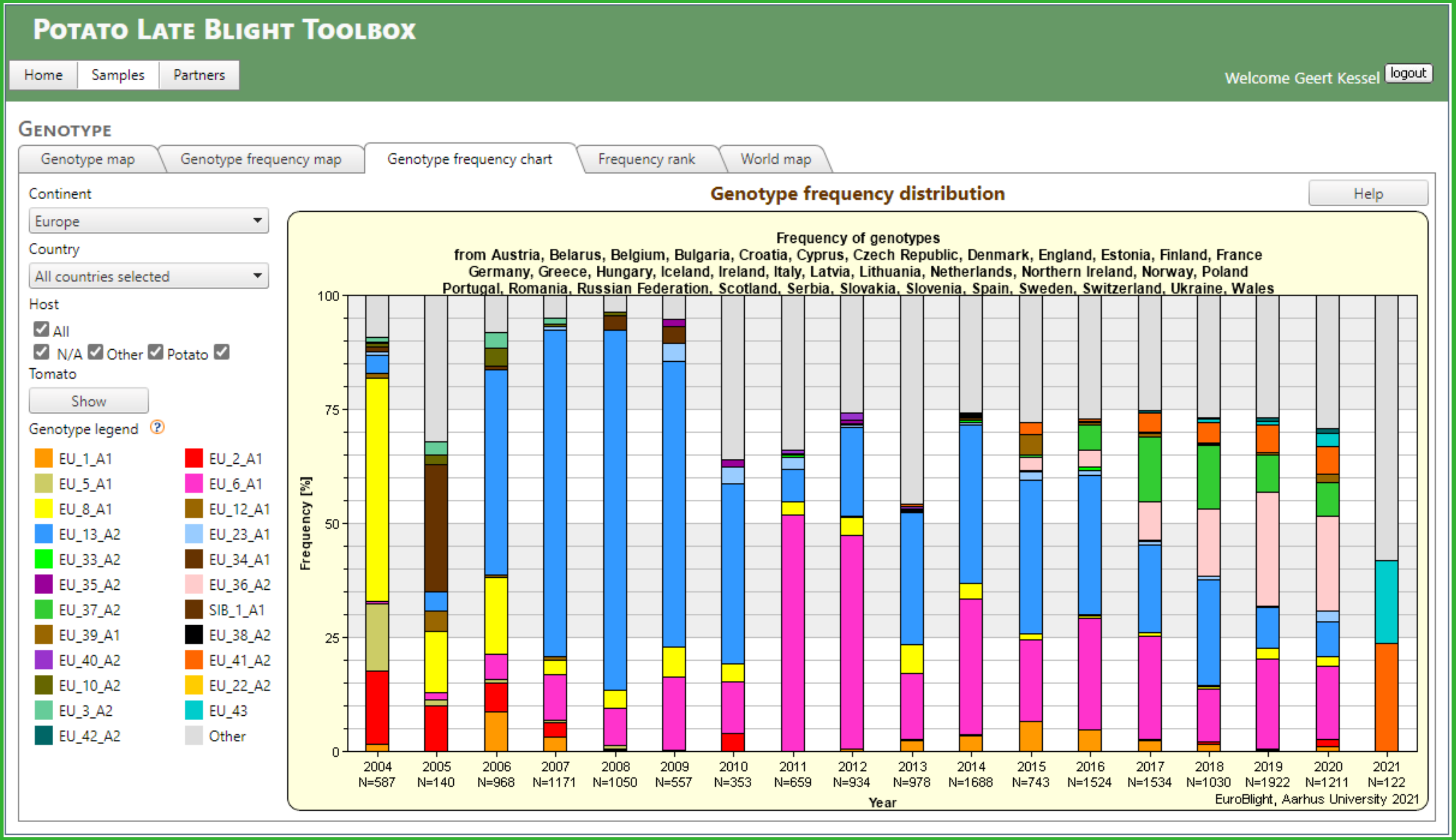
Green33 in 2013



EuroBlight

A potato late blight network for Europe

Europe: *continuous* population changes



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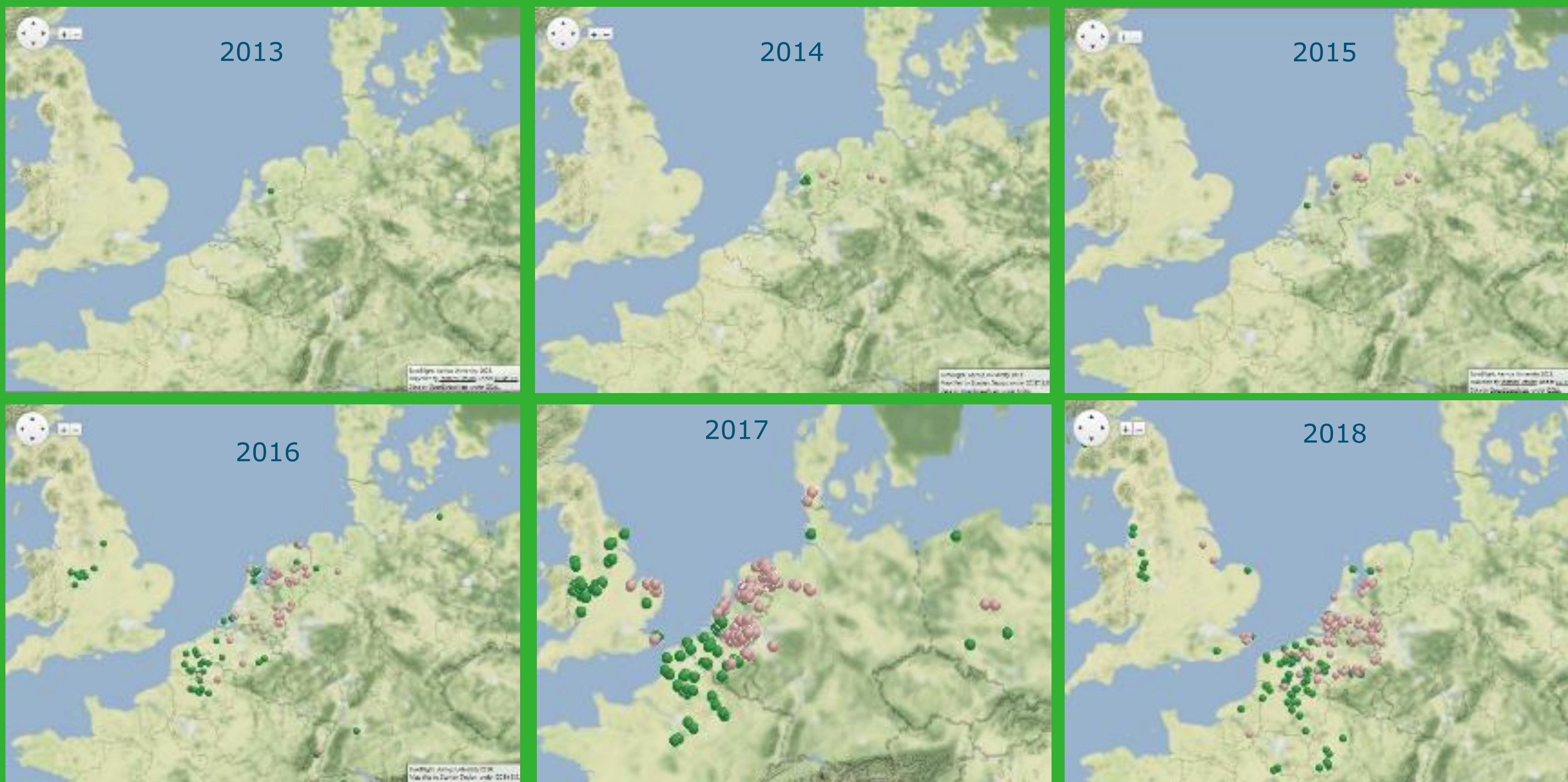
The James Hutton Institute

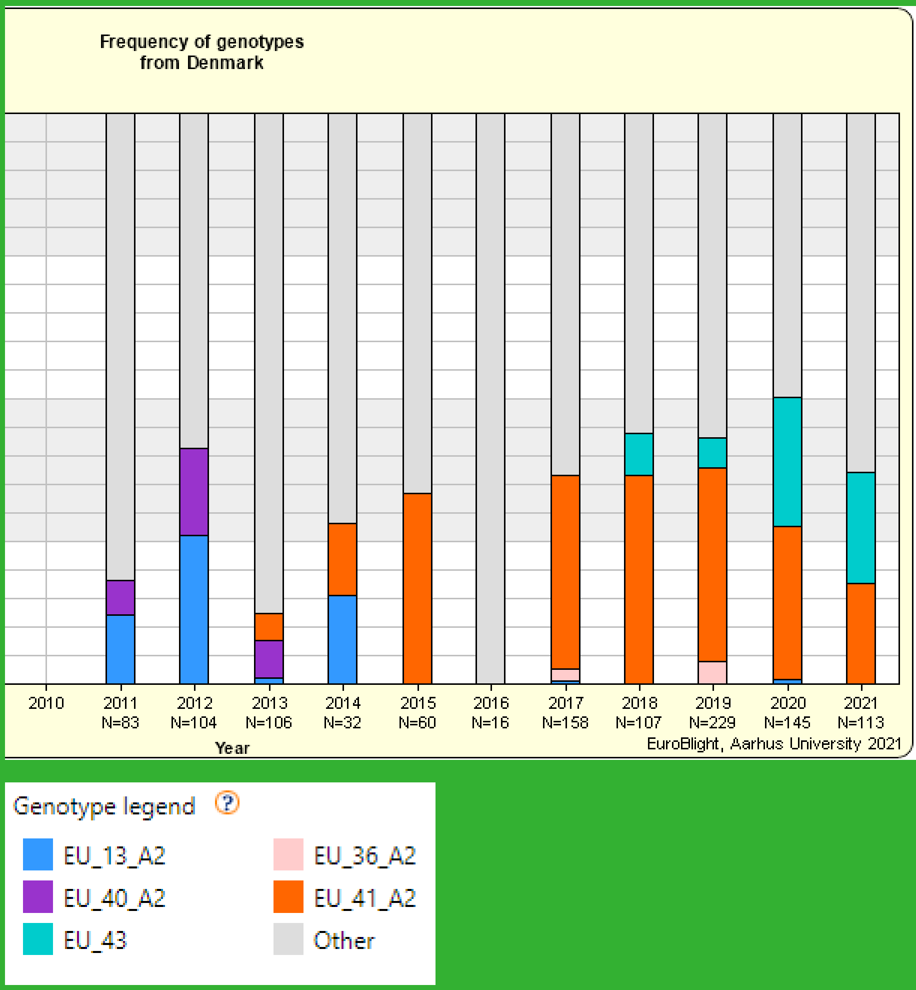
Dr David Cooke, JHI

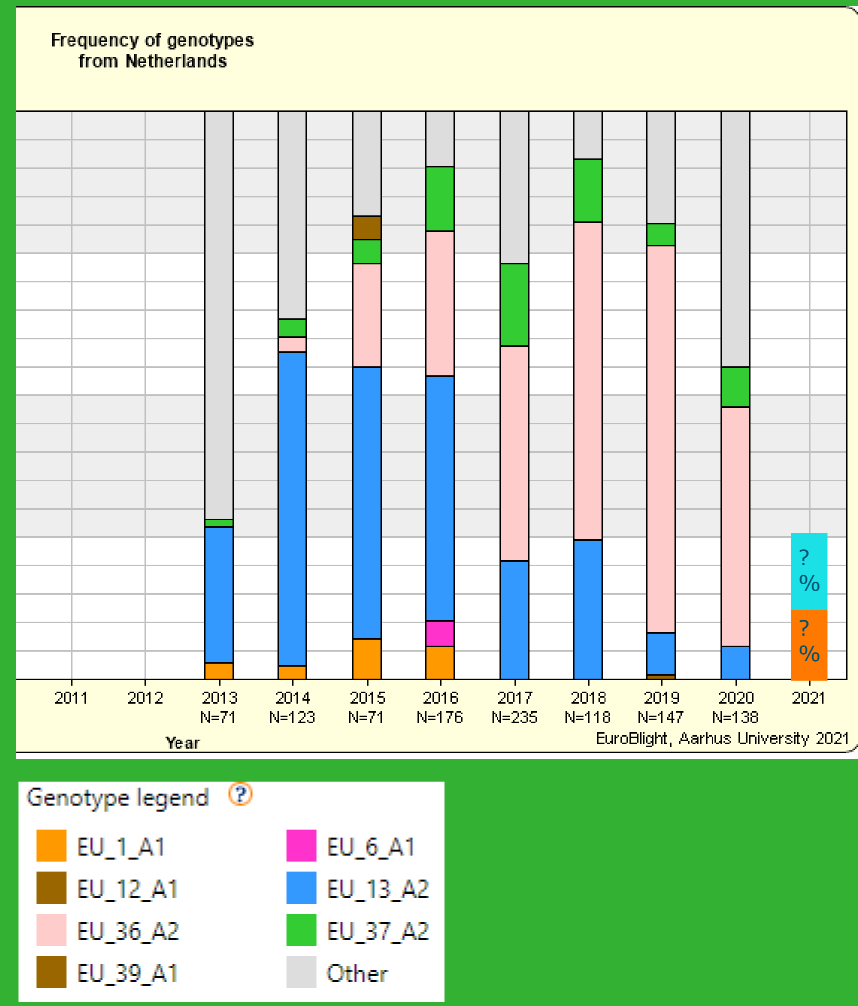
EuroBlight
A potato late blight network for Europe

EU36 & EU37 2013 - 2018



P. infestans population 2020 DK & NL





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EuroBlight
A potato late blight network for Europe

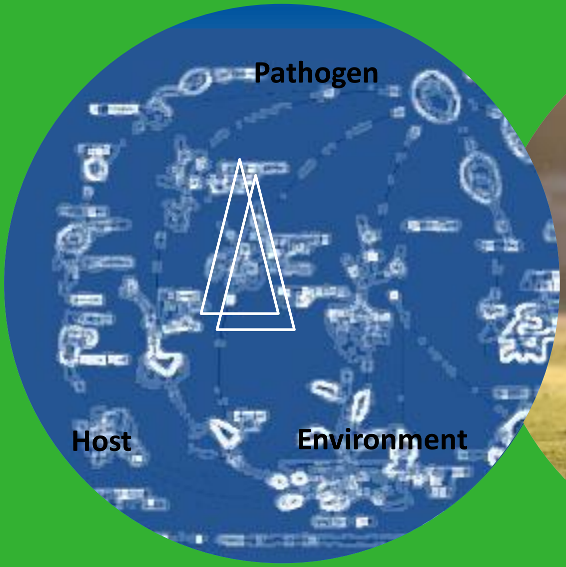
P. infestans clonal line characteristics

- EU_13_A2 (Blue 13)
  - Highly aggressive
  - Resistant Metalaxyl
- EU_33_A2 (Green 33)
  - Not so aggressive
  - Resistant to Fluazinam
- EU_6_A1 (Pink 6)
  - Highly aggressive
- EU_37_A2
  - Highly aggressive
  - Resistant Fluazinam

- EU_36_A2
  - Highly aggressive
  - .... ?
- EU_41_A2
  - ?
- EU_43_?
  - ?

June 2017

Host resistance

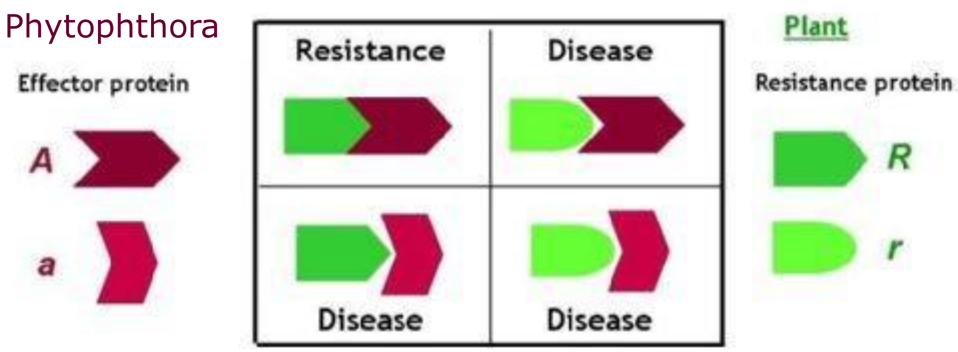


Late blight *R* genes from related wild species

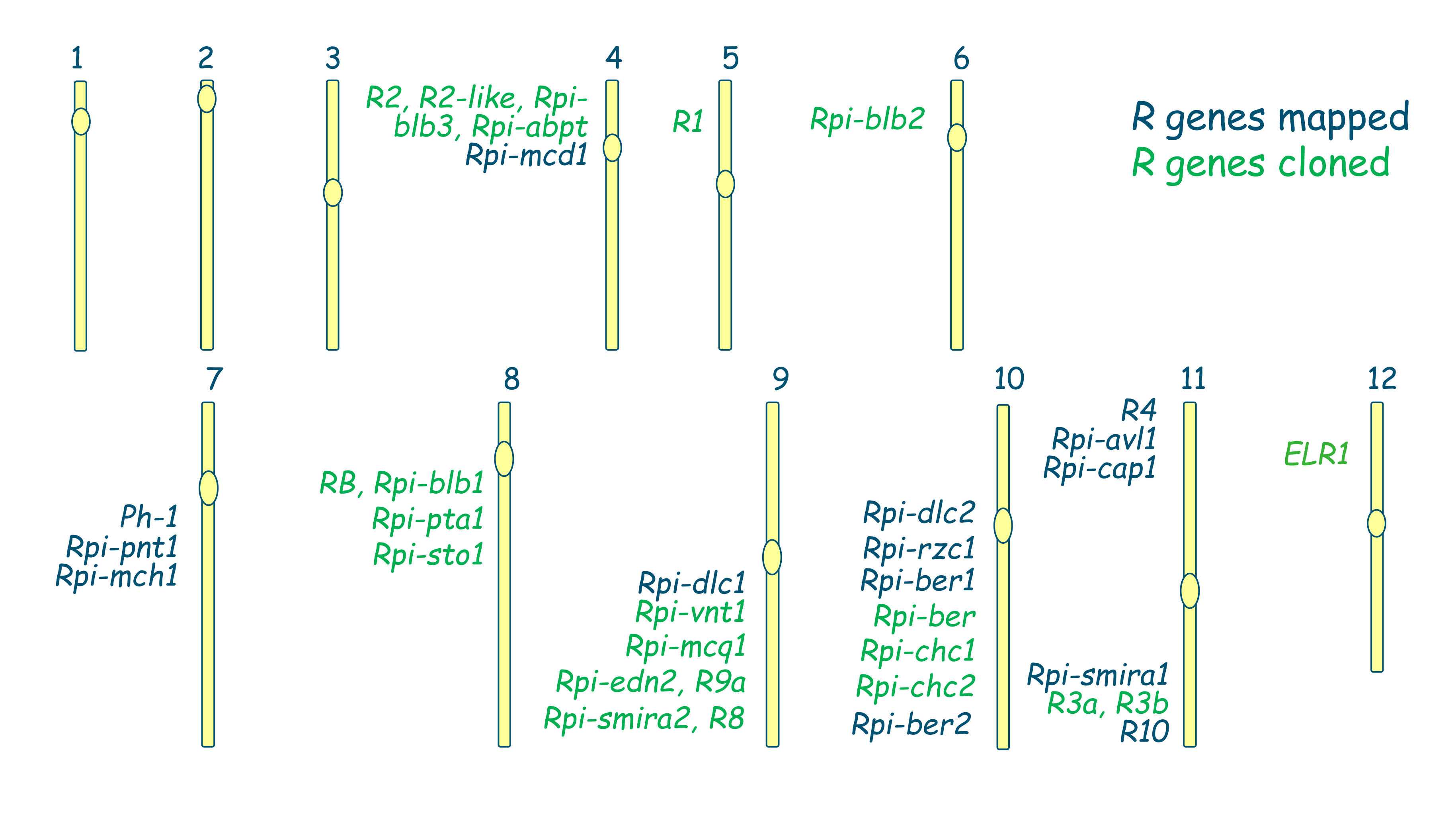
Host resistance

The Gene-for-Gene Model of Plant Immunity

Phytophthora: Effector \ Plant: R-gene	*R*	*r*
A	Resistance	Disease
a	Disease	Disease



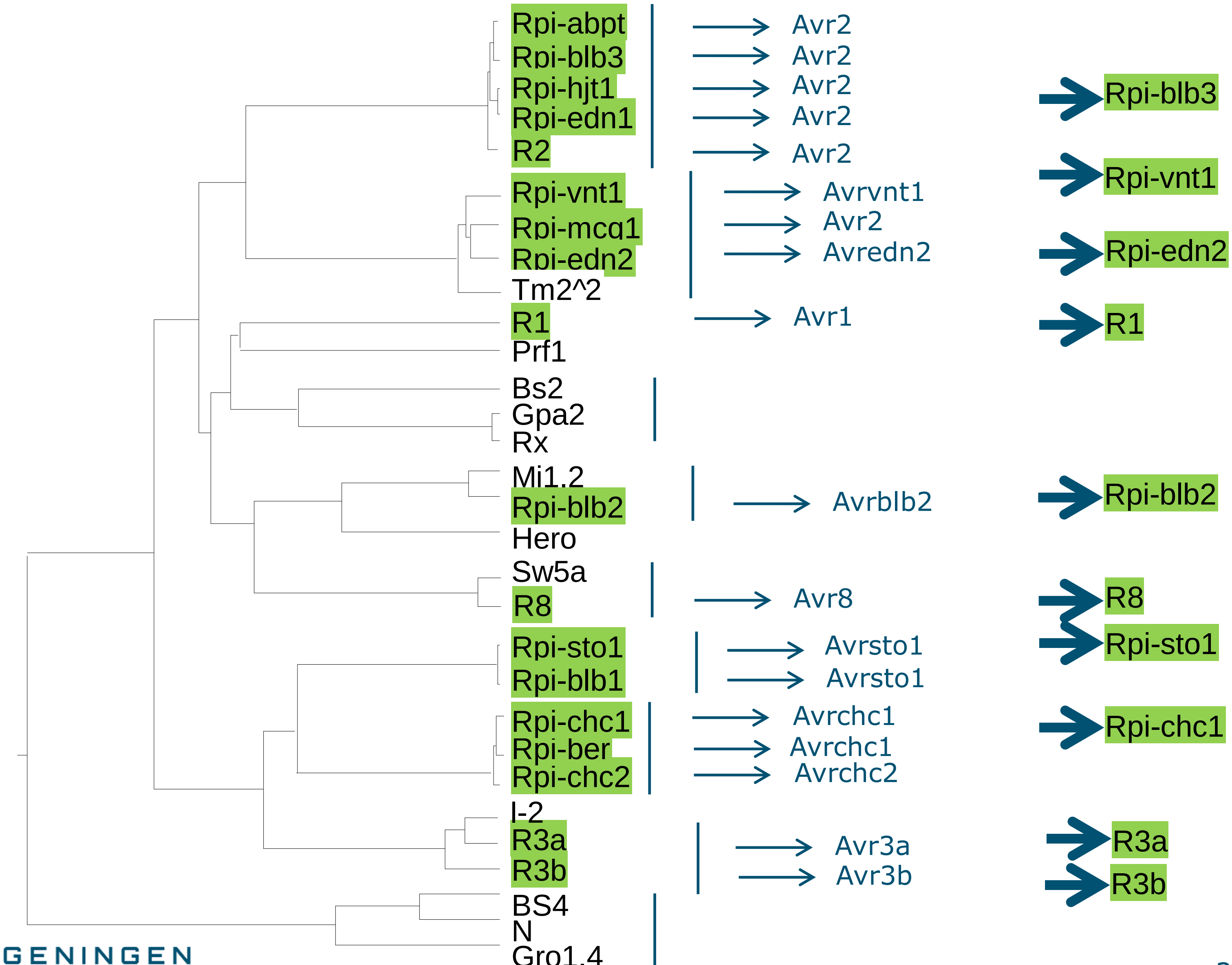
Potato late blight *R* gene mapping and cloning



P. infestans isolates (2008-2014) virulent towards late blight *R* genes (%)

R1	Rpi-blb3	R3a	R3b	Rpi-edn2	R8	Rpi-chc1	Rpi-vnt1	Rpi-blb2	Rpi-blb1	Rpi-sto1
100	47	98	96	2	7	9	2	7	7	2
Narrow	Inter mediate	narrow	narrow	broad	broad	broad	broad	broad	broad	broad

Redundancy elimination among clone R genes



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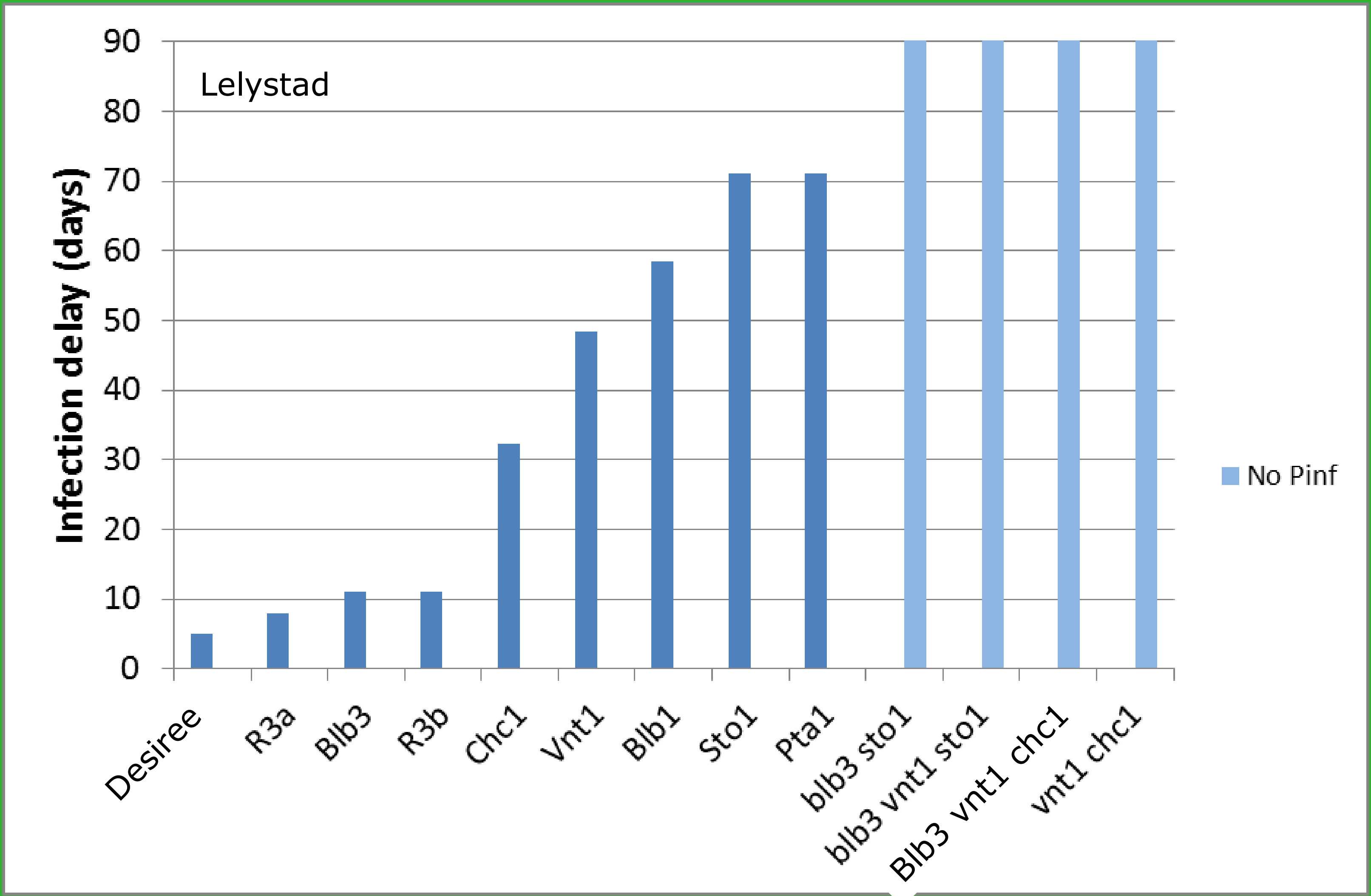
Trap nursery 2011; delay of infection



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Robust potato varieties 2019 (organic, table)

Aanbod biologische robuuste aardappelrassen voor 2019.

rasnaam	type	toepassing	kooktype	bedrijf	NAKareaal pootgoed 2018
Alouette	rode schil	tafel	iets kruimig	Bio Select/Agrico	50
Levante	geel	tafel	iets kruimig	Bio Select/Agrico	*
Carolus	geel	tafel/frites	kruimig	Bio Select/Agrico	106
Twinner	geel	tafel	vastkokend	Bio Select/Agrico	4
Twister	geel	tafel	vastkokend	Bio Select/Agrico	5
Acoustic	creme	tafel	vastkokend	C. Meijer b.v.	*
Cammeo	lichtgeel	tafel/frites	iets kruimig	Caithness Potatoes B.V.	16
Passion	geel/lichtgeel	tafel	vastkokend	Caithness Potatoes B.V.	6
Tentation	geel	tafel	vastkokend	Caithness Potatoes B.V.	4
Sarpo Mira	witvlezig	frites	iets kruimig	Danespo	21
Connect	geel	tafel	kruimig	Den Hartigh	36
Marabel	geel	tafel	iets kruimig	Europlant	25
Otolia	geel	tafel	iets kruimig	Europlant	5
Glorietta	geel	tafel	vastkokend	Europlant	20
Allians	geel	tafel	vastkokend	Europlant	33
HZ 09-7530	geel	tafel	vastkokend	HZPC	*
Triplo	geel	tafel	iets kruimig	HZPC	81
Alanis	geel	frites	iets kruimig	Interseed Holland B.V.	1
Bionica	witvlezig	tafel	vastkokend	N. Vos	1
Sevilla	geel	frites/chips/tafel	kruimig	N. Vos	15
Cephora	geel	frites/tafel	kruimig	Plantera B.V.	2
Vitabella	geel	tafel/frites	vastkokend	Plantera B.V.	77

rassen met een hoofdgen tegen phytophthora — *vroeg te telen rassen*

** geen pootgoed voor keuring bij de NAK aangegeven* — *bron: Bionext en NAK*

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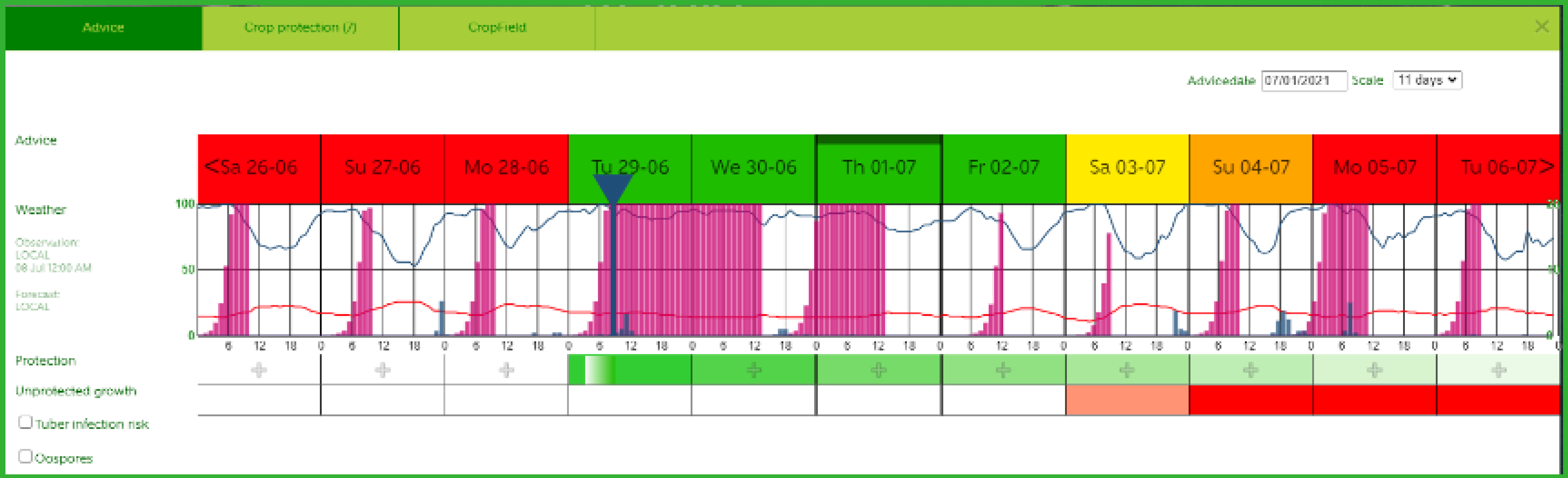
Current disease management

Current common practice late blight control

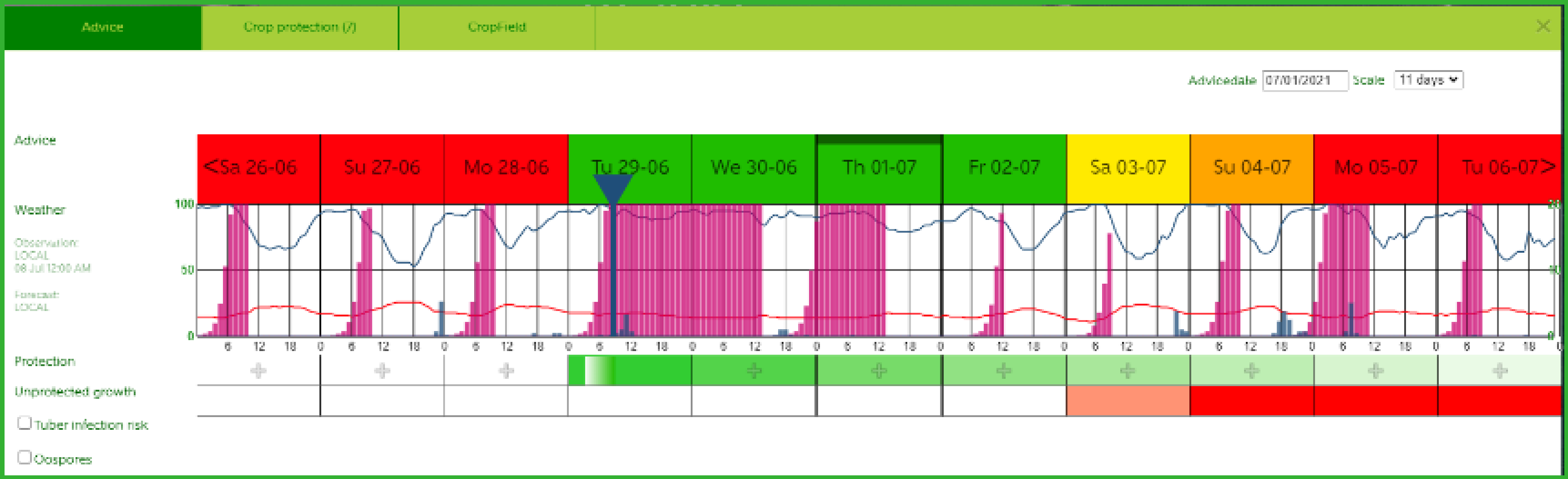
Fixed spray schedules very common around the world.

Considerations before spraying



- Why? (Preventive, curative?, stop-sprays?)
- When?
  - Every Monday?
  - Intelligent "weekly" spray schedule?
  - DSS?

Considerations before spraying



- Which fungicide?
  → Spray strategy (NL: Revus, Zorvec+, Infinito, Ranman)
- Crop phase? Fast growth?, tuber protection?, → Euroblight table
- Other diseases? → Alternaria, sclerotinia, ... ?
- Resistance management? → Alternate, ... (no more mancozeb)
- Availability of fungicides

De Euroblight table P. infestans

Product (Dose rate [litre or kg/ha])	Leaf blight	Tuber blight	New growth	Stem blight	Protec-tant	Curative	Anti sporulant	Rain-fastness	Mobility	Year
copper				●	●◖	0	0	●	C	1900
dithiocarbamates (2.0)[1]	2.0	0.0		●	●●	0	0	●◖	C	1961
chlorothalonil				◖	●●	0	0	●●◖	C	1964
cyazofamid (0.5)	3.8	3.8	●●	●	●●●	0	0	●●●	C	2001
fluazinam (0.4)	2.9			●	●●●	0	0	●●◖	C	1992
zoxamide + mancozeb (1.8)	2.8			●[5]	●●●	0	0	●●◖	C + C	2001
amisulbrom + mancozeb (0.5+2.0)	4.5	3.7		●	●●◖	0	?	●●●	C + C	2007
ametoctradin + mancozeb (2.5)	3.7		?[8]	?[8]	●●◖	0	0	●●●	C + C	2011
fluazinam + azoxystrobin (0.5)	3.6								C + C	2016
famoxadone + cymoxanil				●◖	●●	●●	●	●●◖	C + T	1996
(zoxamide + mancozeb) + cymoxanil (1.8+0.2)	3.4								C + T	2001
mandipropamid (0.6)	4.0		●●	●◖	●●●	●[6]	●◖	●●●	C/T	2005
mandipropamid + difenoconazole (0.6)	4.0		●●	●◖	●●●	●[6]	●◖	●●●	C/T + C	2005
benthiavalicarb (0.5)	4.2								T	2018
benthiavalicarb + mancozeb (2.0)	3.7			●◖ [5]	●●●	●◖	●	●●◖	T + C	2003
cymoxanil + metiram				●◖	●●	●●	●	●●	T + C	1976
cymoxanil + copper				●◖	●●	●●	●	●●	T + C	1976
cymoxanil + mancozeb				●◖	●●	●●	●	●●	T + C	1976
dimethomorph + mancozeb (2.4)	3.0			●◖	●●◖	●	●●	●●◖	T + C	1988
dimethomorph + fluazinam (1.0)	3.7	3.3	●	●	●●◖	●	●●	●●◖	T + C	2012
fenamidone + mancozeb (1.5)	2.6			●◖ [5]	●●◖	0	●◖ [5]	●●	T + C	1998
(zoxamide + cymoxanil) + fluazinam (0.45+0.4)	4.0								C/T + C	2013
(zoxamide + dimethomorph) + fluazinam (1.0+0.4)	4.2								C/T + C	2015
mandipropamid + cymoxanil (0.6)	4.4		●●	●◖	●●●	●●	●◖	●●●	C/T + T	2013
(pyraclostrobin + dimethomorph) + adjuvant (2.5+1.0)	4.0[7]								C/T + T	2012
benalaxyl-M + mancozeb[2]	3.0		●●	●●	●●◖	●●◖	●●◖	●●●	S + C	1981
metalaxyl-M + mancozeb[2]			●●	●●	●●◖	●●◖	●●◖	●●●	S + C	1977
metalaxyl-M + fluazinam[2]			●●	●●	●●◖	●●◖	●●◖	●●●	S + C	
propamocarb + cymoxanil + cyazofamid ((2.0)+0.5)		4.6							S + T + C	2012
propamocarb + cymoxanil (2.0)					●◖	●●◖ [9]	●●◖		S + T	2011
propamocarb-HCl + fenamidone (2.0)	2.5		●◖	●●	●●◖	●●	●●	●●●	S + T	1998
propamocarb-HCl + fluopicolide (1.6)	3.8	3.9	●●	●●	●●●	●●	●●◖	●●◖	S + C/T	2006
oxathiapiprolin (0.15)			●●◖	●●◖	●●●	●●	●●◖	●●●	S	2017
oxathiapiprolin + famoxadone (0.5)	4.9	4.1	●●◖	●●◖	●●●	●●	●●◖	●●●	S + C	2018
oxathiapiprolin + amisulbrom (0.15+0.3)	4.9								S + C	2018
oxathiapiprolin + benthiavalicarb (0.4)	4.9[7]	3.4	●●◖	●●◖	●●●	●●	●●◖	●●●	S + T	2019

[1] Includes maneb, mancozeb, propineb and metiram. [2] See proceedings for comments on phenylamide resistance. [3] Based on EuroBlight field test in 2006-2015. [4] Based on EuroBlight field trials 2009-2012. [5] Based on limited data. [6] In some trials there were indications that the rating was 1½. [7] A provisional rating based on 5 EuroBlight experiments. [8] Observations from several trials indicated that both New growth and Stem blight were ++. [9] In some trials the curative activity was +++.

EuroBlight
A potato late blight network for Europe

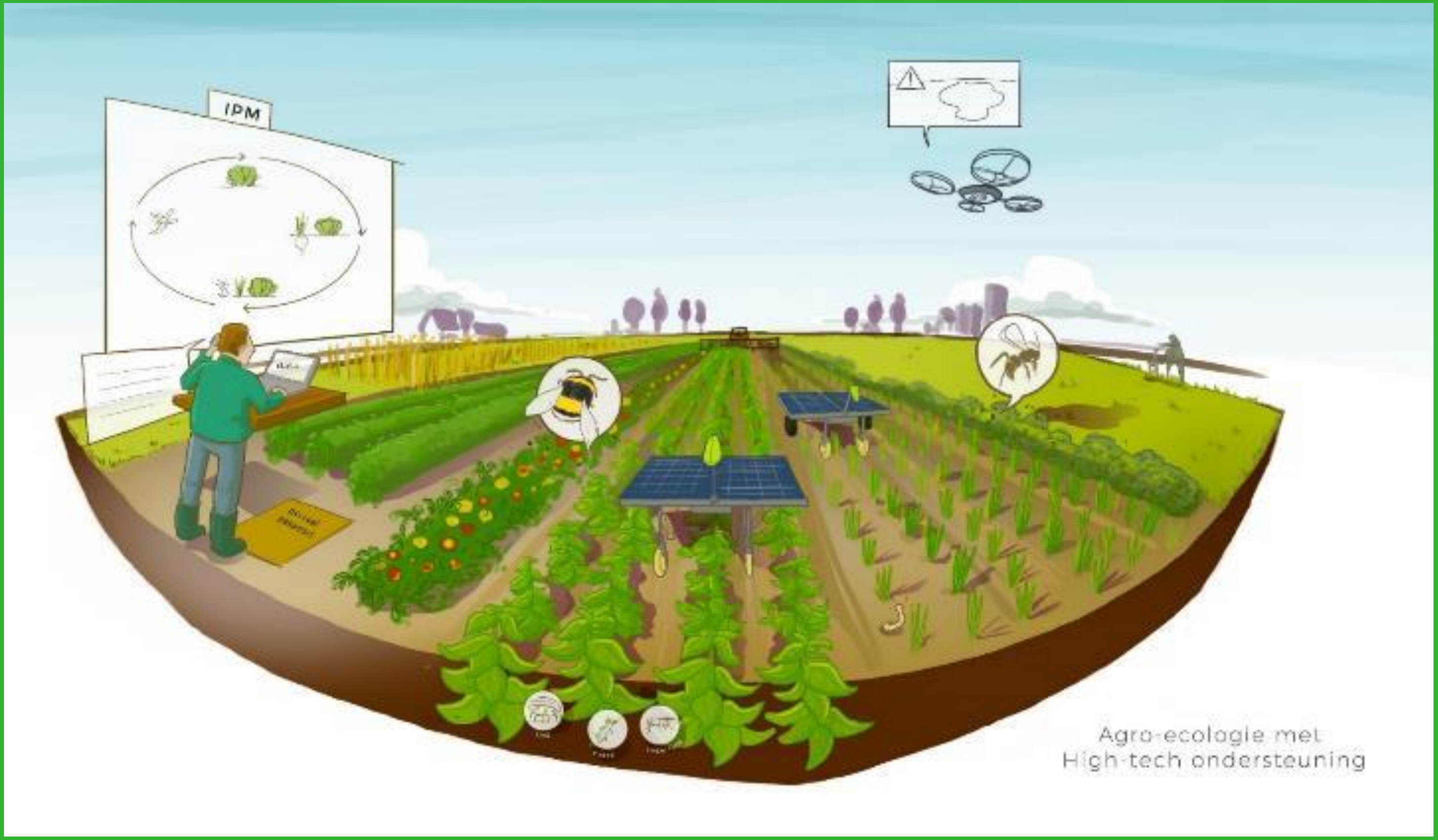
Future disease management

Farm to Fork

Farm2Fork Strategy

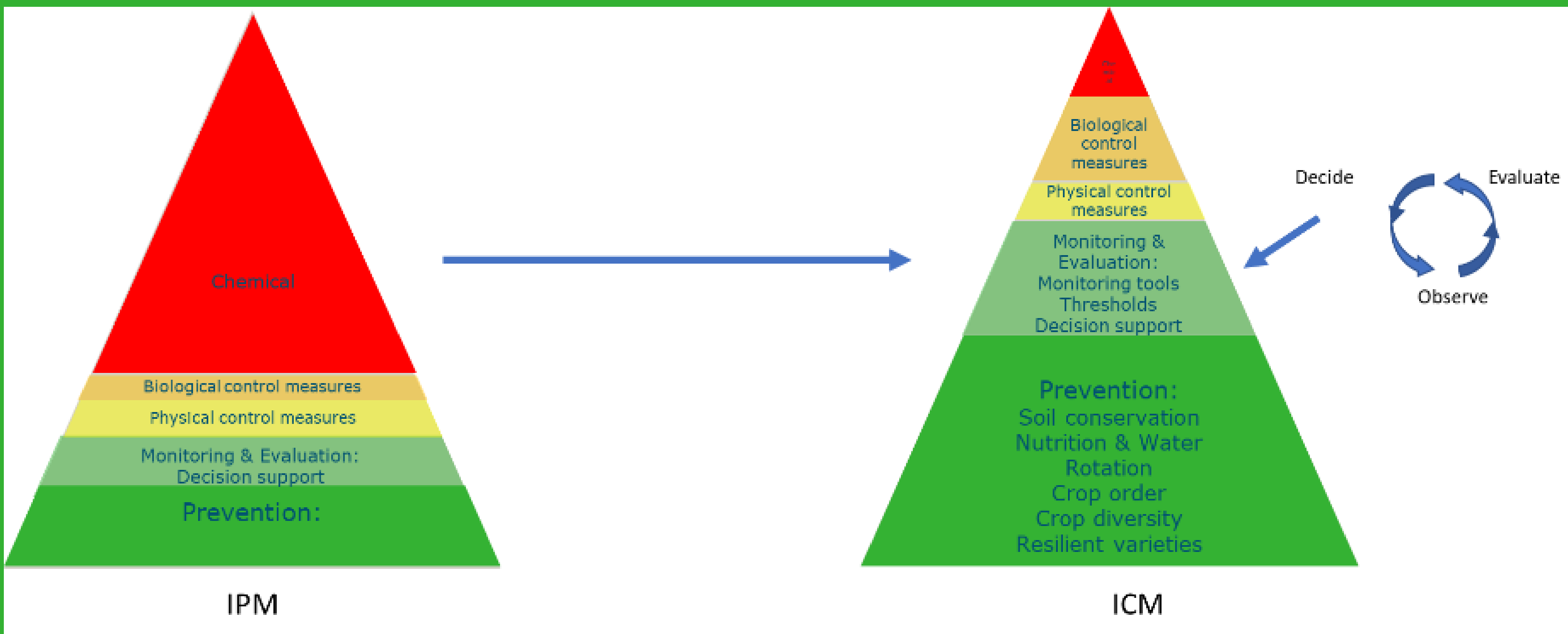
- At heart of EU Green Deal:
  fair, healthy and environmentally-friendly food production
- Linked to the EU biodiversity strategy
- A few objectives:
  - 50% reduction of overall use and risk from chemical pesticides by 2030
  - > = 50% reduction of nutrient losses by 2030
  - >= 20% reduction of use of fertilizers by 2030
  - 25% EU's agricultural land organic

Small scale, resilient agriculture.
Agro-ecology + high tech support
Pesticides only when unavoidable



Solutions ???

Integrated crop protection: from IPM to ICM



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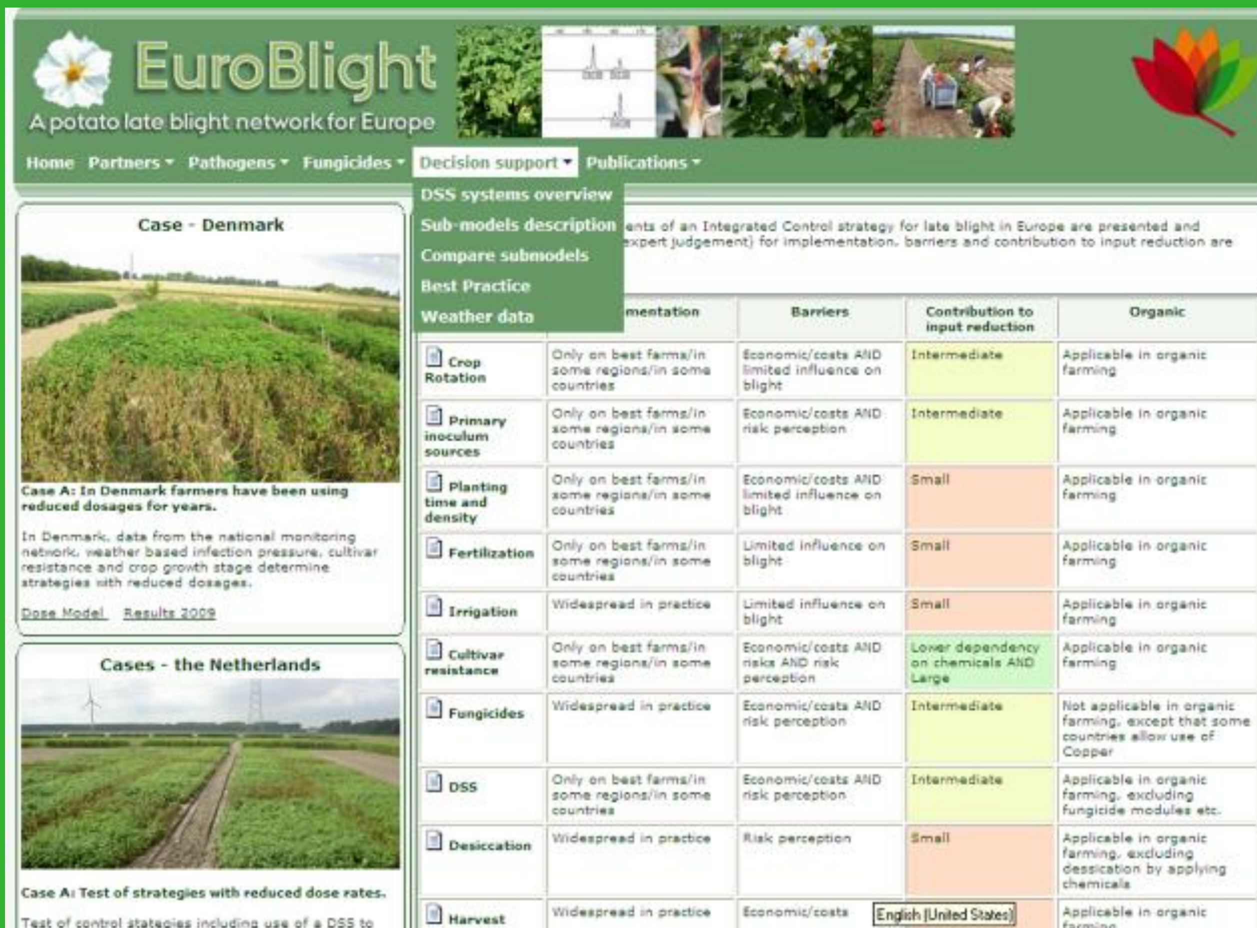
IPM/ICM for Potato Late Blight



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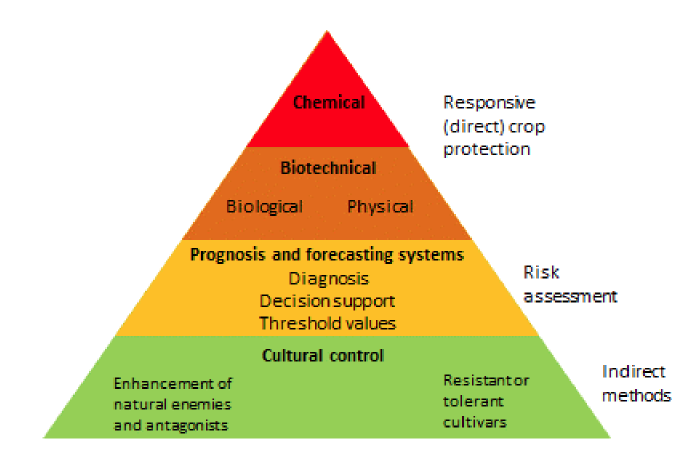
Best

Practises

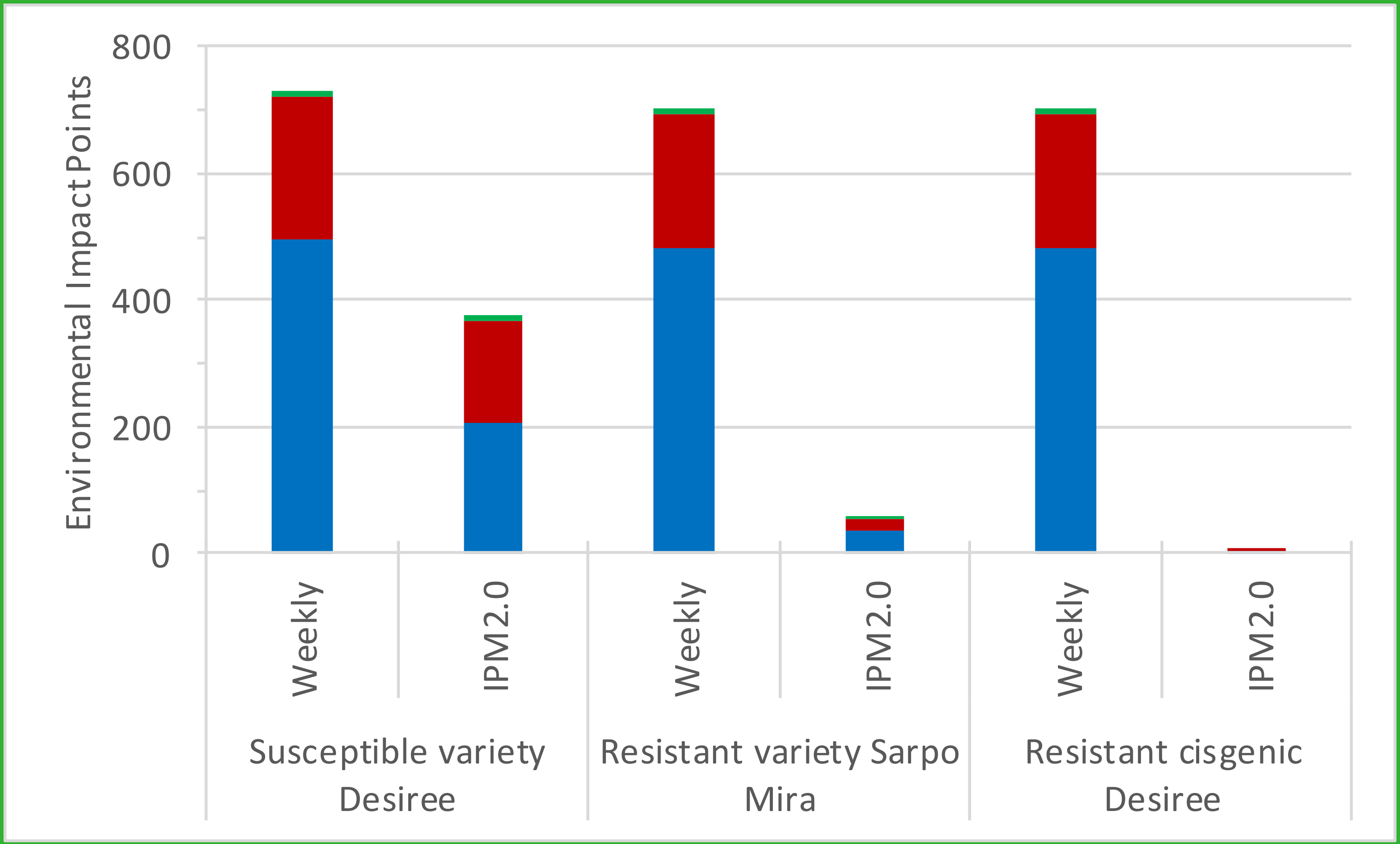
The future of late blight control?

Additions to the IPM toolbox:

- Resistant varieties, preferably R gene stacks, zero tolerance
- Pathogen monitoring
- Data driven decision support systems
- Do not spray unless:
    - Resistance is vulnerable (monitoring)
    - Infection event predicted (DSS)
    - Previous spray insufficient
- Late start (August instead of May, under high disease pressure only)
- Precision spraying (25 cm nozzels, VRA, ..)
- Specific, low impact fungicides
- ...



Environmental impact on susceptible and resistant varieties



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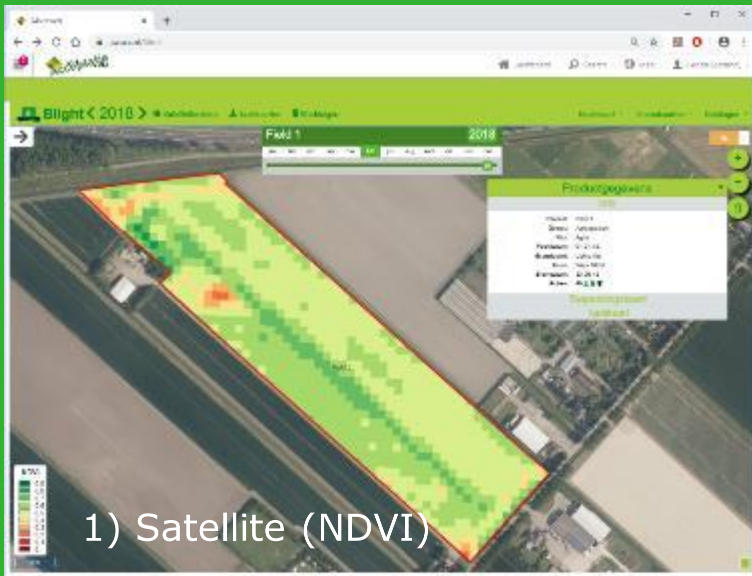
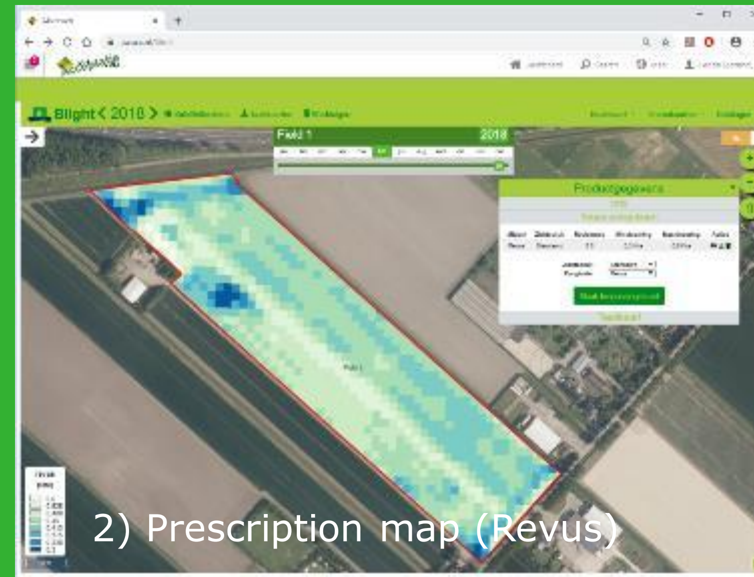
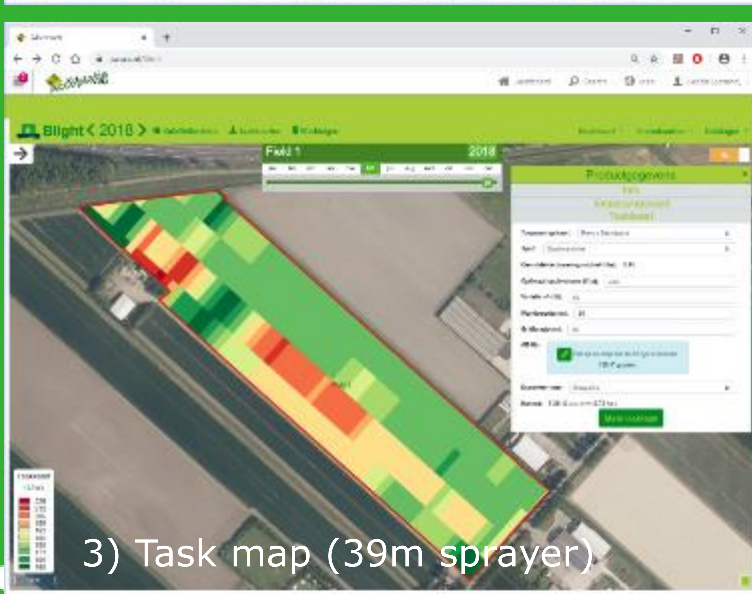
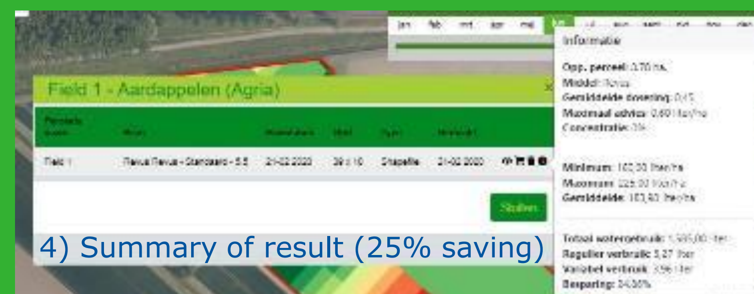
5 field trials, 2 countries (IE & NL), 3 years

Precision spraying: VRA in de BlightApp









Pitfalls for future disease management

Farm to Fork

Host resistance

MOLECULAR PLANT PATHOLOGY (2008) **9**(3), 385–402

DOI: 10.1111/J.1364-3703.2007.00465.X

Review

Plant diseases that changed the world

Phytophthora infestans: the plant (and *R* gene) destroyer

WILLIAM FRY*

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SUMMARY

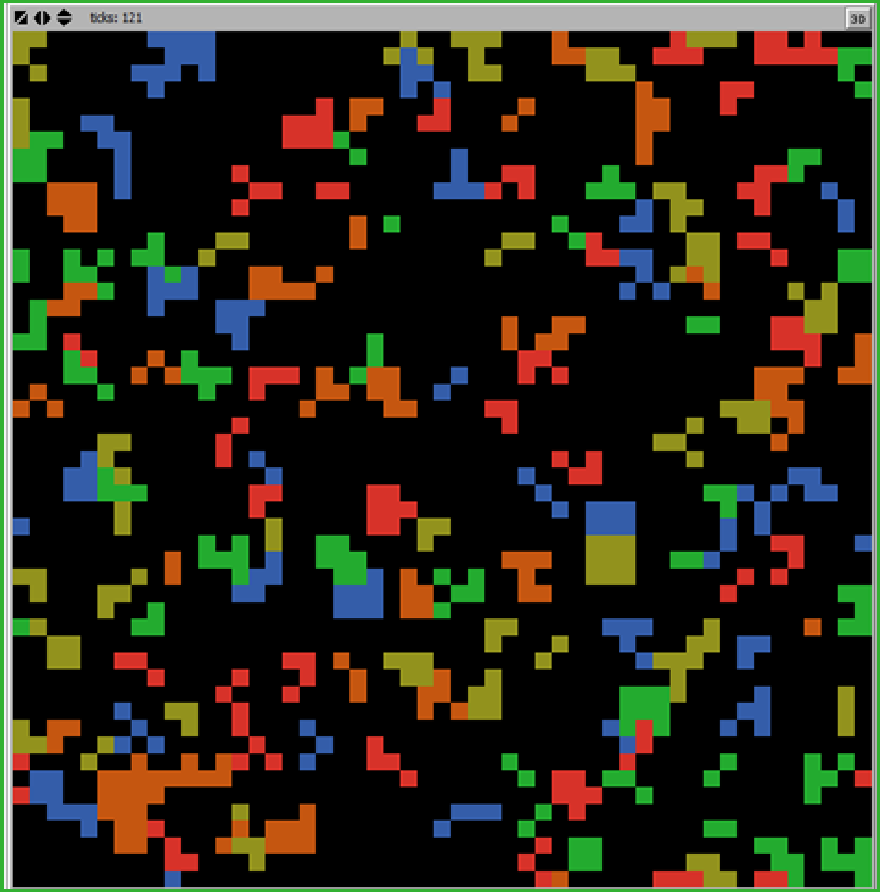
Phytophthora infestans remains a problem to production agriculture. Historically there have been many controversies concerning its biology and pathogenicity, some of which remain today. Advances in molecular biology and genomics promise to reveal fascinating insight into its pathogenicity and biology. However, the plasticity of its genome as revealed in population diversity and in the abundance of putative effectors means that this oomycete remains a formidable foe.

Scholar identified 13 400 articles, with 4450 since 2002—and this search did not find all of the contributions. There are many books (e.g. Dowley *et al.*, 1995; Ingram and Williams, 1991; Lucas *et al.*, 1991), thousands of research articles and thousands of popular reports, and many historical treatments (e.g. Turner, 2005). The 'romance' occurs because many, many scientists have had high hopes that their investigations would lead to control of this dangerous pathogen. The 'controversies' (some continuing to today) develop from differences in method/interpretation—aided by ego. The vast literature creates a special challenge in writing a short overview of this organism and mandates that it be highly selective.

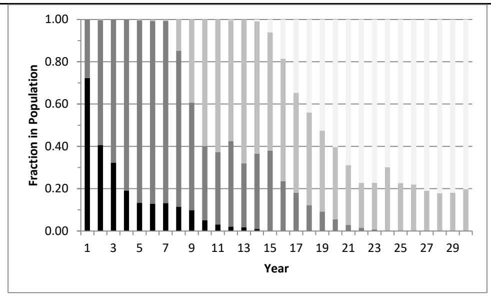
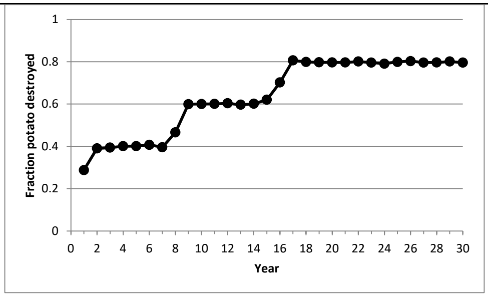
The susceptibility of single R genes, The power of stacking of R genes

P. infestans			Minimum	Maximum
Mutation Frequency:	1.00E-08	-	1.00E-07	1.00E-09
Sporulation Density:	100	sp/mm^2	10	1000
	1.00E+08	sp/m2		
Potato				
Acreage in NL	160000	ha	140000	170000
1 ha	1.00E+04	m2		
Avg LAI	4	m2 foliage / m2 soil	3	5
Potato foliage in NL	6.40E+09	m2		
Combined Potato & P. infestans:				
Percentage foliage destroyed	100%		0	100
Number of virulent mutants to a single R gene:	6.40E+09			
Number of virulent mutants to a double R gene:	64			

Stacking R genes, a simulation study



Invasion at landscape level while Stacking R genes

<table>
<tr><th>Host diversity</th><th>Pathogen population diversity</th><th>Potato destroyed in landscape</th></tr>
<tr><td>20% R0, +
20% R1, +
20% R12, +
20% R123, +
20% R1234</td><td>
</td><td>
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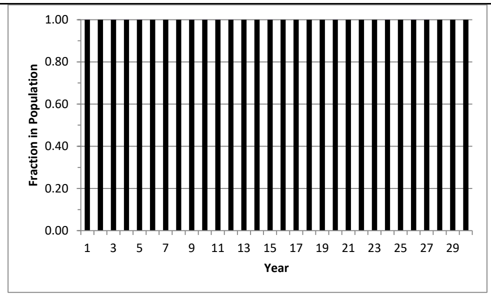
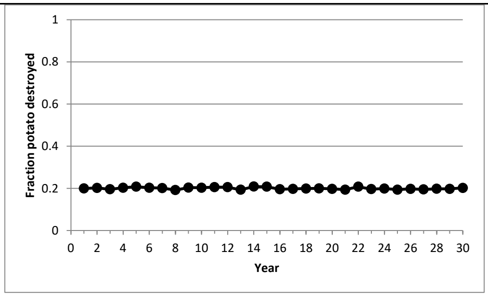
<tr><td>20% R0, +
20% R1, +
20% R12, +
20% R123, +
20% R1234
+
Protectant fungicides</td><td>
</td><td>
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Figure 1. The effect of providing R genes as stepping stones in the landscape with or without application of additional protectant fungicides. Pathogen races: race 0: ■, race 01: ■.

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32 30 JANUARI 2021 | NIEUWE OOGST AKKER- & TUINBOUW

WUR-onderzoeker Geert Kessel waarschuwt aardappeltelers voor virulente mutaties van de aardappelschimmel

Zuinig zijn op resistentie tegen phytophthora

MAUD DOEDE

Voor de resistentieveredeling van aardappelen is wat betreft werking maar een beperkt aantal specifieke resistentiegenen tegen phytophthora beschikbaar. Om de robuuste rassen sterk te houden, is het van belang dat virulente, resistentiedoorbrekende phytophthorastammen geen ruimte krijgen.

ACHTERGROND

Onderzoeker Geert Kessel van Wageningen University & Research (WUR) adviseert aardappeltelers met robuuste aardappelen om in het groeiseizoen planten, die zijn aangetast door phytophthora, zo snel mogelijk te verwijderen en te vernietigen. 'Deze virulente mutaties moeten niet de kans krijgen zich te verspreiden en groot te worden in de phytophthorapopulatie.'

Kessel gaf vorige week tijdens de Biokennisweek een workshop over resistentiemanagement. Hij deed dit in het kader van het convenant 'Versnelde transitie naar robuuste aardappelrassen'. Robuust betekent voornamelijk resistent tegen phytophthora. Om het doel van het convenant te realiseren, is het van groot belang dat aardappeltelers zuinig zijn op de resistente rassen.

De onderzoeker liet in zijn presentatie zien hoe phytophthora zich in de praktijk manifesteert en wat daarvan de impact is op resistente rassen. Hij maakt een vergelijking met het coronavirus.

'Als het was gelukt om de eerste patiënt met corona goed te isoleren, dan was dit virus nooit uitgegroeid tot een pandemie. Zo is het ook met phytophthora. Als we virulente mutanten consequent de kop indrukken, dan verdwijnen ze vanzelf weer.'

VARIATIE VEEL GROTER

De afgelopen twee jaar heeft Kessel met zijn collega's van de demovelden met robuuste aardappelrassen op drie locaties in Nederland isolaten met phytophthoravlekken verzameld. Uit analyses blijkt dat in 2019 vooral de phytophthorastam EU 36 is gevonden op de robuuste rassen. Vorig jaar was de variatie veel groter. Naast de EU 36 betrof dit bijvoorbeeld Blue 13, EU 37 en een aanzienlijke 'grijze' groep met nieuwe, min of meer unieke genotypen.

> 'Resistentiegenen zijn zeldzaam en daarmee waardevol'

De grotere variatie en vooral de grote bijdrage van deze grijze groep met verschillende nieuwe genotypen in 2020 laat volgens Kessel zien hoe phytophthora in staat is om zich genetisch snel aan te passen aan veranderende omstandigheden. De isolaten van de demovelden zijn door de WUR-onderzoekers ook getest op hun virulentie. Dit is uitgevoerd met alle relevante resistentiegenen tegen phytophthora.

De virulentietoets bevestigt dat vooral vertegenwoordigers uit de grijze groep af en toe zeldzame virulenties bevatten.

'Gelukkig komen deze virulenties nog niet op grote schaal in de praktijk voor', stelt Kessel. 'Maar het is zaak om juist bij deze onbekende stammen ervoor te zorgen dat de selectiedruk laag blijft. De basis van goed resistentiemanagement en dus behoud van de resistenties is ervoor zorgen dat de aanwezigheid van virulente sporen zoveel mogelijk beperkt blijft.'

De WUR-onderzoeker benadrukt tot slot dat er niet eindeloos veel resistentiegenen tegen phytophthora beschikbaar zijn. 'We moeten het voorlopig doen met de resistentiebronnen die nu bekend zijn. Resistentiegenen zijn zeldzaam en daarmee waardevol. Des te meer reden om hier zuinig mee om te gaan in de aardappelteelt.'

Telers moeten virulente stammen van phytophthora consequent de kop indrukken. Foto: Syngenta

Tak for din opmærksomhed!

Spørgsmål?