ETH zürich



Spongospora subterranea – An Underestimated Pathogen of a Key World Food Crop

Biology, Occurence, Control Management, Host Resistance,

Research Outlook

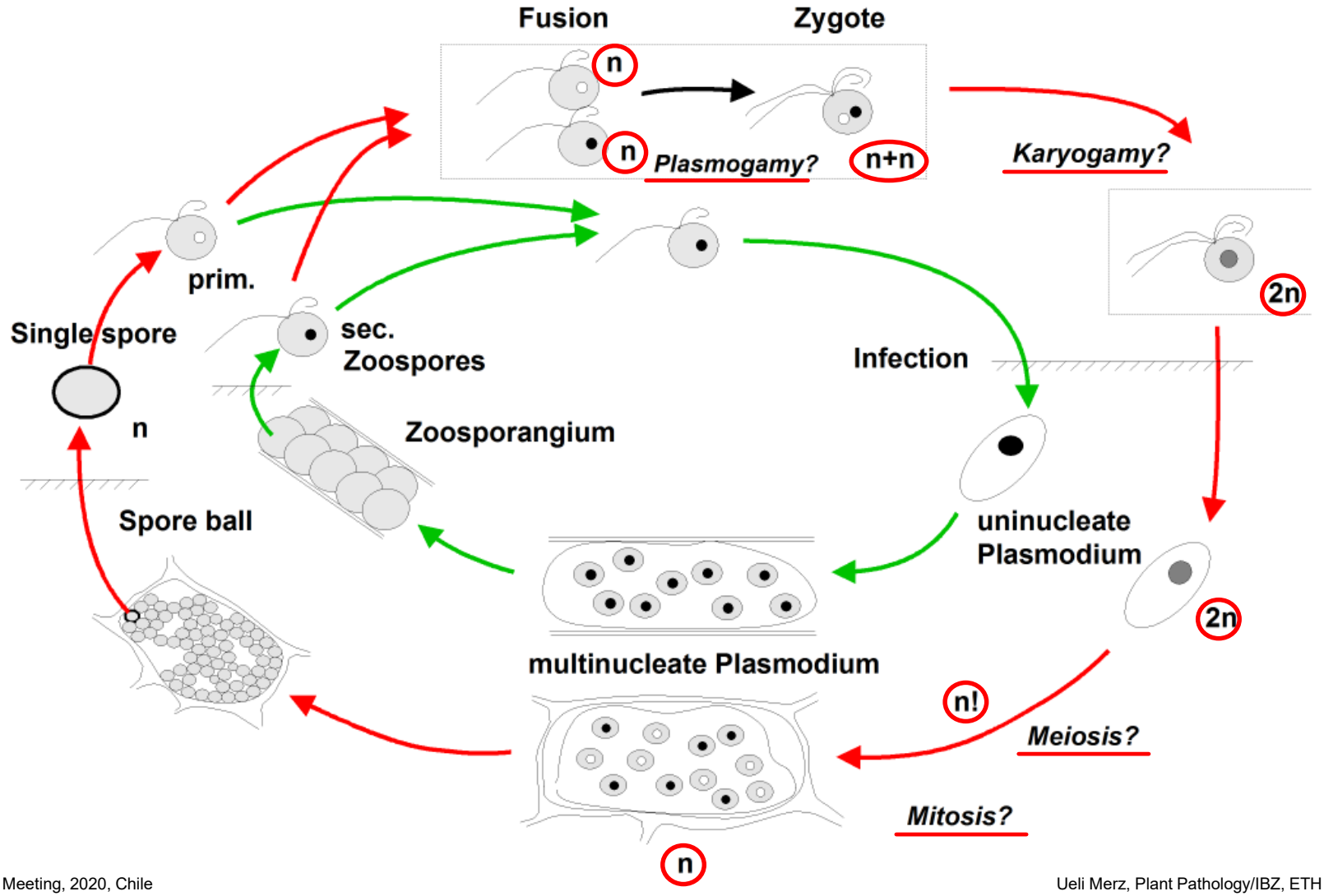
Ueli Merz, Plant Pathology/IBZ, ETH Zurich

Sarna polvorienta (Powdery scab) y Agallas (Root galls) de la papa are both caused by

Spongospora subterranea

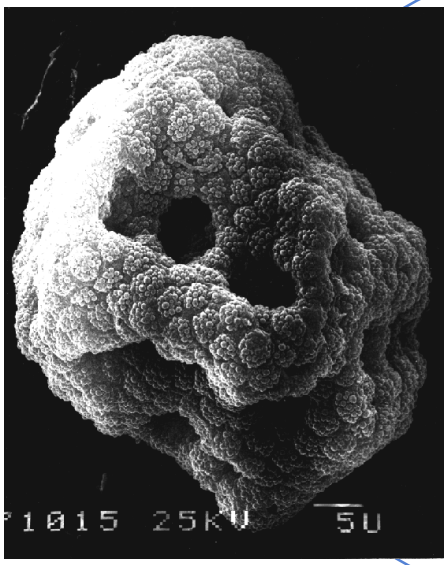
a protozooan organism living in the soil

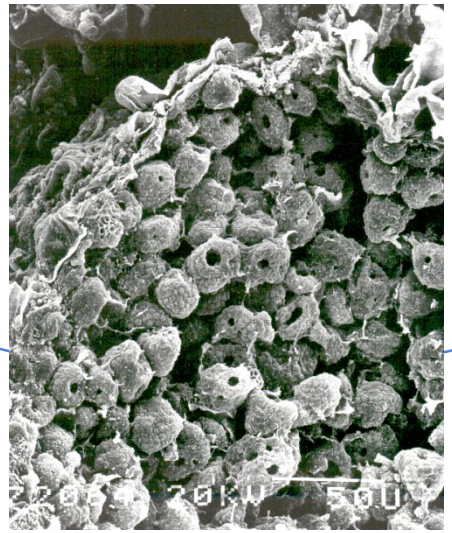
S. subterranea: (hypothetical) Life cycle



S. subterranea
Life cycle part I

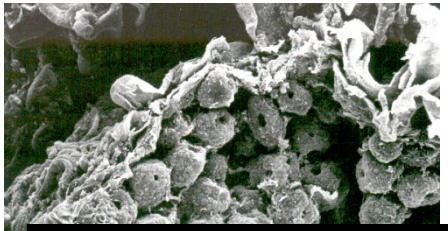
Survival:
production of
resting structures

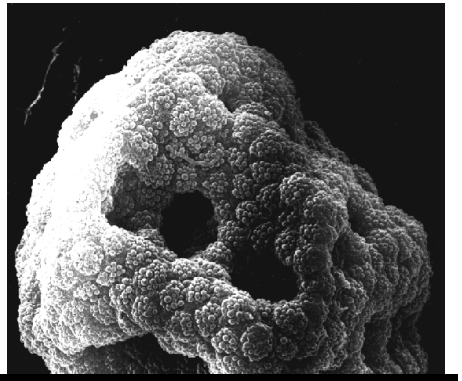


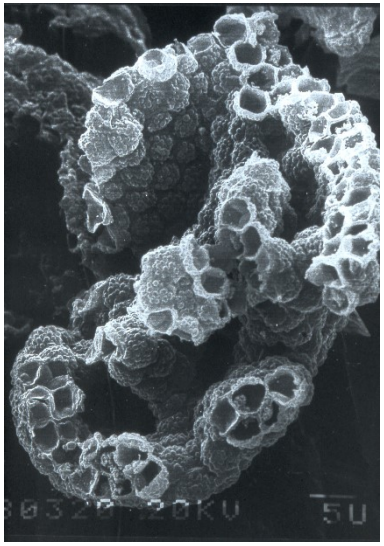


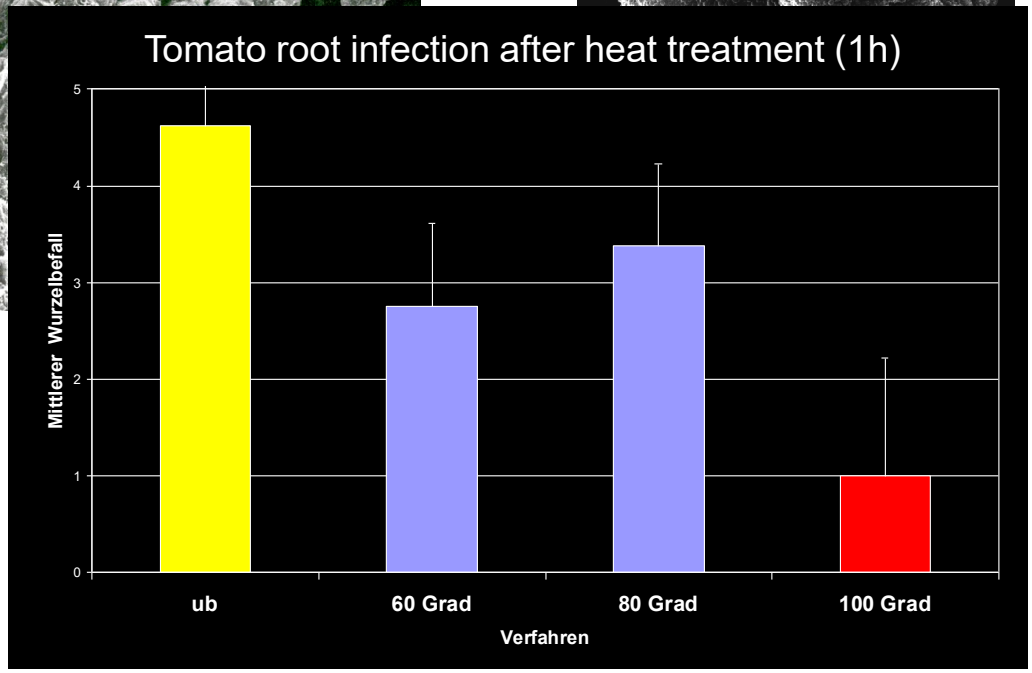
Sporosorus /
Restingsporeball

Survival structure: Sporosorus



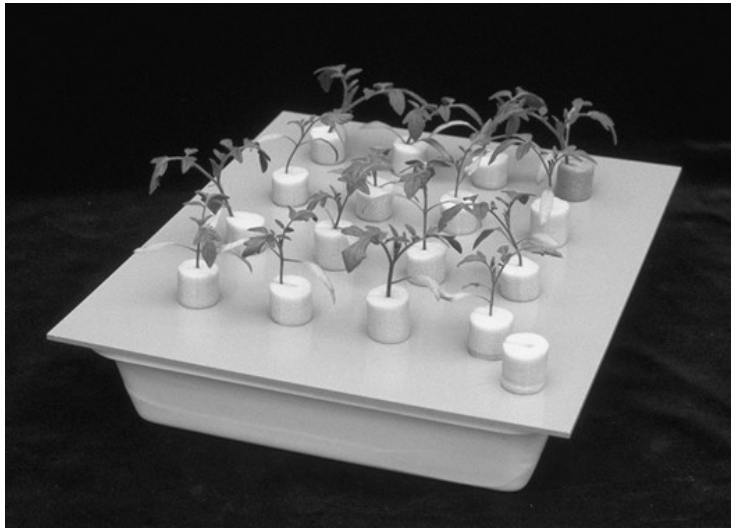






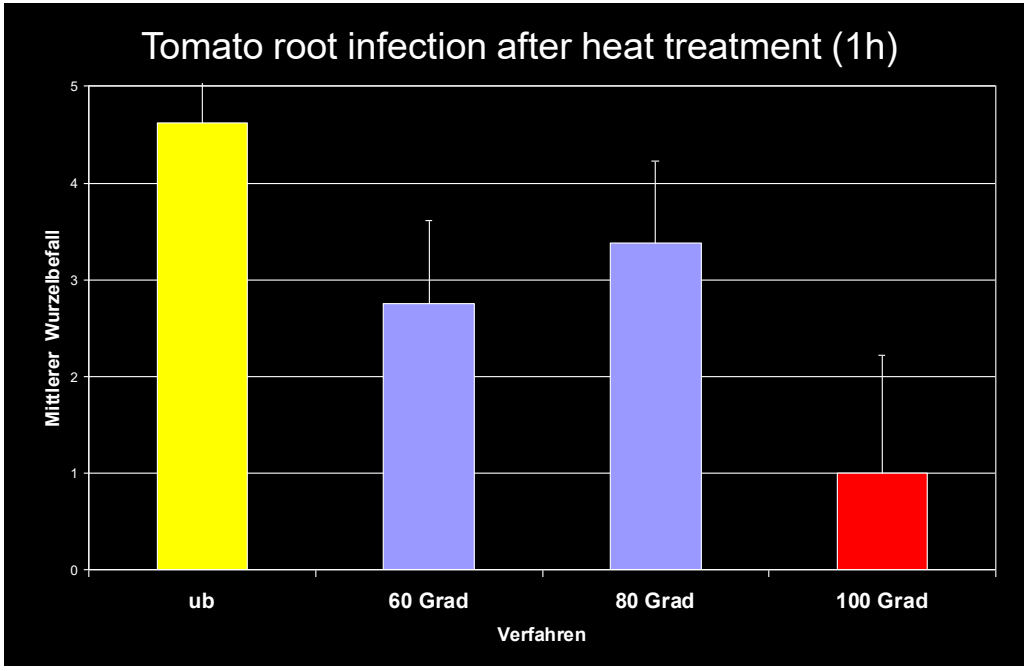
- **500-1000 single spores**
- **Viability: > 10 Jahre**
- **Very resistant to environ-mental stresses**

Very resistant to environmental stresses

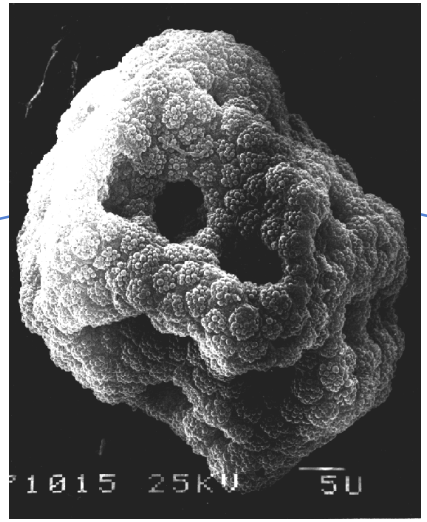


Bioassay with tomatoes

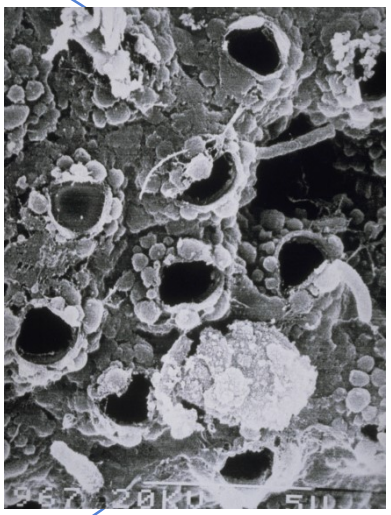
Heat treatment of sporosori



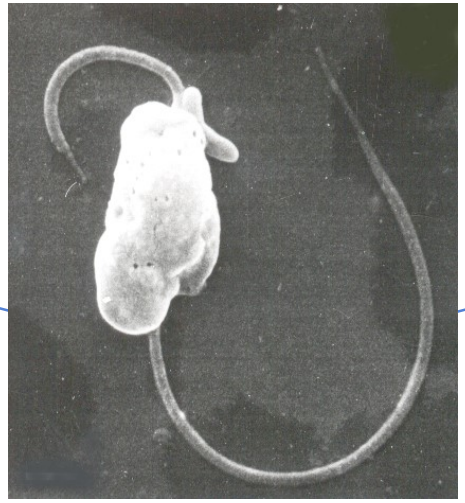
S. subterranea
Life cycle part II



Host infection

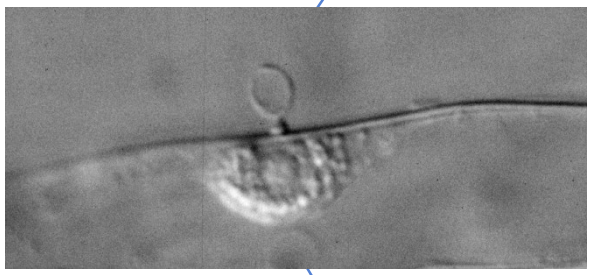


Zoospores emerge

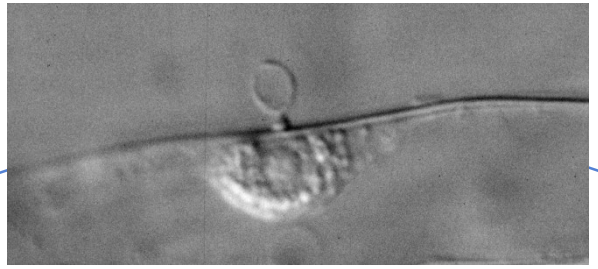


Prim. zoospore

Host infection

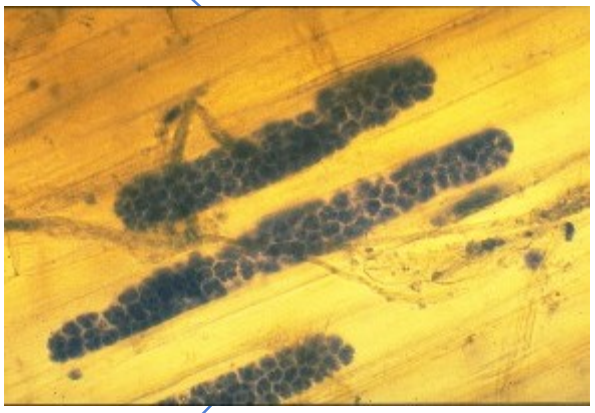


S. subterranea
Life cycle part III

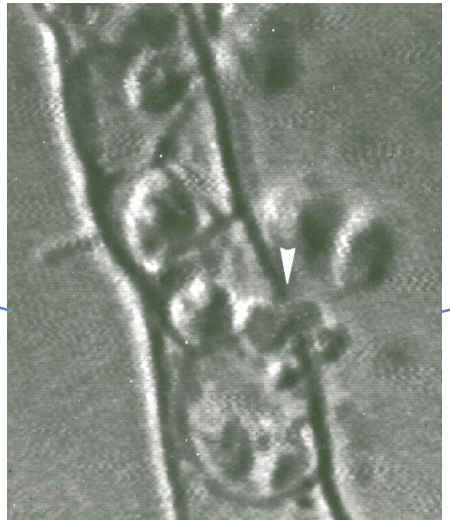


Multiplication

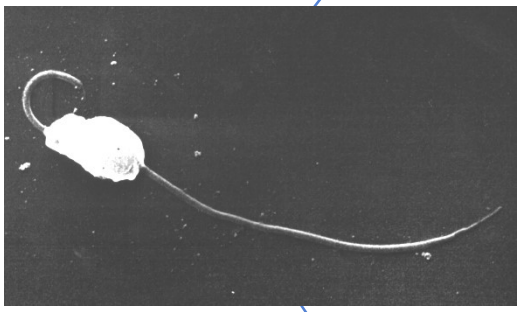
Zoosporangia



in the roots



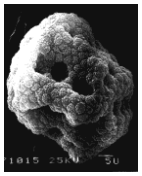
Zoospores emerge

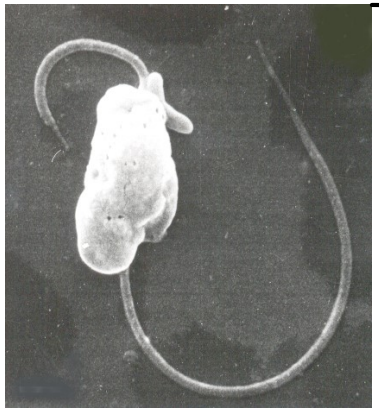


Sec. zoospore

Spread with zoospores

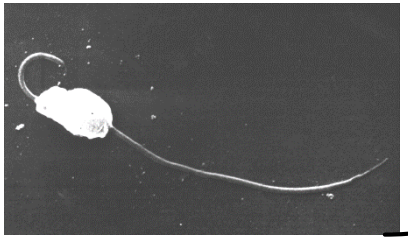
Primary from sporosori





Need free water to swim

Secondary from sporangia



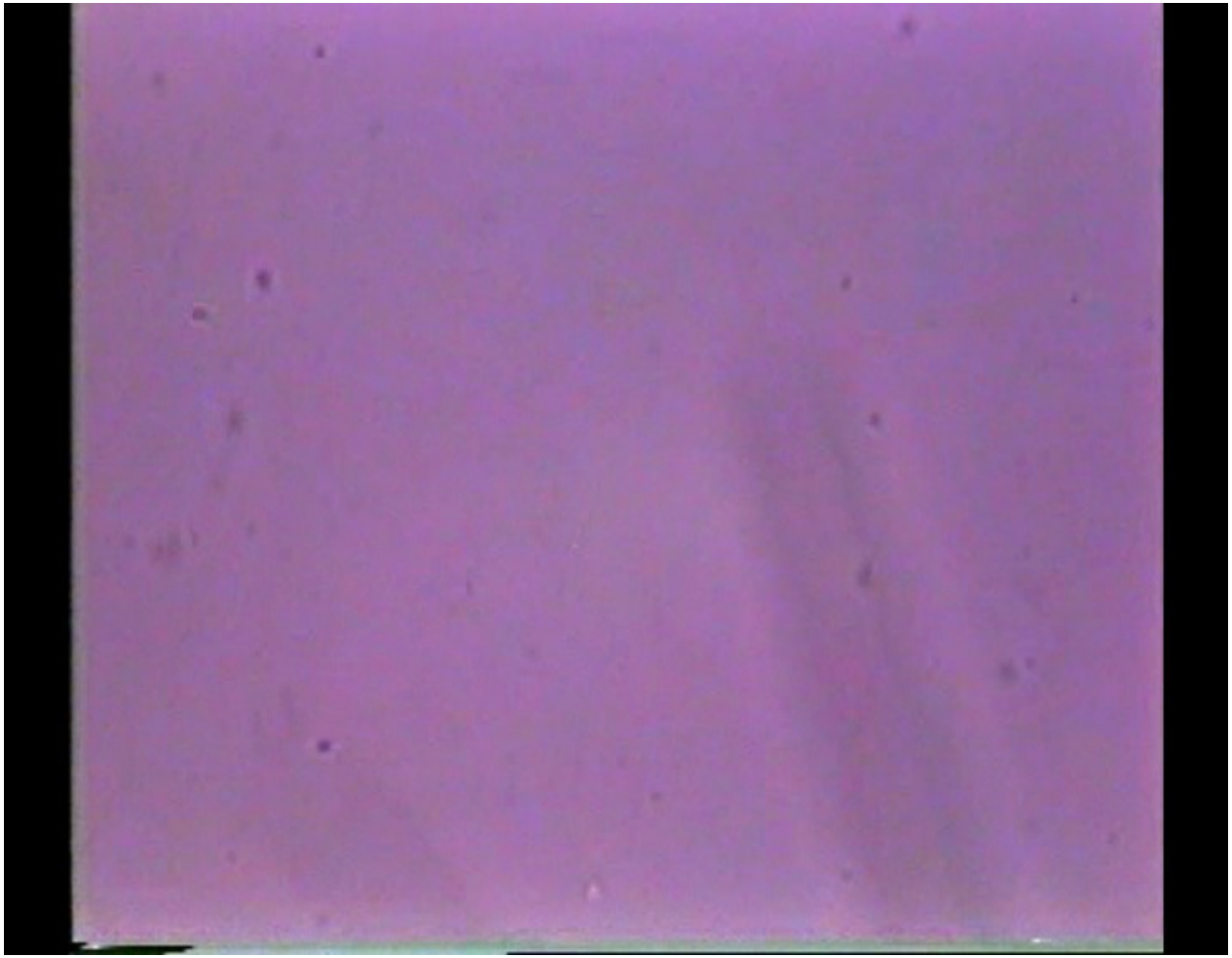
Infection

Powdery scab

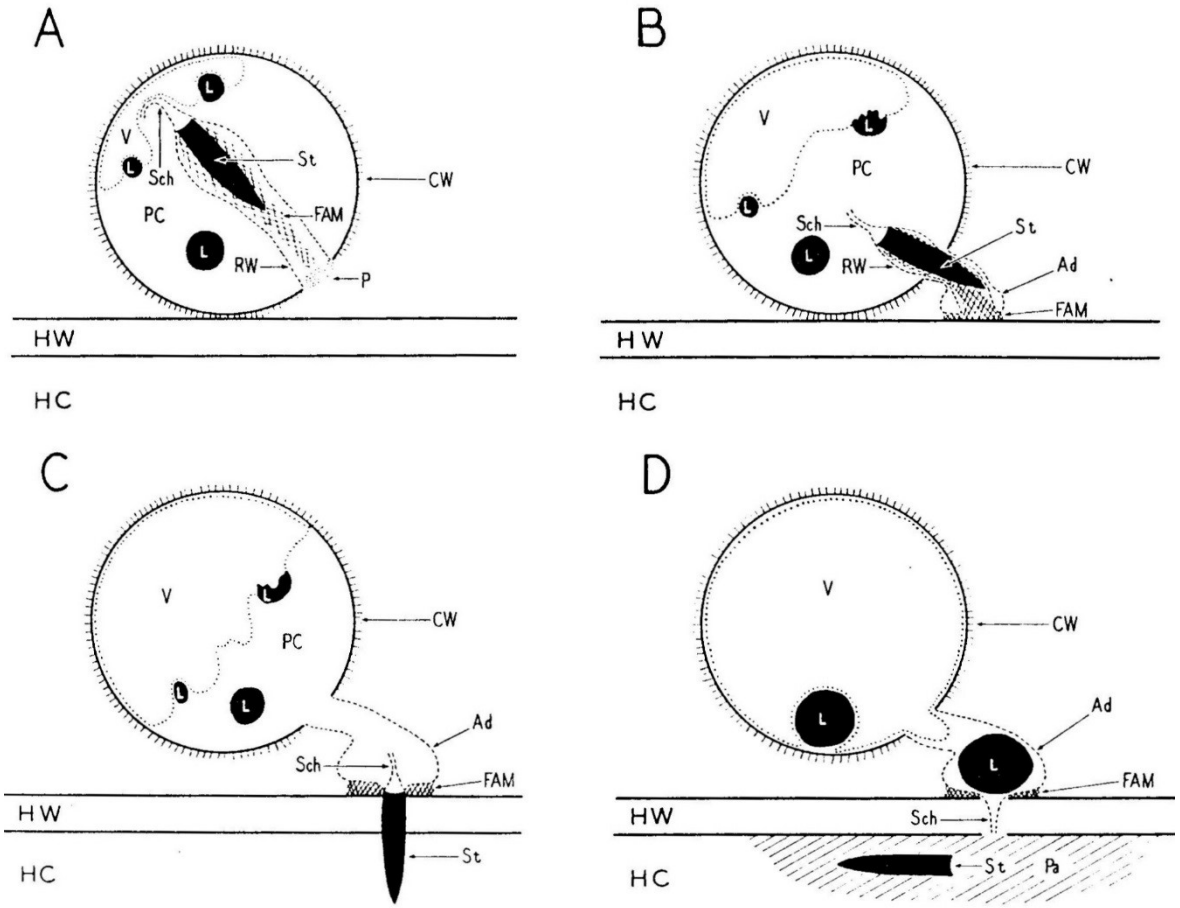
Root galls

Zoosporangia

Swimming zoospores

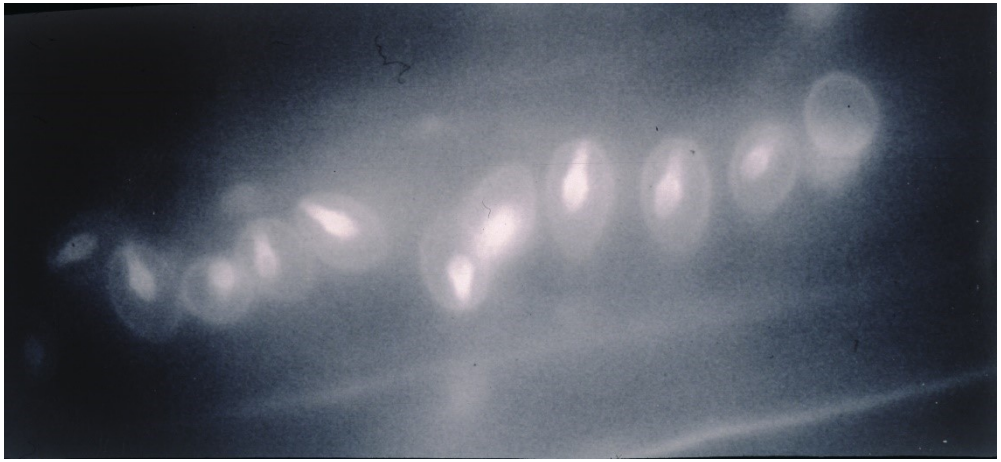


Unique Host Cell Penetration Mechanism



Aist and Williams, 1971

Unique Host Cell Penetration



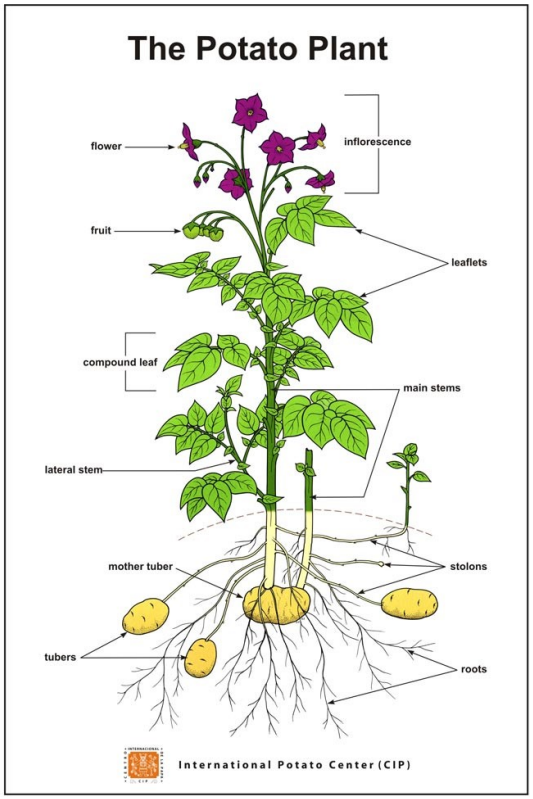
Encysted zoospores with penetration structure (‘Rohr’)

First post-infection stage: Plasmodium with one nucleus

Spongospora subterranea causes two diseases

on botanically different plant parts – tuber vs root - with different genetic background of resistance

Powdery scab (tuber) damage

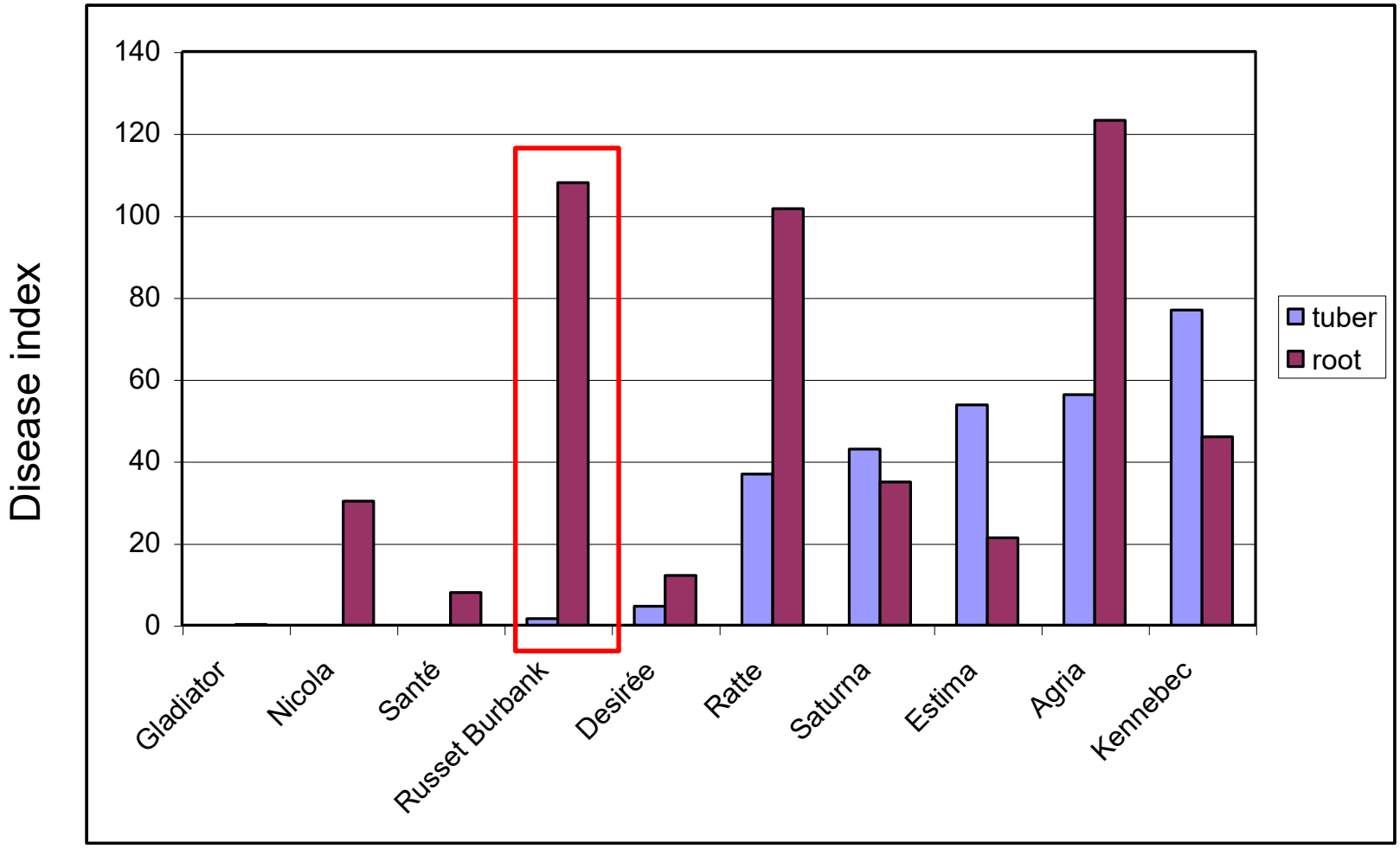


- Quality problem (shelf)
- Processing: losses
- Storage: secondary pathogens/weight loss
- Huge losses for seed producers when lot is rejected

Root gall damage

- Yield reduction
- ‘Stealth’ inoculum production

Different genetic background of resistance



Resistance screening: LaFretaz, CH, 2004

Plant Pathology (2015)

Doi: 10.1111/ppa.12419

Root infection of potato by *Spongospora subterranea*: knowledge review and evidence for decreased plant productivity

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[a]*The New Zealand Institute for Plant & Food Research Limited, PB 4704, Christchurch 8140;* [b]*Bio-Protection Research Centre, Lincoln University, PO Box 85084, Lincoln 7647, New Zealand; and* [c]*ETH Zurich, Plant Pathology/IBZ, Universitätstr. 2, CH-8092 Zürich, Switzerland*

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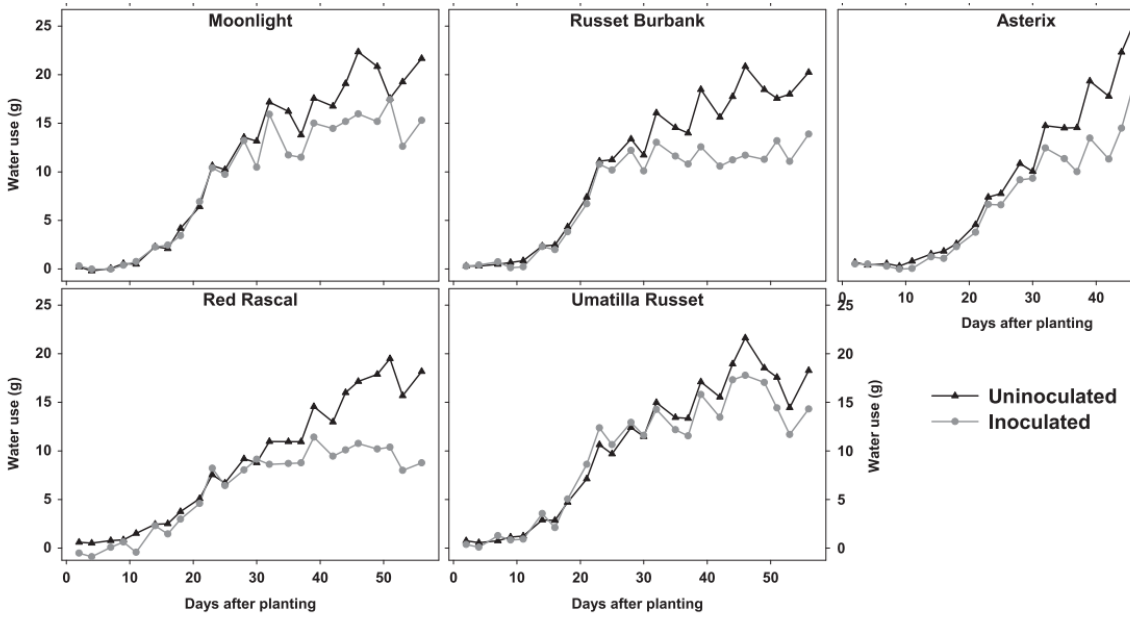

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Root galling: Yield reduction

Resistance to Root Galling Caused by the Powdery Scab Pathogen *Spongospora subterranea* in Potato 2008

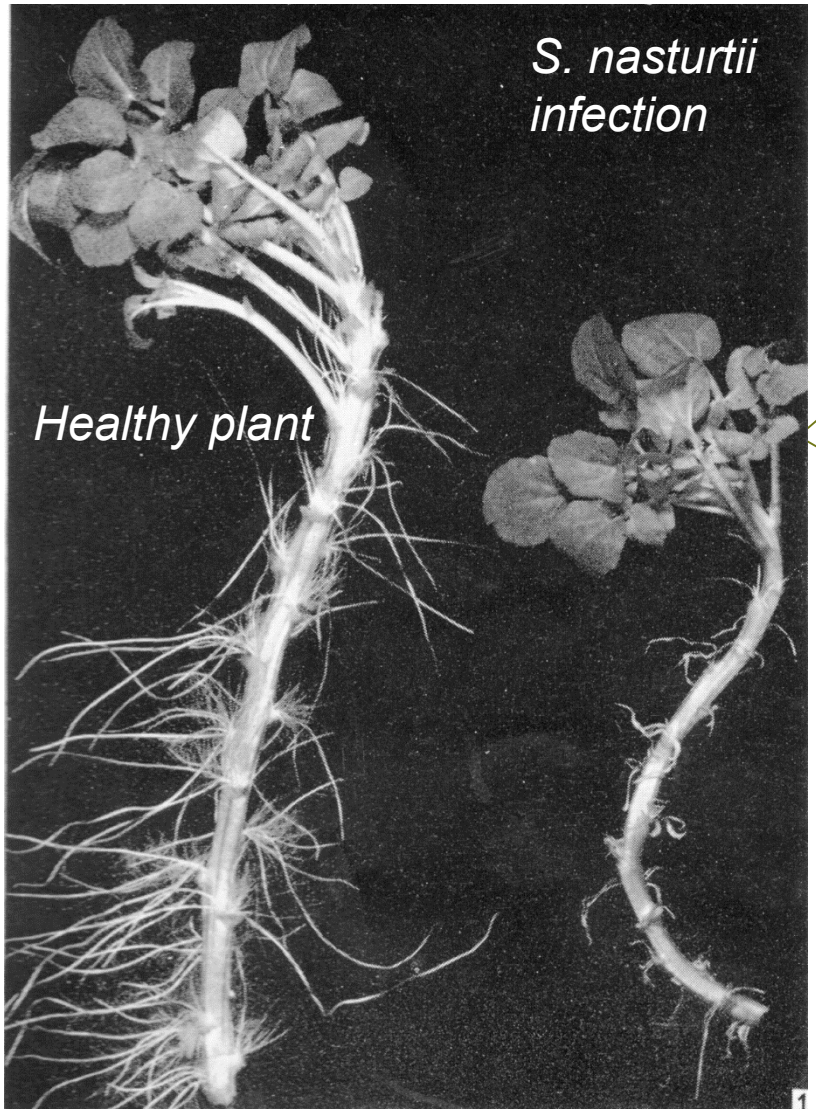
Nadav Nitzan, USDA-ARS, Prosser, WA 99350; **Tom F. Cummings** and **Dennis A. Johnson,** Washington State University, Pullman, WA 99164; **Jeff S. Miller,** Miller Research, LCC., Rupert, ID 83350; **Dallas L. Batchelor,** Weather Or Not, Pasco, WA 99301; **Chris Olsen,** L.J. Olsen, Inc., Othello, WA 99344; **Richard A. Quick** and **Charles R. Brown,** USDA-ARS, Prosser, WA 99350

"The potato industry of Washington State is concerned with damage to roots caused by powdery scab and its potential to reduce yield weight in tonnage and affect tuber size and quality."

Vektor (transmission) of Mop-Top Virus

Spongospora subterranea (summary)

- Soilborne pathogen
- Survival structures (sporosori)
- Prim. / Sec. Zoospores
- Two diseases: Powdery scab / Root galls
- Damage: Tuber quality, seed lot rejection, reduced plant growth
- Vector of the Mop-Top Virus

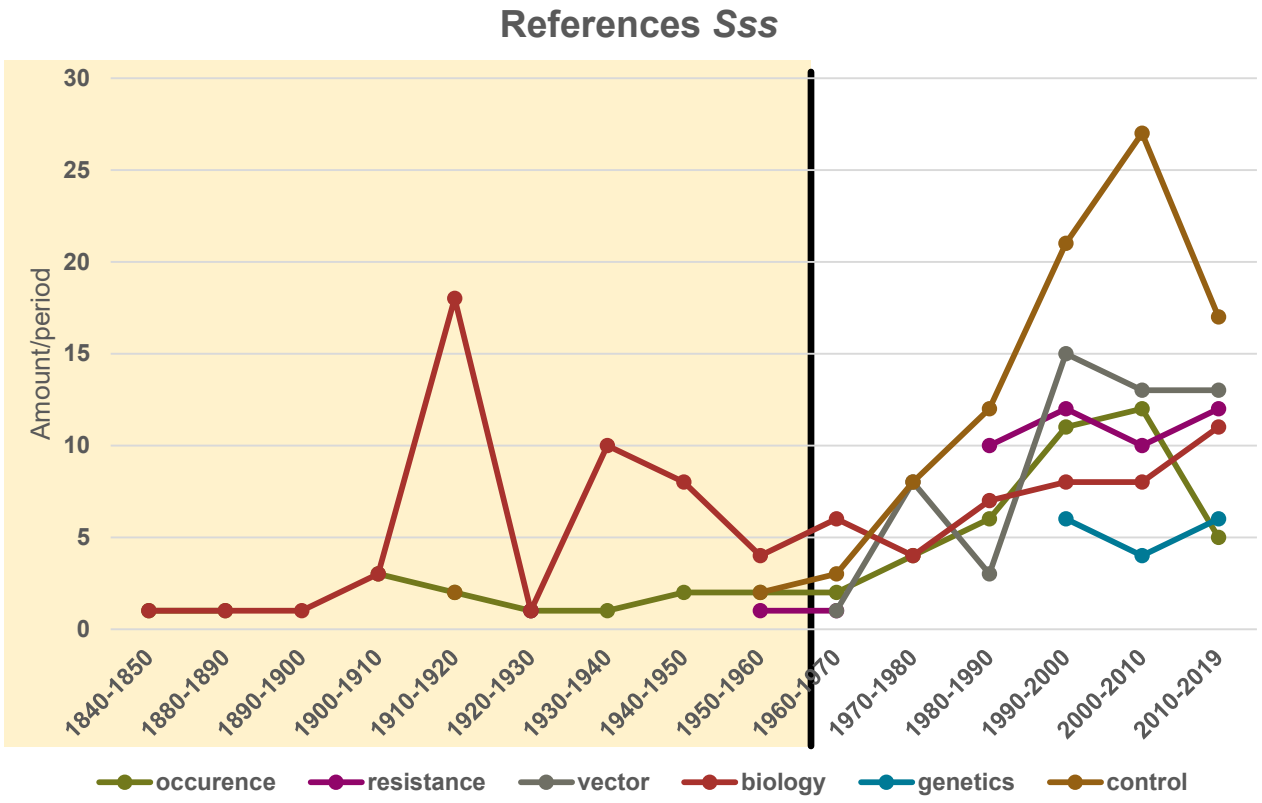


Spongospora subterranea

Spongospora nasturtii

Crook Root Disease of Watercress

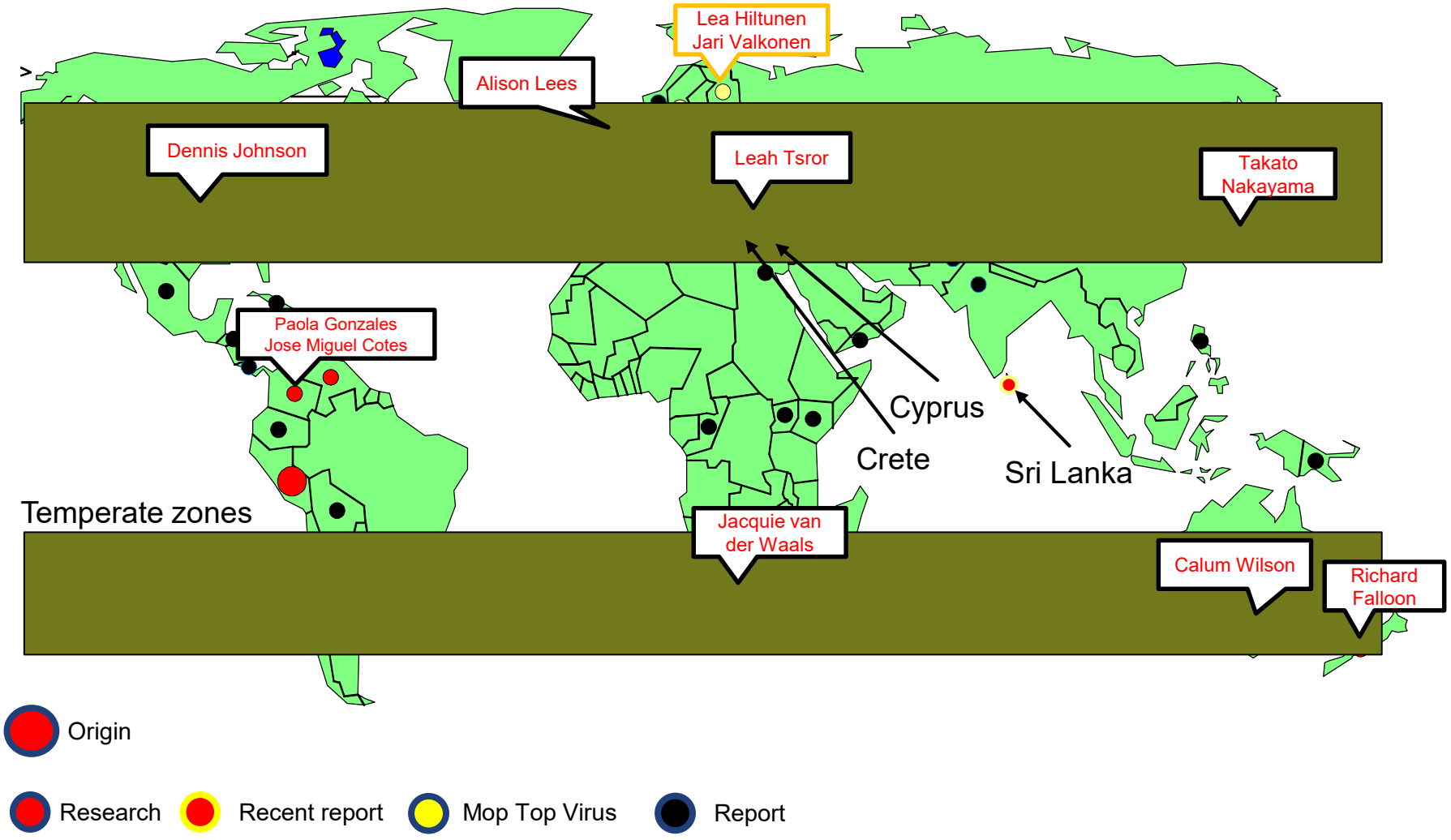
A lot of substantial knowledge of the biology (and epidemiology) of *S. subterranea* has been gathered before 1960!

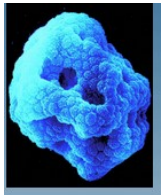


Reasons for increasing importance since 1970

- Increasing number of susceptible cultivars
- Cropping intensity (reduced crop rotation)
- Cultural practices (minimal tillage)
- Irrigation (global warming)
- Ban of Mercury (good control of ‘soilbornes’)
- Ware potatos washed
- Negligence.....

Spongospora worldwide





HOME
How to get there
Registration
Program
Participants
Group picture
WS pictures

Back to Workshops

3rd International Powdery Scab Workshop

July 17 - 21, 2016

Einsiedeln, Switzerland

Hotel Allegro

http://www.hotel-allegro.ch/en/home/

Participants of 12 countries:
China
Deutschland
Finland
Frankreich
Netherlands
Israel
Kolumbien
Neuseeland
Südafrika
Schweiz
USA
UK

PLANT CLEAN SEED INTO CLEAN SOIL

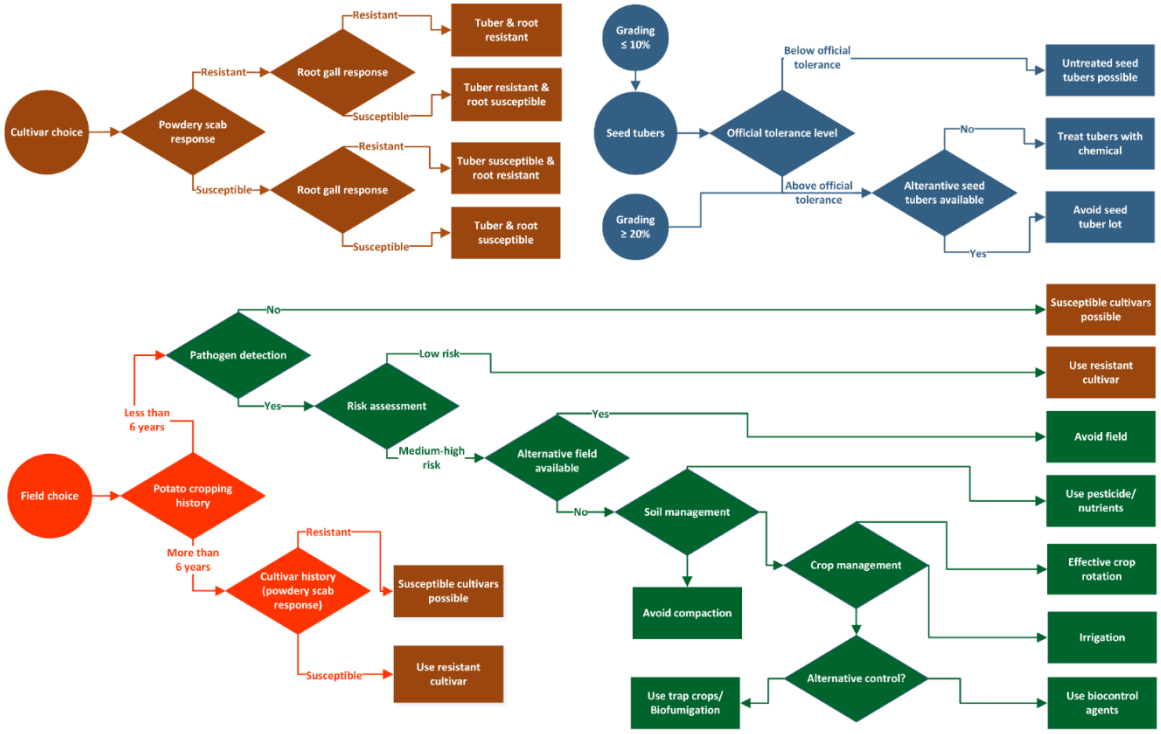
Current knowledge of *S. subterranea* and epidemiology of the diseases it causes allows formulation of grower guidelines based on integrated disease management options

Host resistance

Seed tuber quality

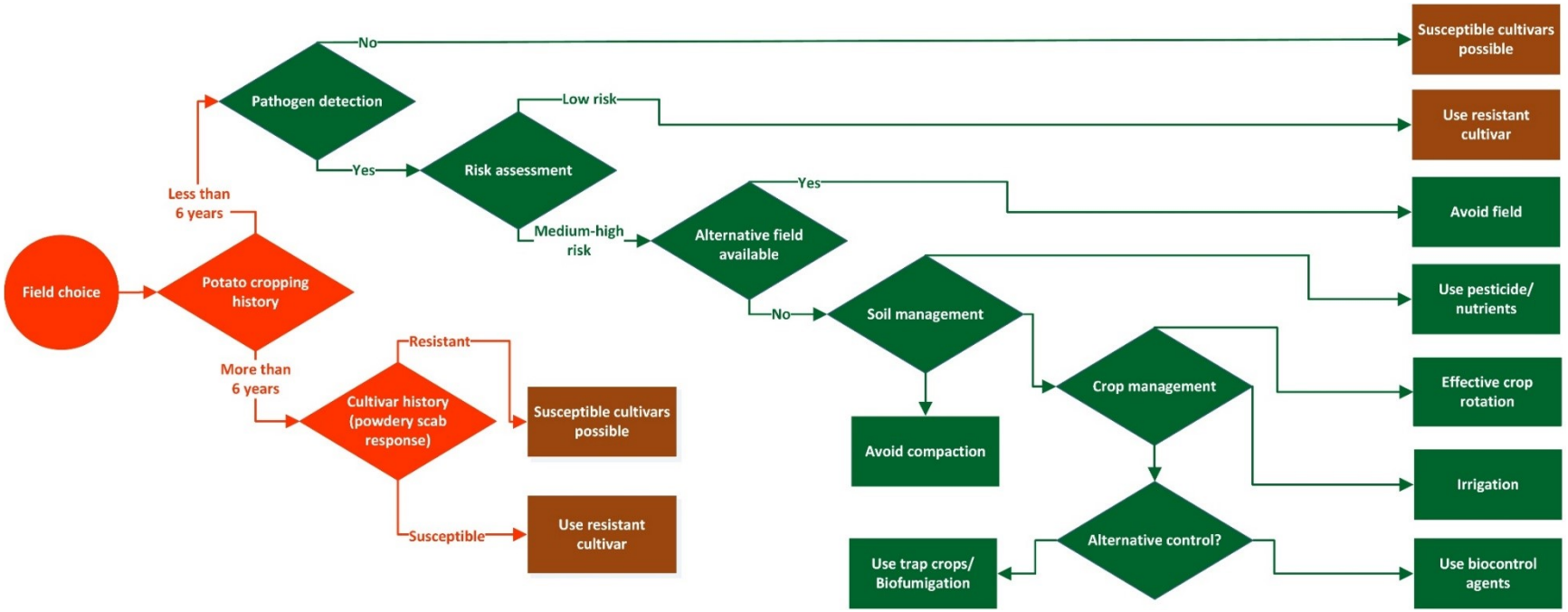
Field history

Control measures

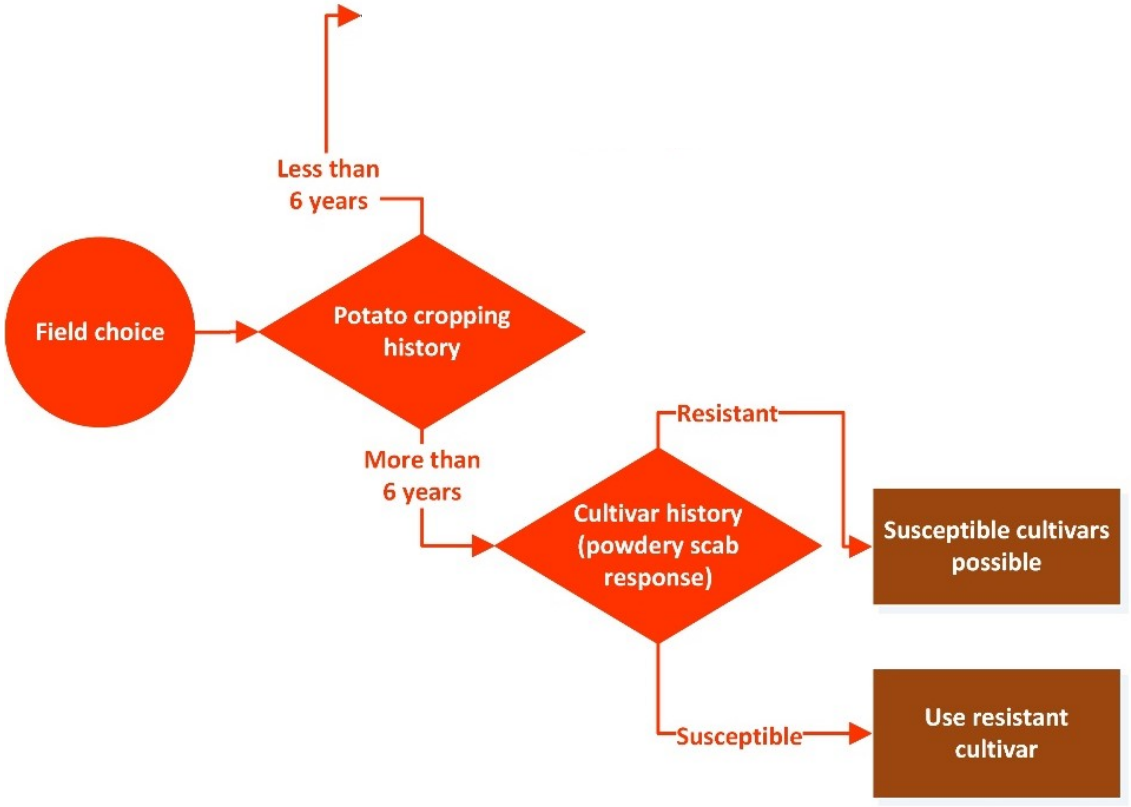


Merz U. and R. Falloon eds. (2017). Proceedings of the 3rd International Powdry scab Workshop, Einsiedeln, Switzerland, July 18-21, 2016. Potato Research 60(2), 195-215.

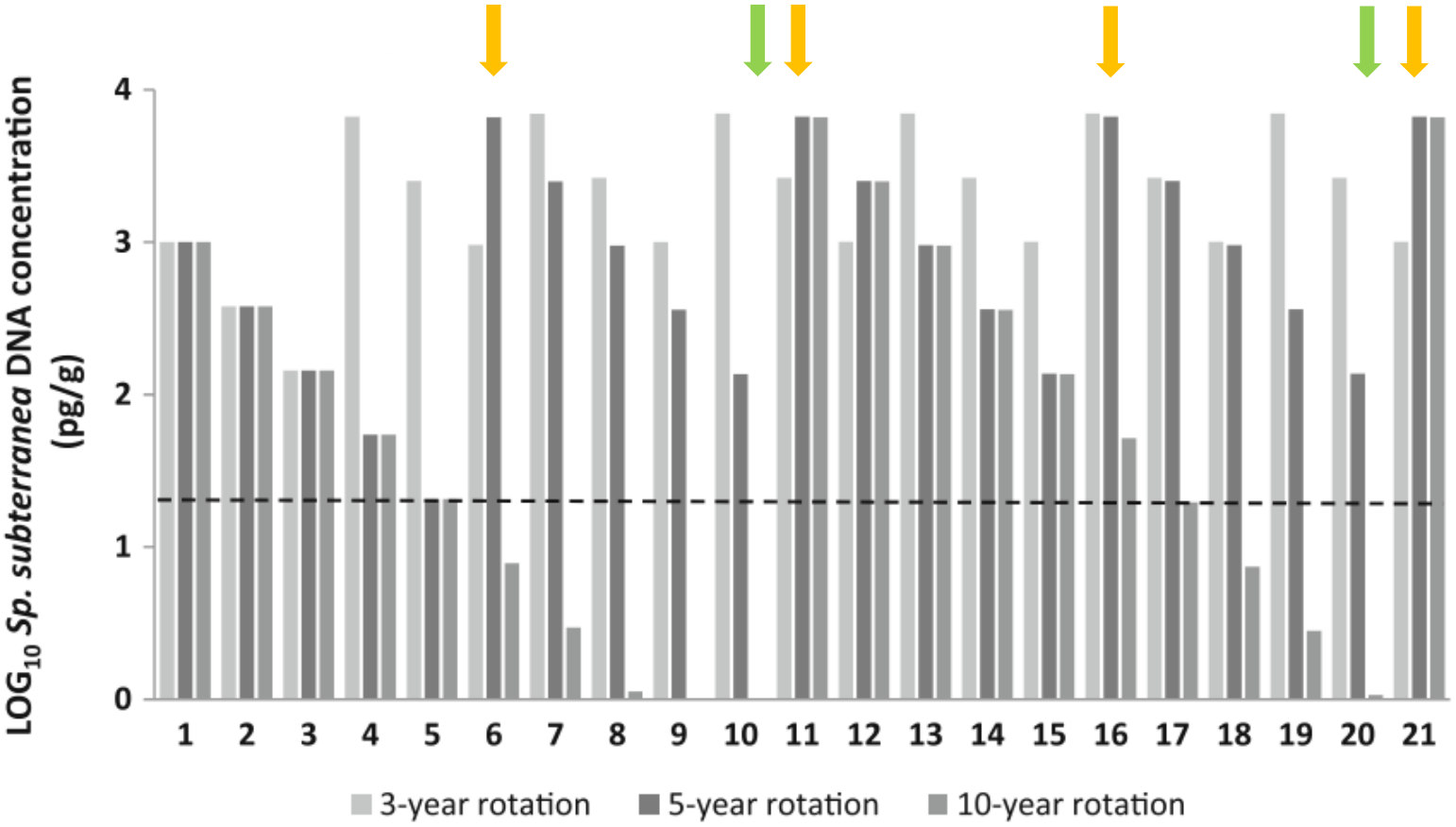
The Soil: Field history and control measures



Field history (</> 6 years)

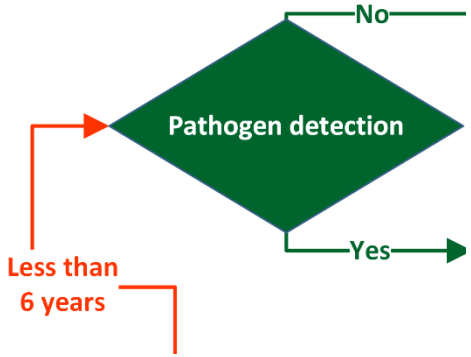


The soil: History of potato cropping (>6 Years)



Sparrow et al, 2015, Australasian Plant Pathology

The soil: Contamination test and disease risk



Sampling procedure (commercial test in Scotland)

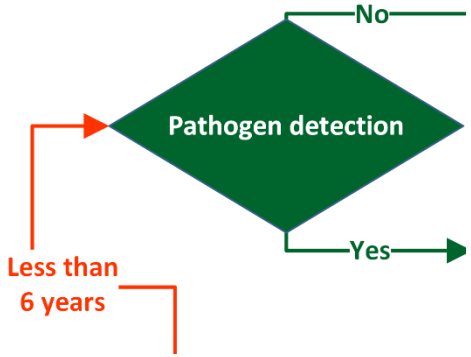
- max 4ha
- 100 samples of 10g
- W-shape of sampling path
- Bulk: 60g for Q-PCR

Commercial tests - thresholds

SRUC

- **Low risk category**: Where Sss is undetected, provided sampling has been carried out correctly and seed planted is free of contamination, little if any powdery scab develops. This has been confirmed from grower feedback
- **Moderate risk category**: Where the test detects any Sss sporeballs (even if well below 1 sporeball/g soil) and up to 10 sporeballs/g there is a Moderate risk. Experience suggests under Scottish conditions commercial levels of disease can develop
- **High risk category**: Where the test detects >10 sporeballs/g the risk is high and experience has shown that even if conditions are sub-optimal, disease will occur

PREDICTA Pt: Soil contamination test in Australia

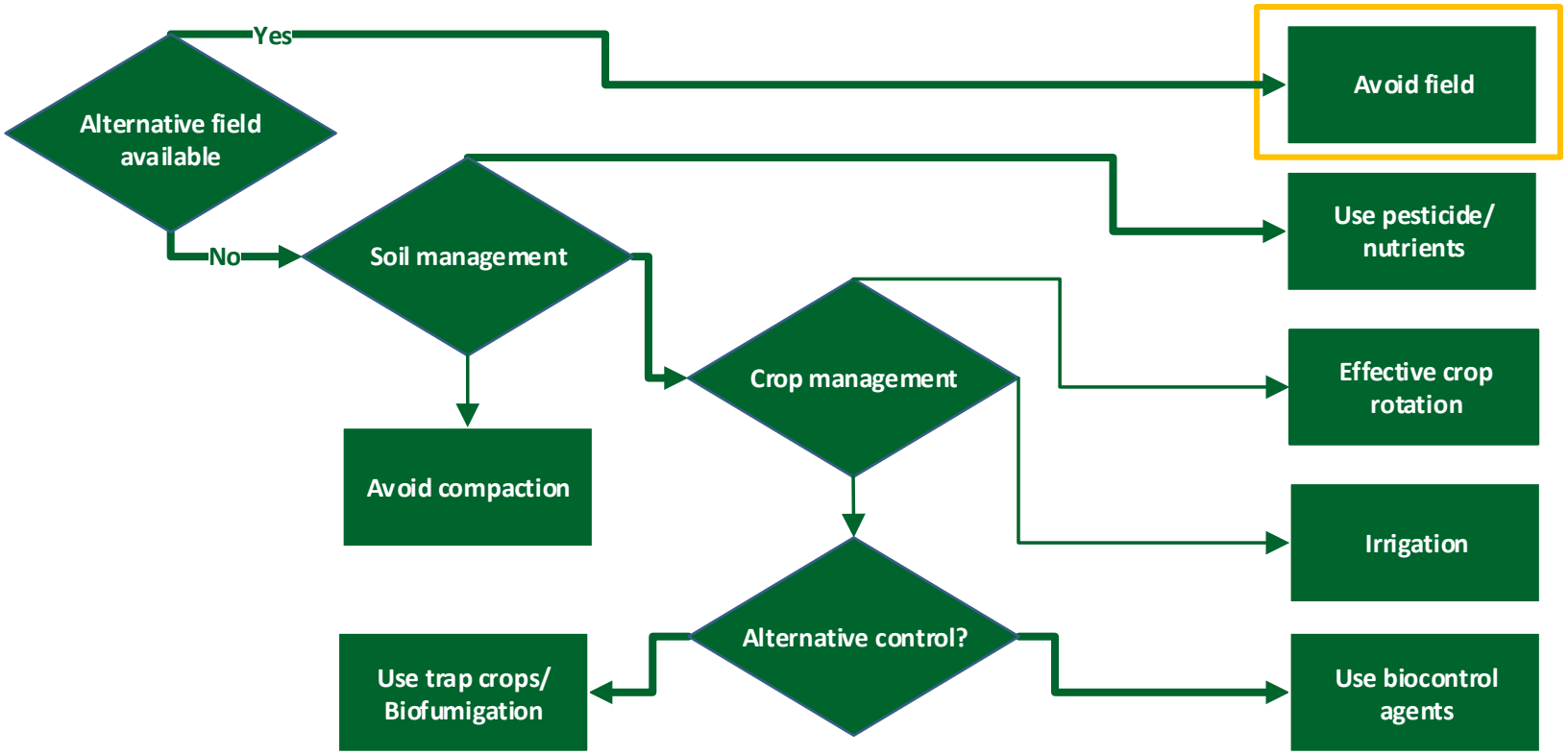


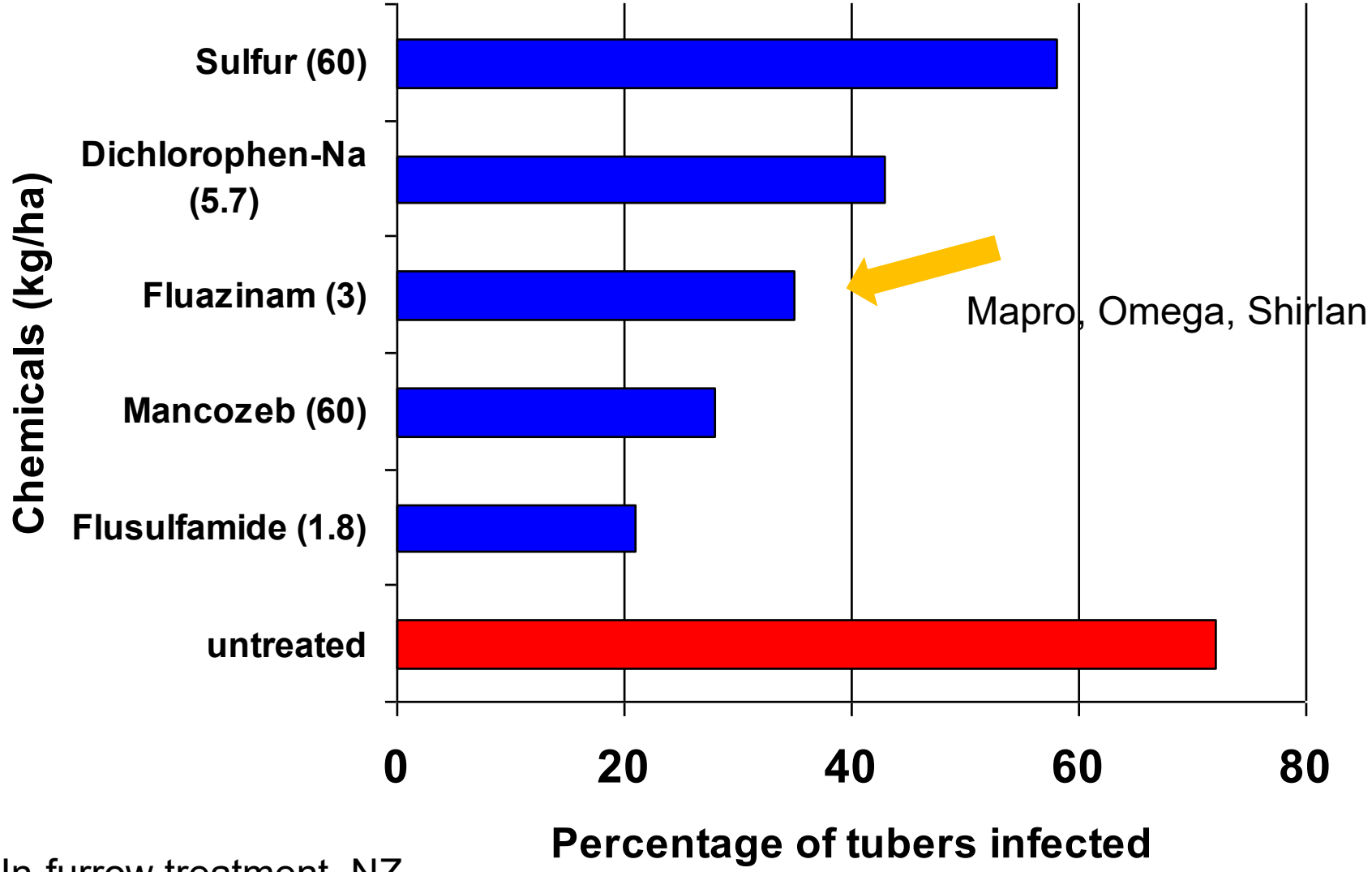
Disease risk:
- Powdery scab
- Black dot
- Root knot nematode

Population densities of:
- *Streptomyces* txtA gene
- *Rhizoctonia* AG 3+2.1
- *Verticillium dahlia*
- Nematodes
  - *Meloidogyne hapla*
  - 3 *Pratilenchus* species

The Soil: Disease risk 'none to low'

The Soil: Disease risk 'medium to high' – Agronomical measurements





In-furrow treatment, NZ

Nufarm | Find a Product | Our Products | Crop Management | Offers & Updates | Our Story | Contact

Nufarm New Zealand > Nando

Nando

HORTICULTURE

For the control of a wide range of diseases in grapes, field tomatoes, potatoes and vegetable brassicas.

Product Group: Fungicide
Active Ingredient: 500g/litre Fluazinam
Formulation: Suspension concentrate

Benefits of Nando:

- Nando is a a powerful protectant fungicide.
- It is a contact fungicide thus complete coverage of foliage is important.
- Nando is safe to use, has low mammalian toxicity and is non-volatile.

Nando used in Potatoes, Tomatoes and Brassicas:

As a foliar spray provides:

- superior sclerotinia control in potatoes and tomatoes
- excellent late blight control in potatoes and tomatoes
- very good control of early blight in potatoes

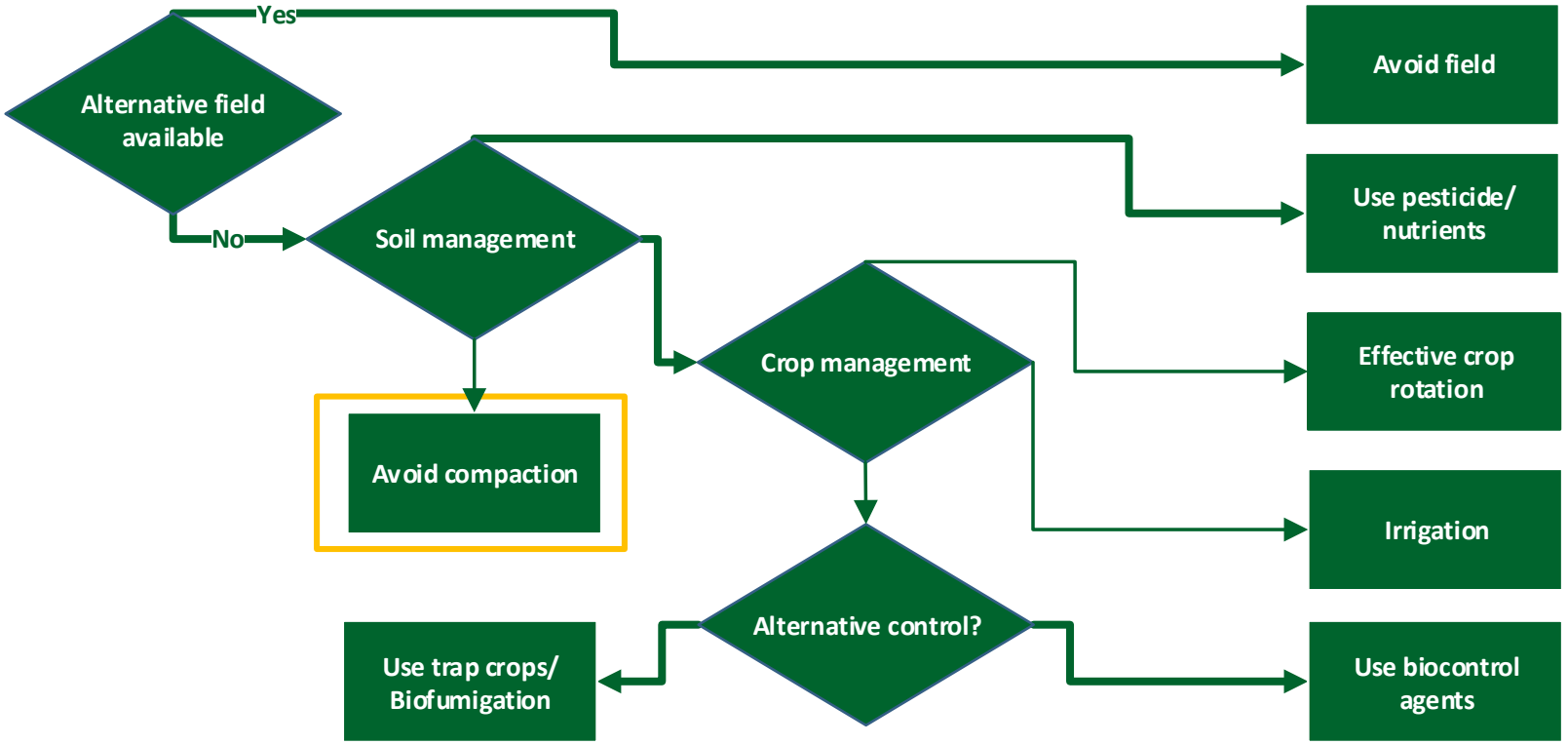
When pre-plant incorporated into the soil provides:

- extremely effective protection against powdery scab of potatoes
- extremely effective reduction in severity of club root in brassicas

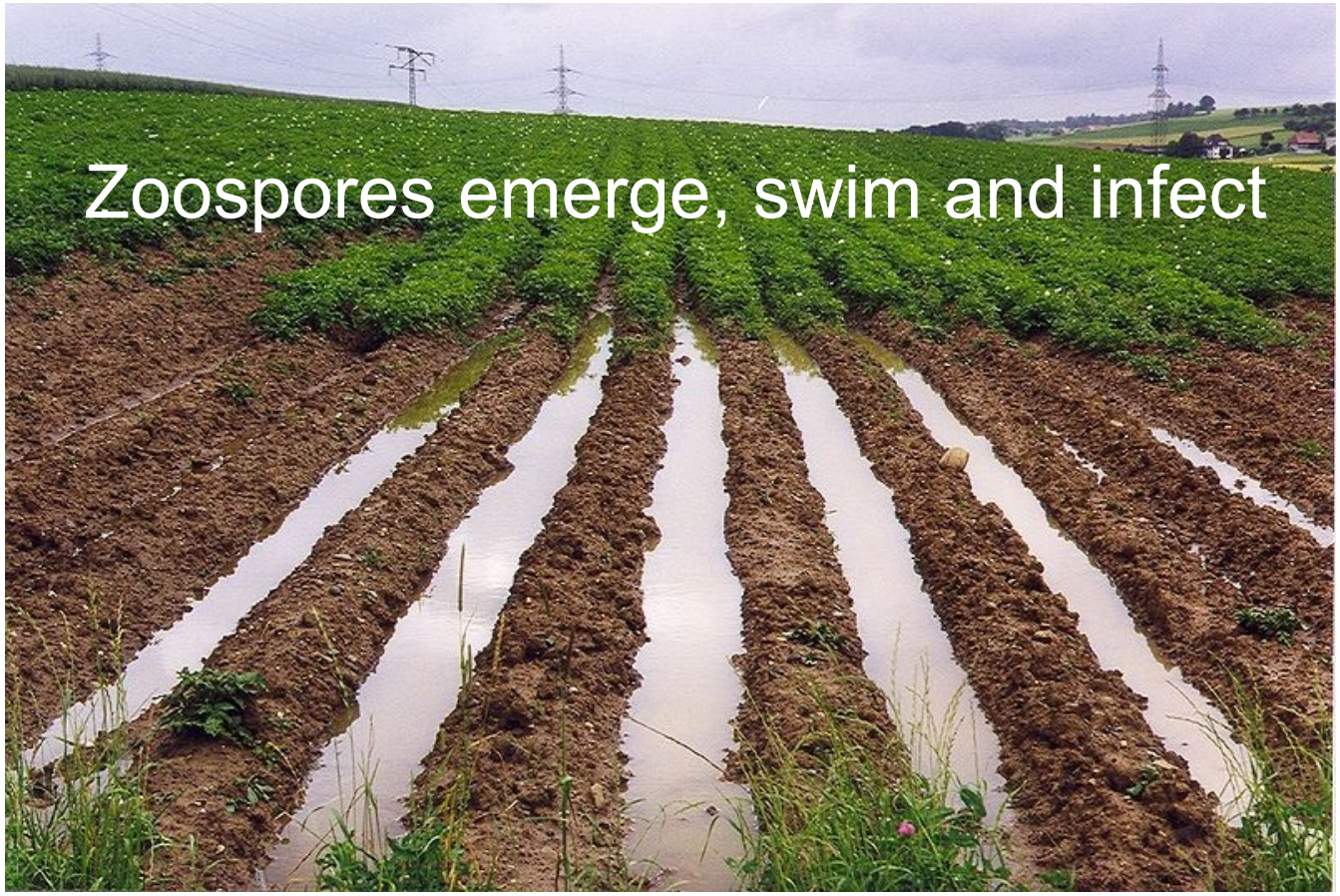
Download Label | Download HazNote | Download MSDS

https://nufarm.com/nz/product/nando/

The Soil: Disease risk 'medium to high' – Agronomical measurements



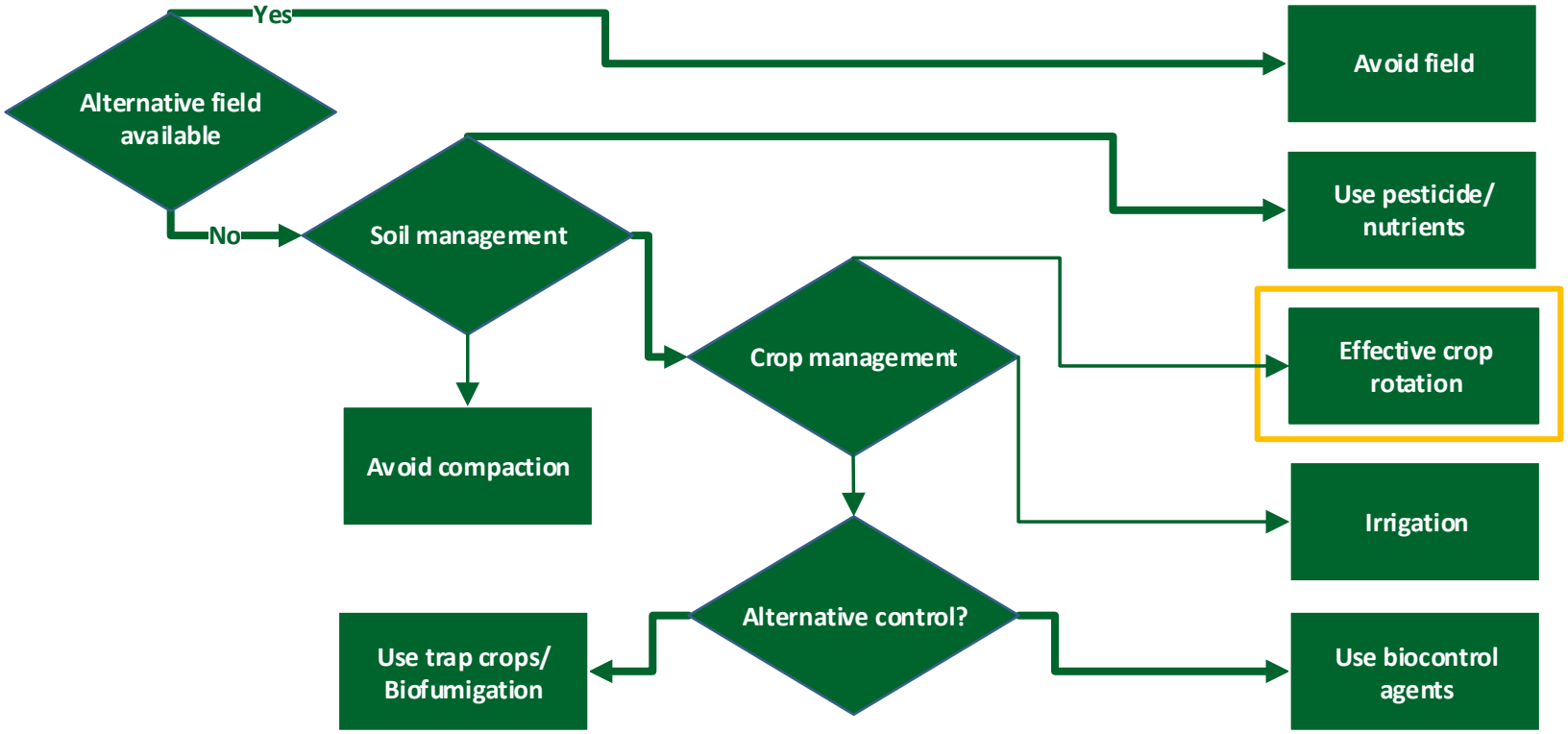
Avoid compaction → Waterlogging



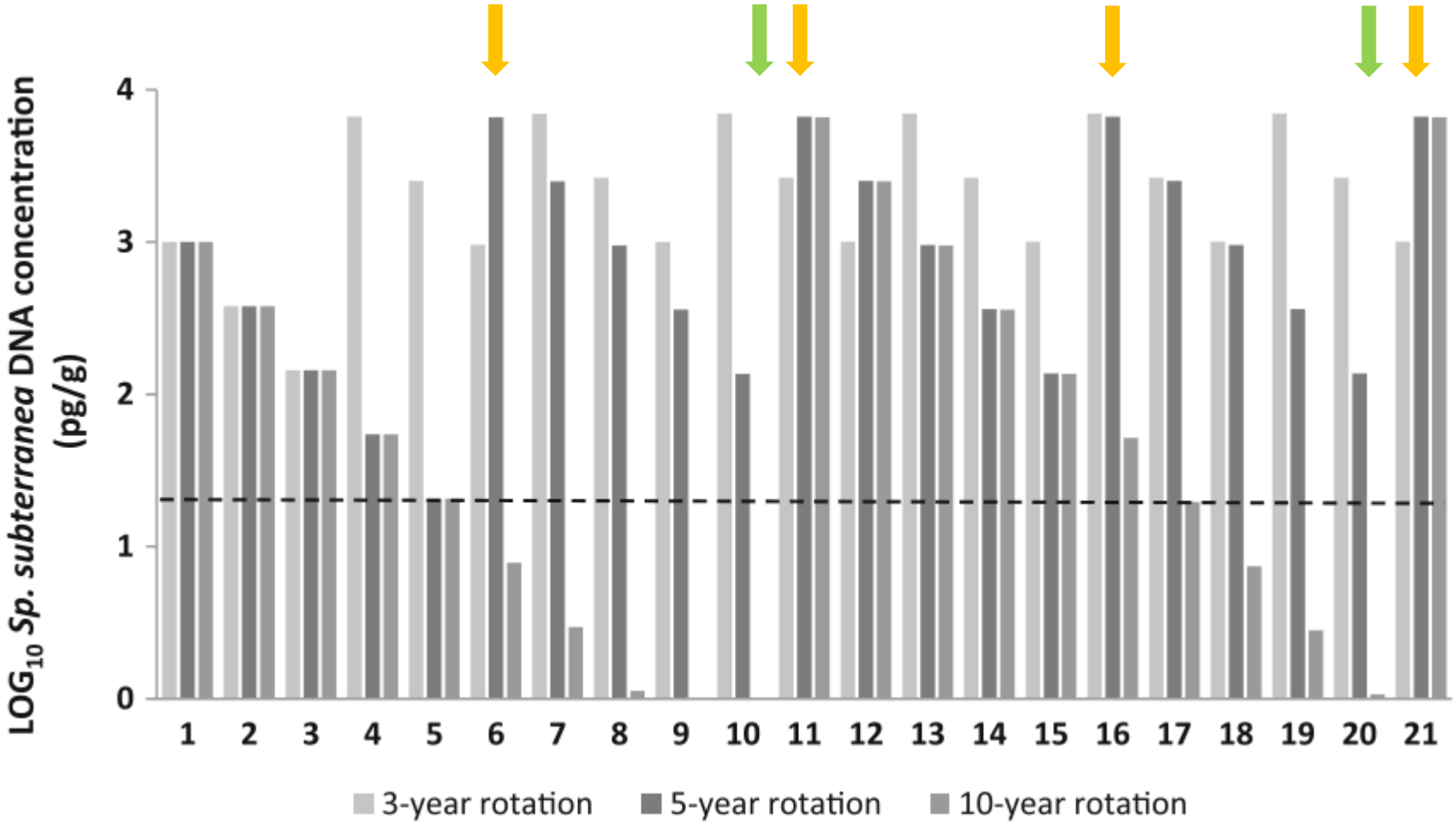
Proliferated lenticells are susceptible for infection

Photo Source: D. Johnson

The Soil: Disease risk 'medium to high' – Agronomical measurements



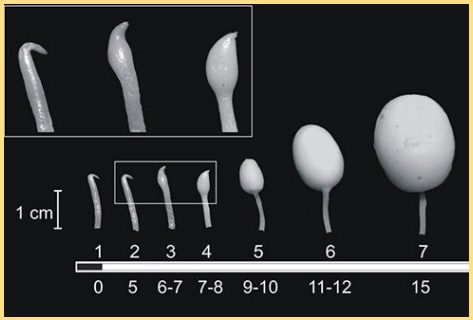
Crop Rotation

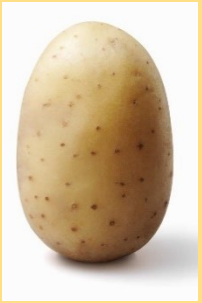


Sparrow et al, 2015, Australasian Plant Pathology

Control of *S. subterranea*, boost of *S. scabiei*

Tuber Initiation





about 6 weeks after planting

for 4-5 weeks

until tubers 25-30mm

The Soil: Alternative ‘Biocontrol’

Journal of Plant Diseases and Protection
April 2004, Volume 111, Issue 2, pp 145–150 | Cite as

Two *Trichoderma harzianum-based* bio-control agents reduce tomato root infection with *Spongospora subterranea* (Wallr.) Lagerh., f. sp. *subterranea*, the vector of *Potato mop-top virus*

Authors Authors and affiliations

S. L. Nielsen ✉, J. Larsen

Use biocontrol agents

The Soil: Alternative 'Biofumigation' with Indian mustard (*Brassica juncea*)

Use trap crops/
Biofumigation

"Biofumigation has saved what we do. Because we haven't got the broad range of crops to grow we had to find a better way of growing potatoes in a quick rotation."

"People always want to plant something they can get money off, and this stuff doesn't. They're happy to go and buy a drum of Nemacur and Roundup type products and kill something, but this (brassica planting) is long-term thinking."

Darren Long, MG Farm Produce, Tasmania

The Soil:

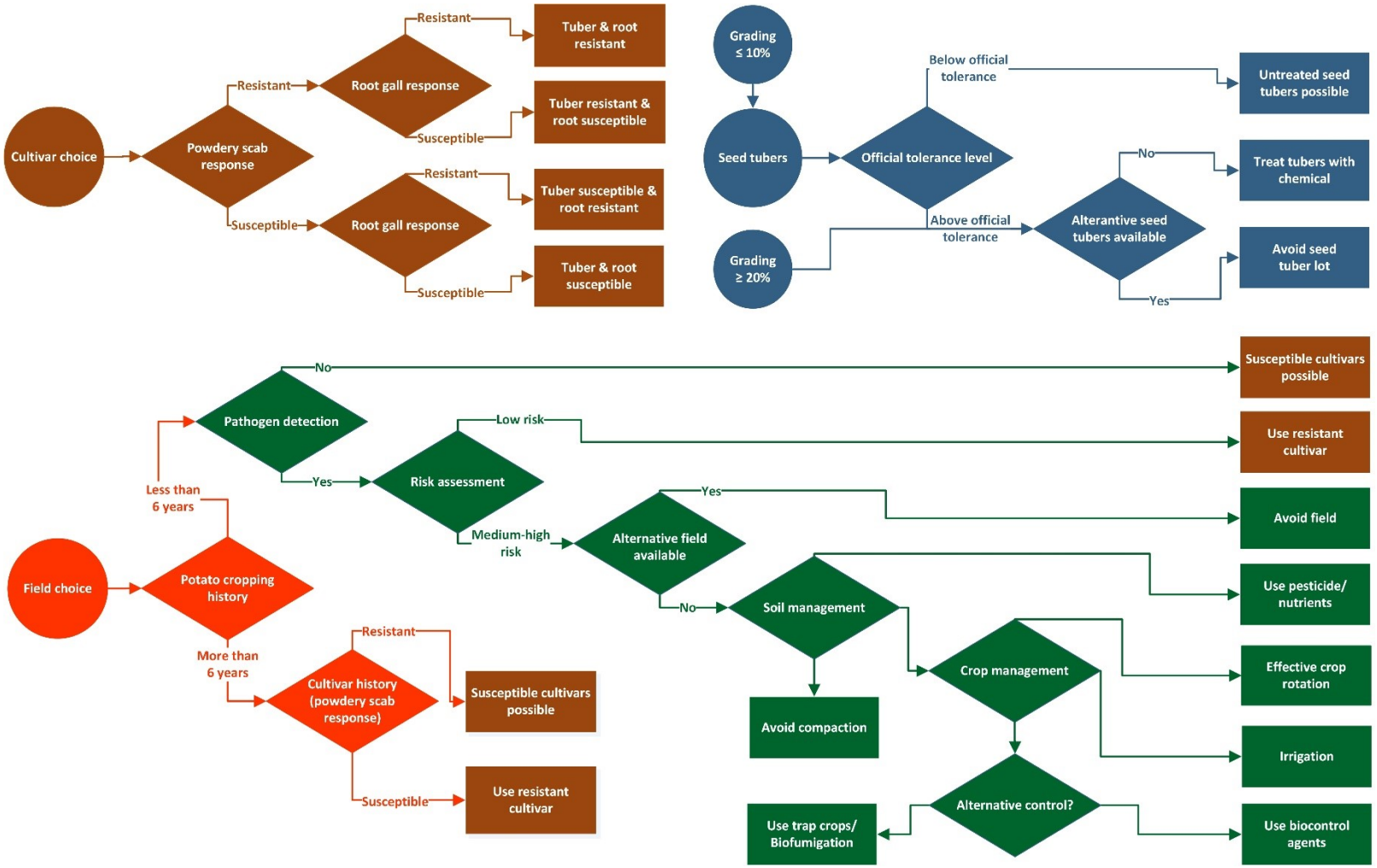
Most important for crop disease

A soil, once contaminated, stays infectious for many years

Contaminated soil can also spread the disease, e.g. machinery

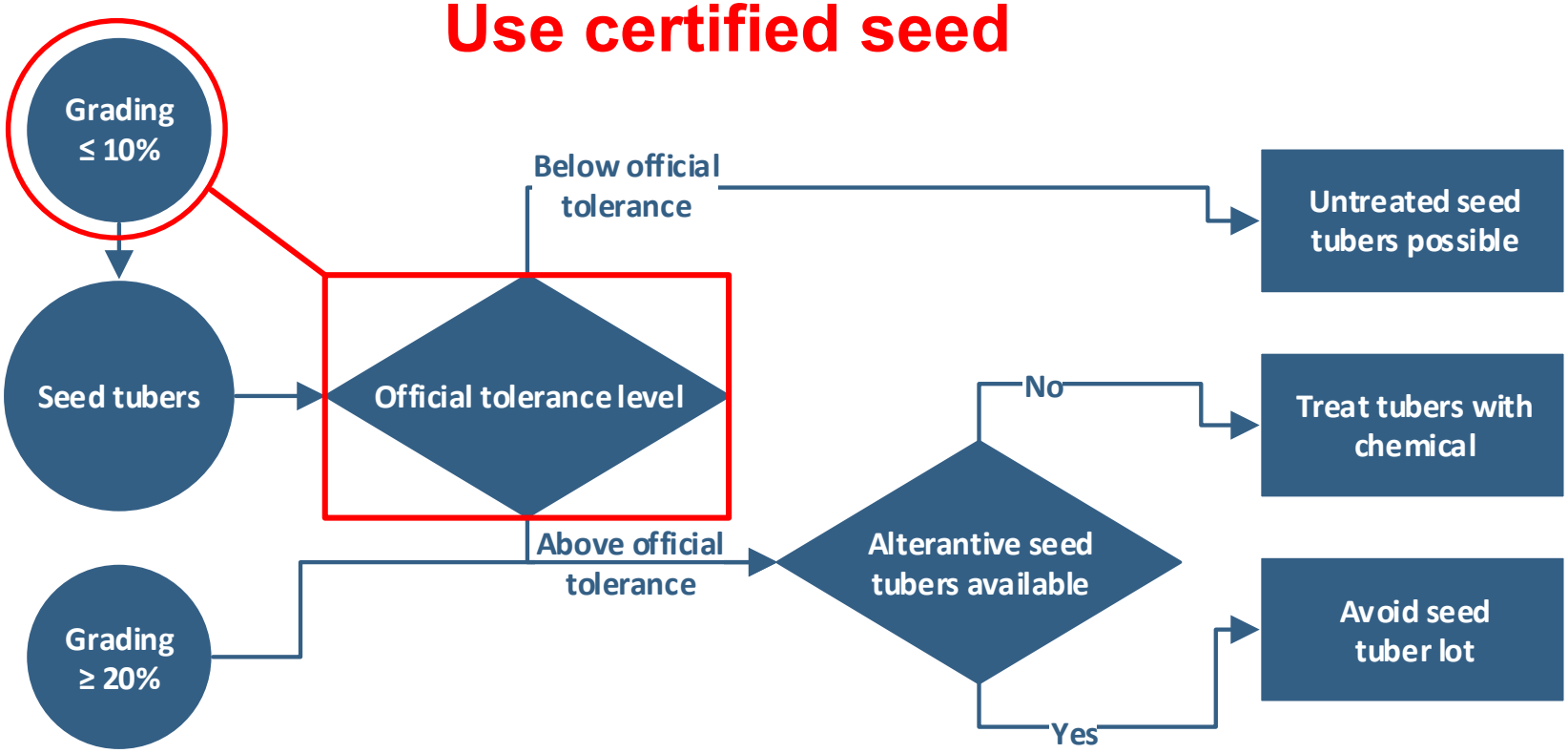
There is no single effective and easy control method to decontaminate a soil

Integrated Management: Growers Guidelines



U. Merz & R.E. Falloon

The Seed: Biggest source of disease spread!



Seed tuber quality

Table 1 Impact of grading powdery scab infested seedlots on pathogen inoculum levels

Seedlot (initial powdery scab incidence)	Cultivar(year)	Treatment	*S. subterranea* (pg DNA/g peel)[a]	Disease risk rating[b]
1 (20 %)	Innovator(2011)	Pre-grading	1,130,585 (6.05)	H
		Post-grading	399,432 (5.60)	H
		LSD (0.05)	ns	
		P value (*P* > *F*)	0.07	
2 (40 %)	Innovator(2011)	Pre-grading	1,164,655 (6.07)	H
		Post-grading	445,393 (5.65)	H
		LSD (0.05)	ns	
		P value (*P* > *F*)	0.12	
3 (5 %)	Russet Burbank (2011)	Pre-grading	93,492 (4.97) b*	H
		Post-grading	7,856 (3.90) a	L
		LSD (0.05)	(0.27)	
		P value (*P* > *F*)	<0.001	
4 (5 %)	Innovator (2011)	Pre-grading	126,324 (5.10) b	H
		Post-grading	5,452 (3.74) a	L
		LSD (0.05)	(0.40)	
		P value (*P* > *F*)	<0.001	
5 (35 %)	Innovator (2012)	Pre-grading	568,883 (5.76)	H
		Post-grading	251,808 (5.40)	H
		LSD (0.05)	ns	
		P value (*P* > *F*)	0.09	
6 (12 %)	Innovator (2012)	Pre-grading	311,158 (5.49)	H
		Post-grading	313,539 (5.50)	H
		LSD (0.05)	ns	
		P value (*P* > *F*)	0.86	
7 (10 %)	Russet Burbank (2012)	Pre-grading	167,348 (5.22)	H
		Post-grading	44,543 (4.65)	H
		LSD (0.05)	ns	
		P value (*P* > *F*)	0.08	
8 (7 %)	Russet Burbank (2012)	Pre-grading	115,624 (5.06) b	H
		Post-grading	6,284 (3.80) a	L
		LSD (0.05)	(0.35)	
		P value (*P* > *F*)	<0.001	

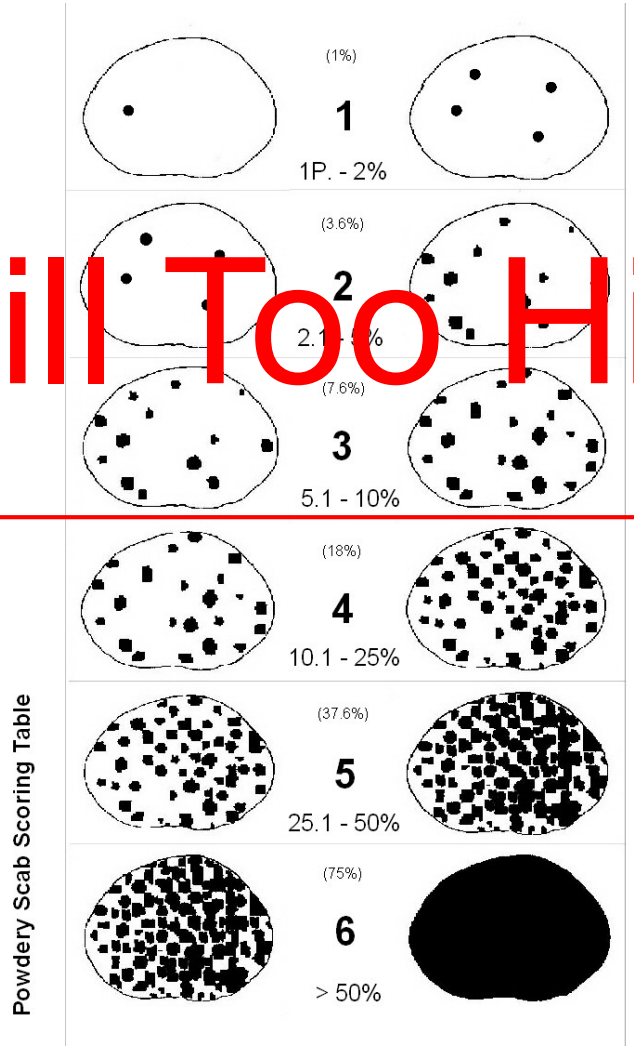
Tegg R.S. *et al.*, 2016

The Seed: Tolerance level and certification

EU Directive of February 2014

	Common Scab	Powdery Scab
Basic-Seed	5 out of 100 tubers (5%): > 1/3 of surface	3 out of 100 tubers (3%): > 1/10 of surface
	Together not more than 6%	
Certified Seed	5 out of 100 tubers (5%): > 1/3 of surface	3 out of 100 tubers (3%): > 1/10 of surface
	Together not more than 8%	

The Seed: Tolerance level



Still Too High

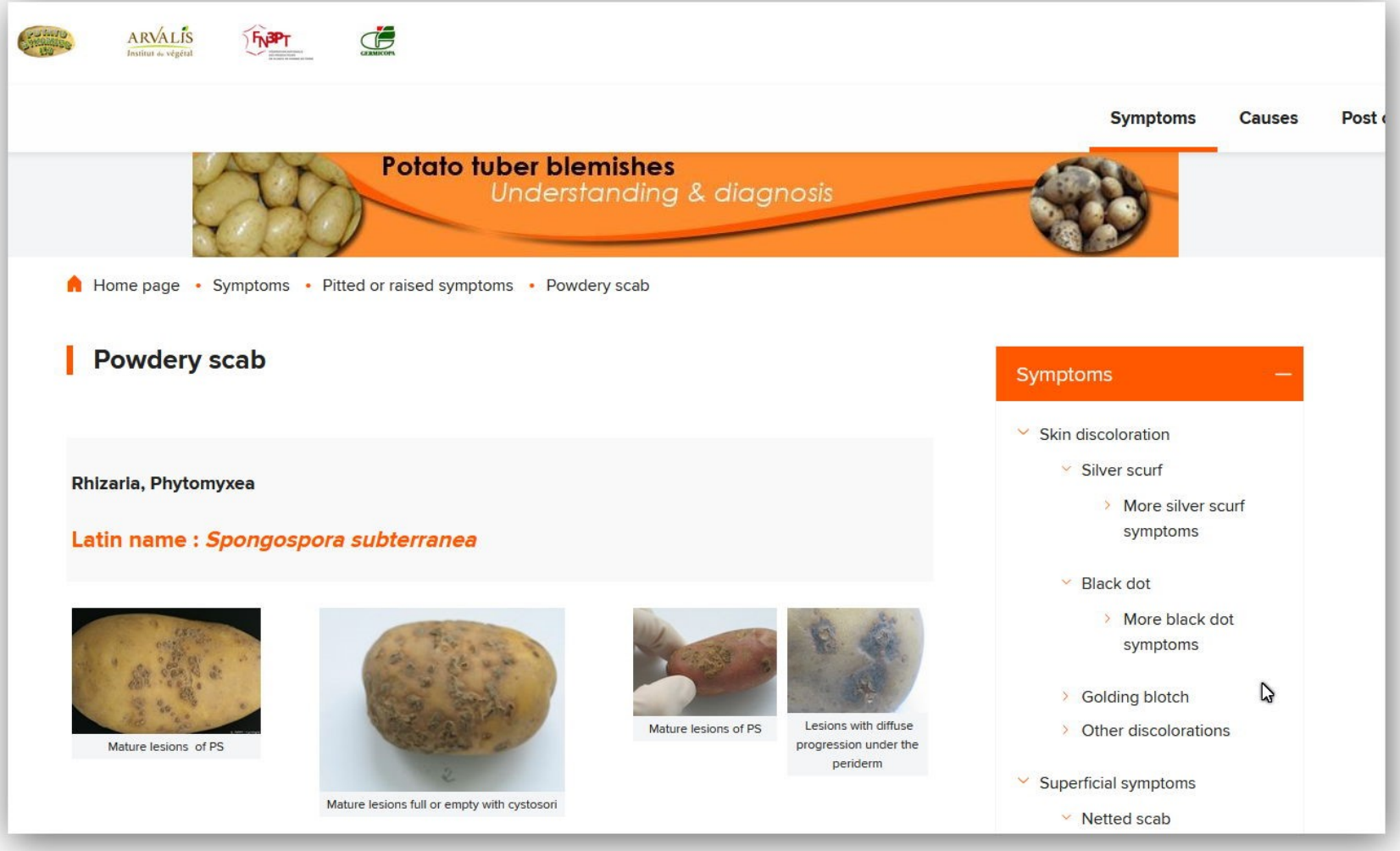
The Seed: Tolerance level and certification

EU Directive of February 2014

	Common Scab	Powdery Scab
Basic-Seed	5 out of 100 tubers (5%): > 1/3 of surface	3 out of 100 tubers (3%): > 1/10 of surface
	Together not more than 6%	
Certified Seed	5 out of 100 tubers (5%): > 1/3 of surface	3 out of 100 tubers (3%): > 1/10 of surface
	Together not more than 8%	

The Seed: Tolerance level and certification

The Seed Certification: Inspectors Tool ‘AgriStrip’



https://www.potato-tuber-blemishes.com/Symptoms/Pitted-or-raised-symptoms/Powdery-scab

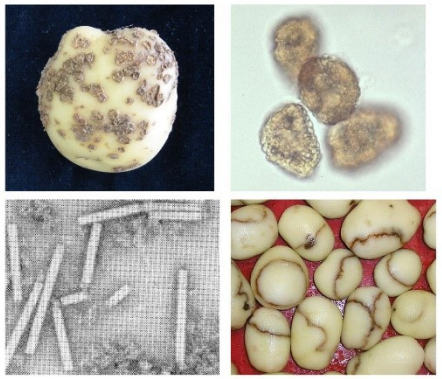
Grading: scabby tubers fed to cattle

Dung heap: farm manure spread to the field contains infective sporosori

Control of major contaminant

農研機構 NARO 独立行政法人 農業・食品産業技術総合研究機構

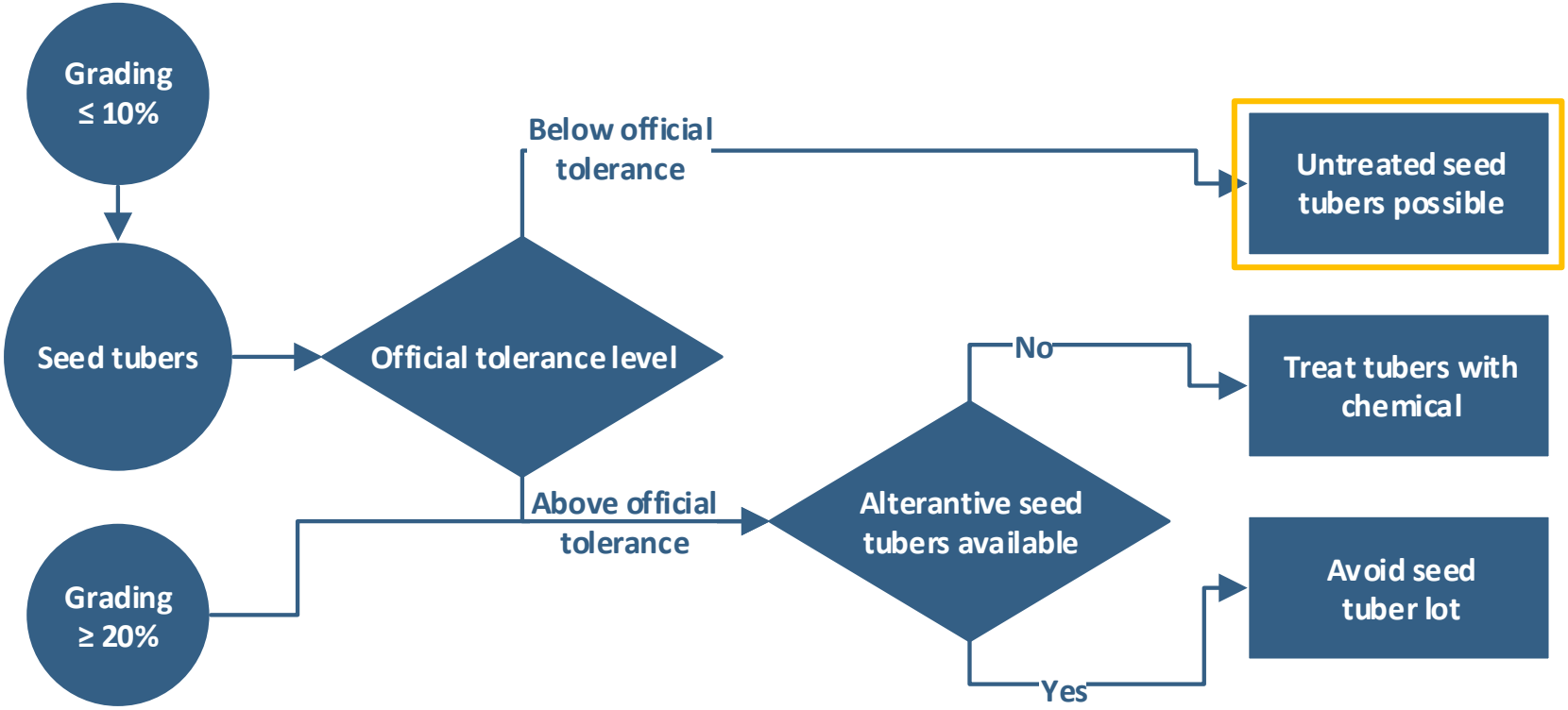
- Powdery scab (*Spongospora subterranea*)
  - Spore ball (aggregate of resting spores) is highly tolerant against diverse environmental conditions (*heat, drought* etc.).
  - Practical method for effective sterilization of potato grounds has not been developed.
  - The pathogen transmits *Potato mop-top virus* (PMTV), the causal agent of potato spraing.



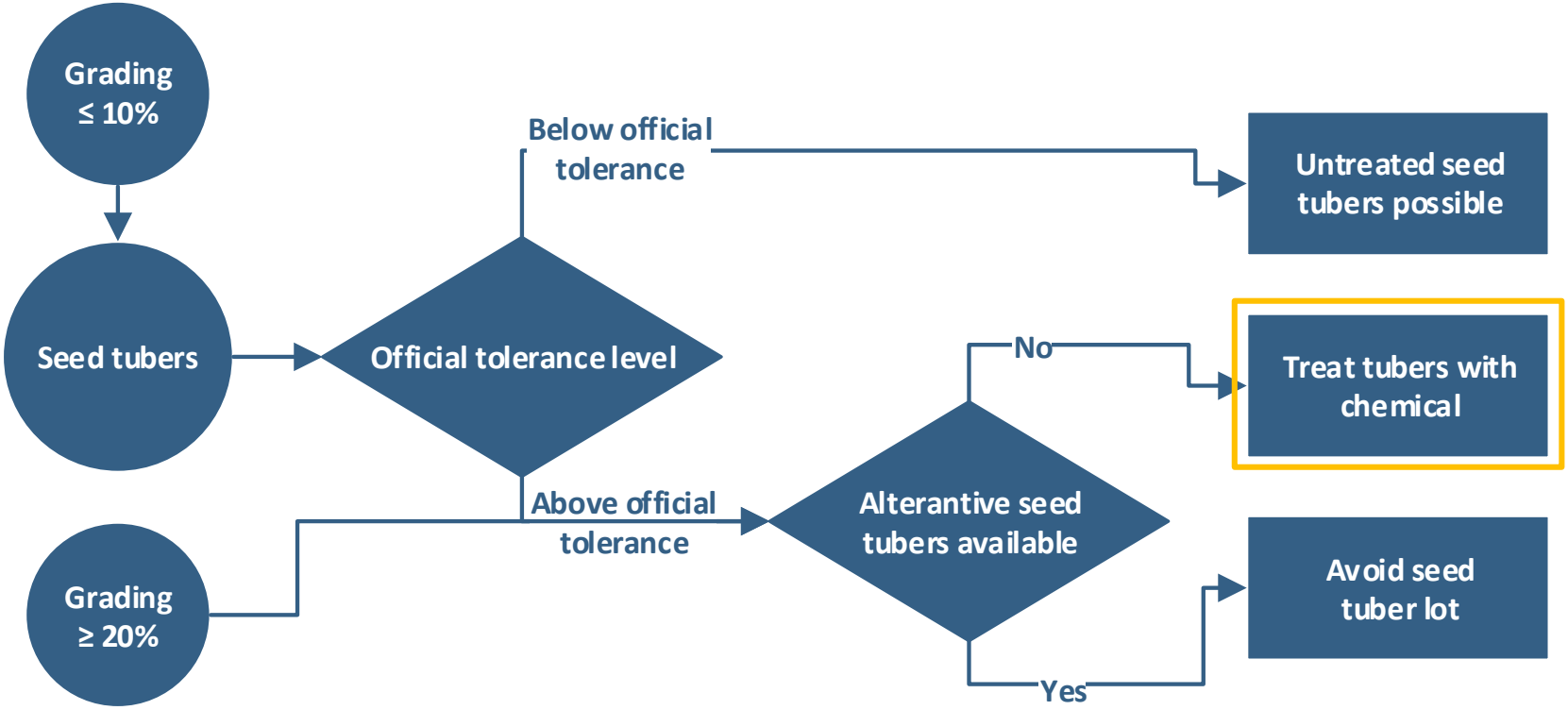
Throwing of the dung manure that came from cattle fed potato grounds into cropping fields has been suspended by Hokkaido prefectural government since 2007.

Takato Nakayama, NARO, Japan

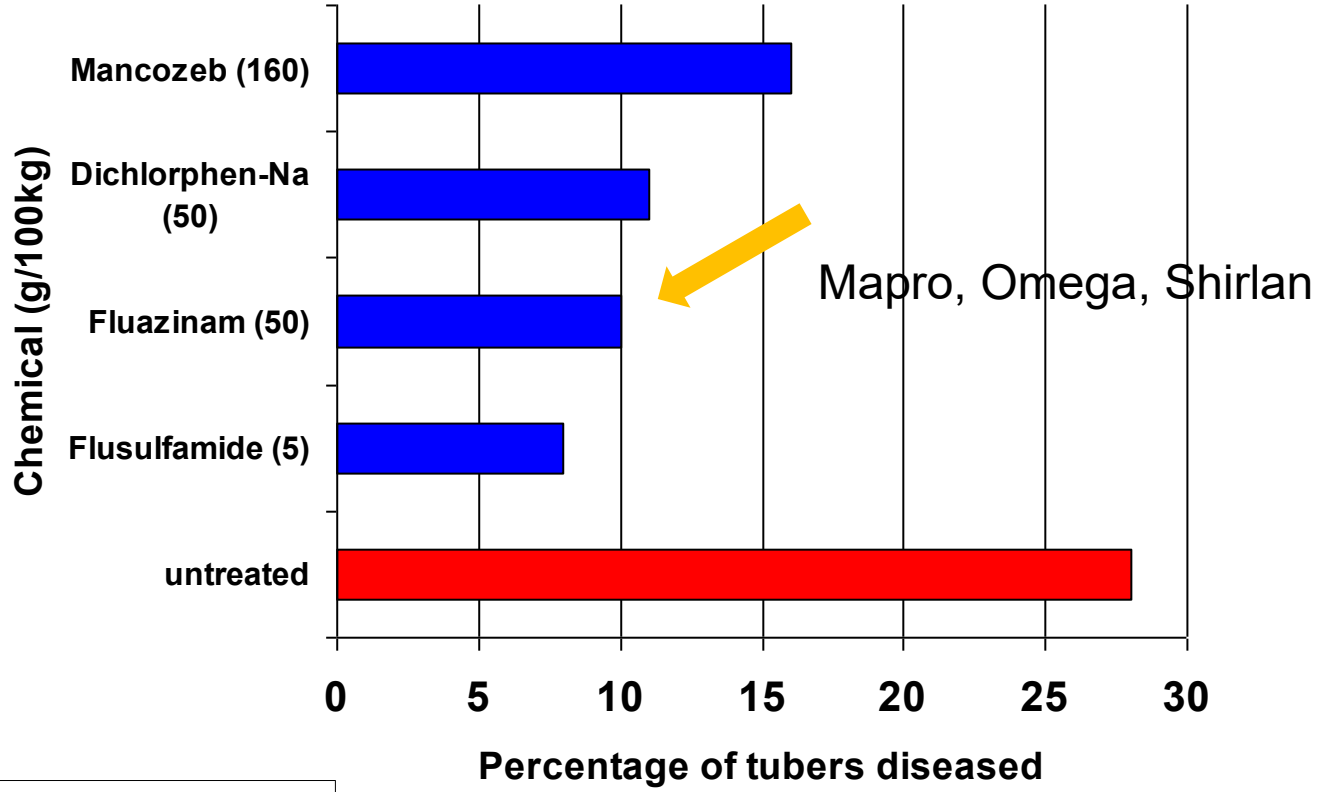
The Seed


Grading
≤ 10%
Seed tubers
Official tolerance level
Below official
tolerance
Untreated seed
tubers possible
No
Treat tubers with
chemical
Above official
tolerance
Alterantive seed
tubers available
Grading
≥ 20%
Avoid seed
tuber lot
Yes

The Seed


Grading
≤ 10%
Seed tubers
Official tolerance level
Below official
tolerance
Untreated seed
tubers possible
No
Treat tubers with
chemical
Above official
tolerance
Alterantive seed
tubers available
Grading
≥ 20%
Avoid seed
tuber lot
Yes

The Seed: Chemical treatment of infected tubers



Seed treatment trial, NZ

The Seed: Alternative ‘Biocontrol’

Journal of General Plant Pathology
July 2017, Volume 83, Issue 4, pp 253–263 | Cite as

Biocontrol of powdery scab of potato by seed tuber application of an antagonistic fungus, *Aspergillus versicolor*, isolated from potato roots

Authors Authors and affiliations

Takato Nakayama

The Seed:

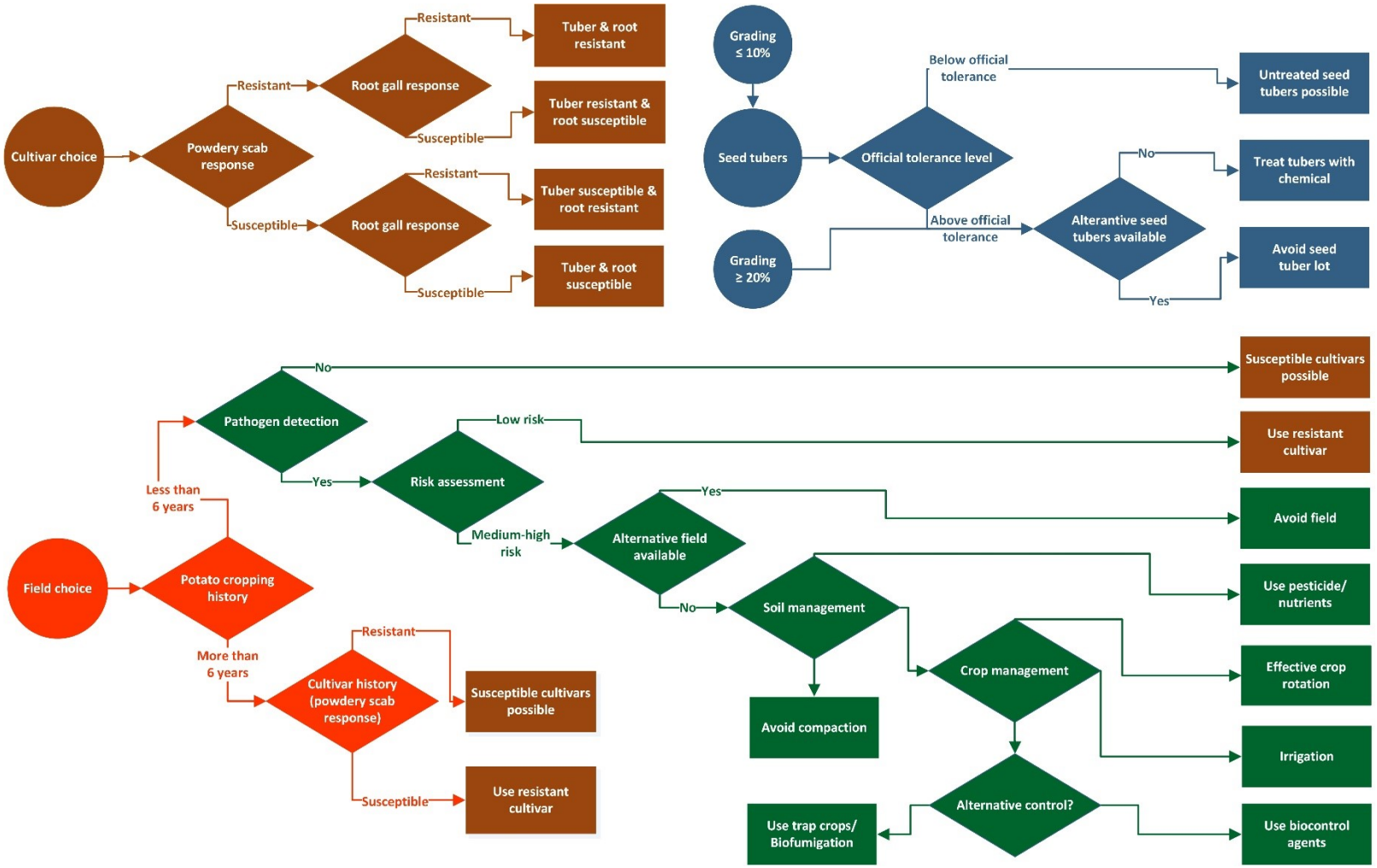
Most important for field to field disease spread

Diseased seed in healthy soil hardly causes diseased harvest, but will contaminate the soil

A soil, once contaminated, stays infectious for many years

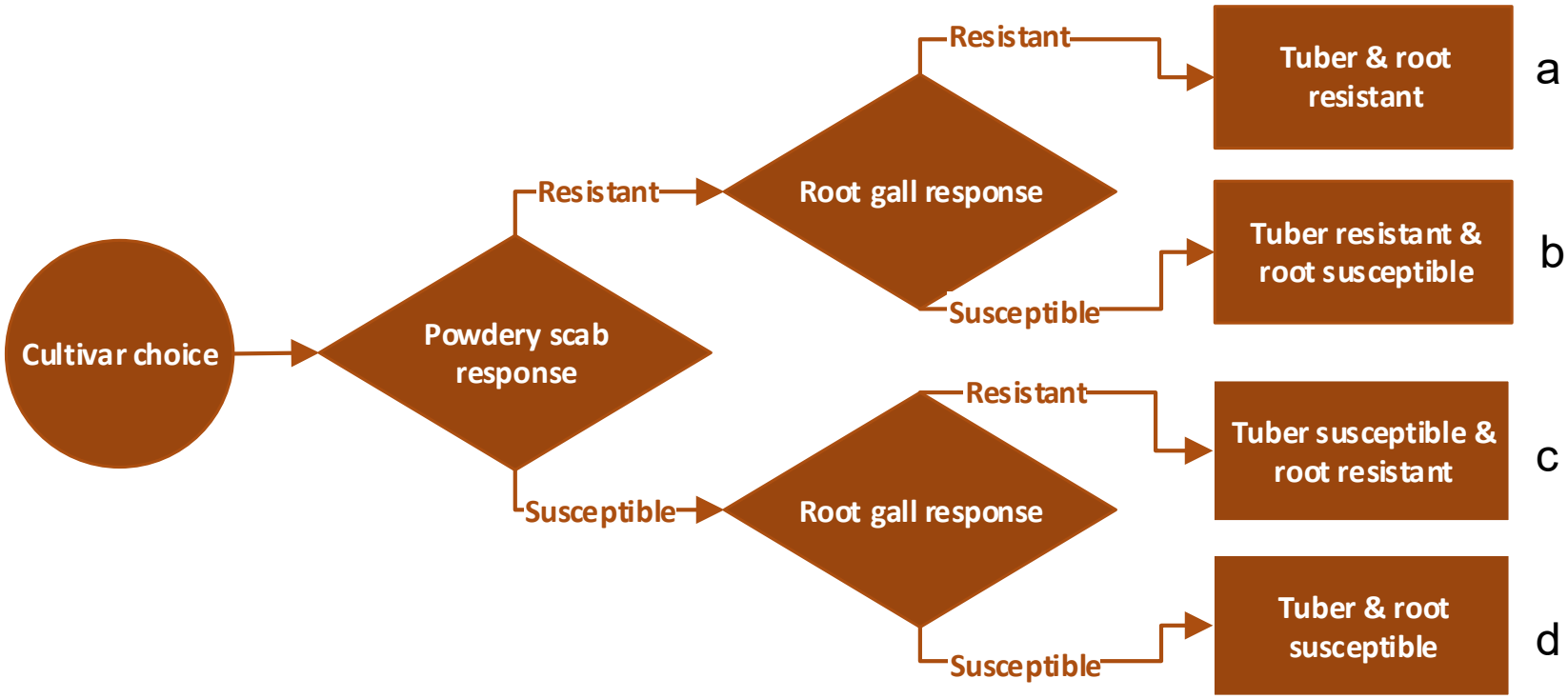
Avoid diseased seed or try to use only seed with little disease

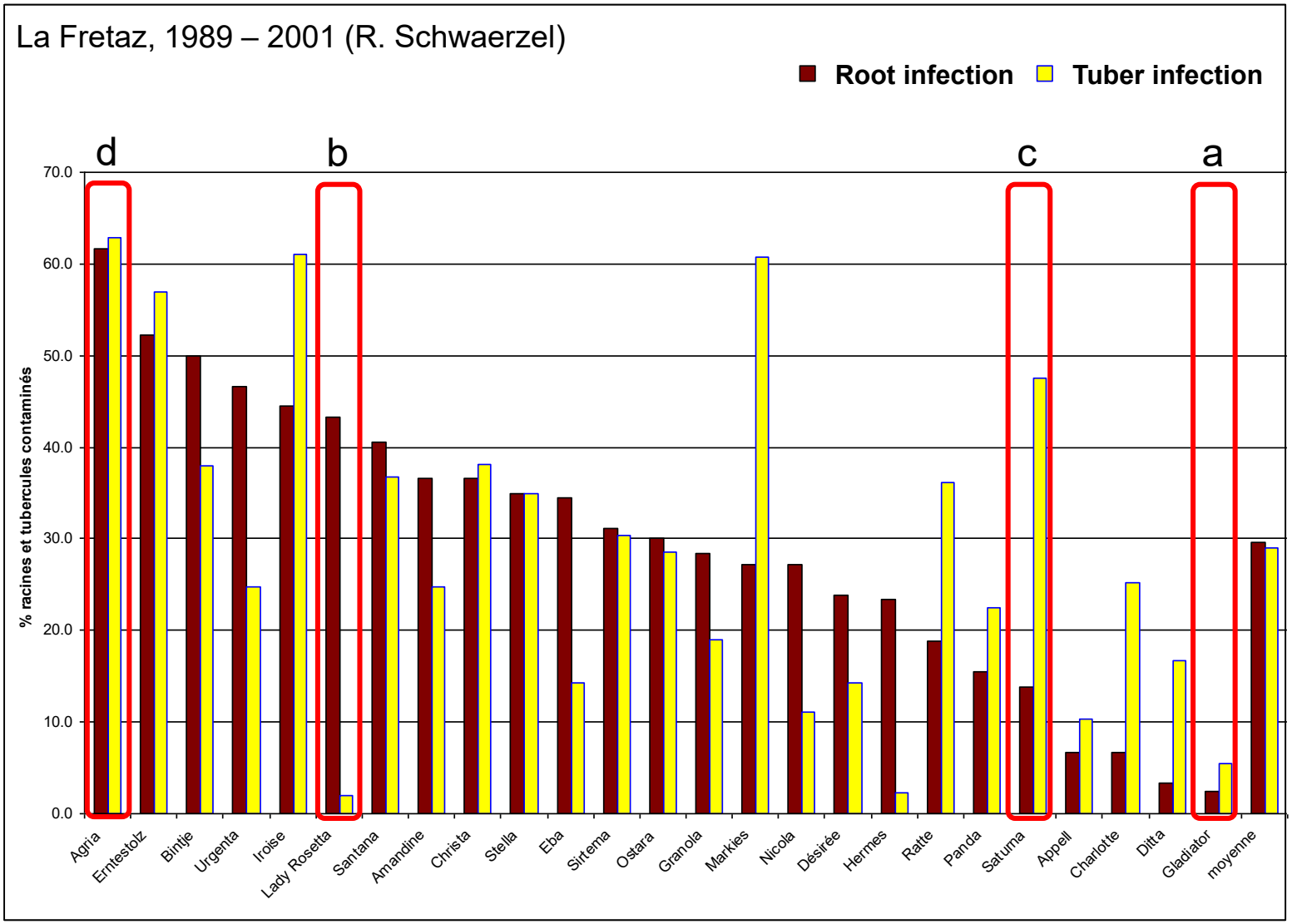
Integrated Management: Growers Guidelines



U. Merz & R.E. Falloon

The Cultivar

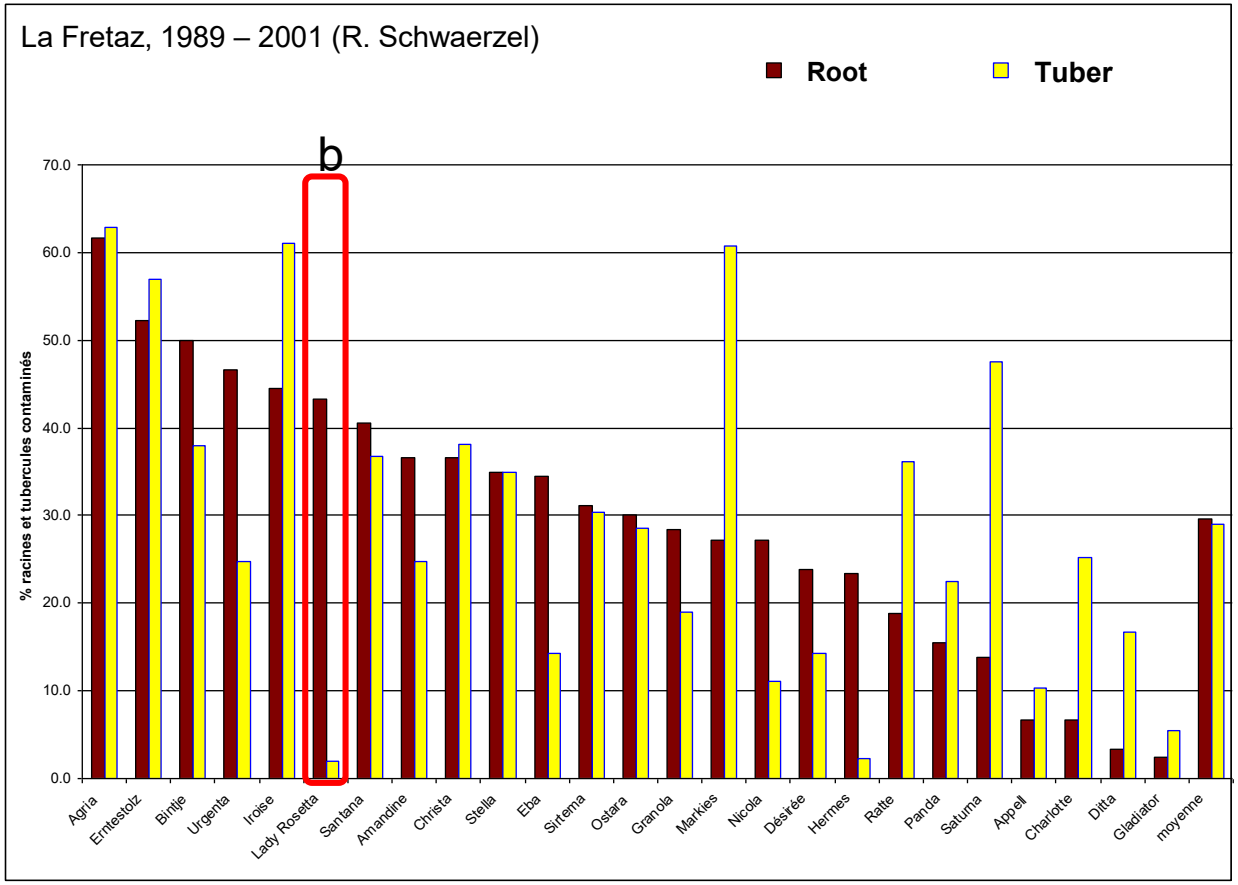



La Fretaz, 1989 – 2001 (R. Schwaerzel)
Root infection
Tuber infection
d
b
c
a
% racines et tubercules contaminés
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Agria
Erntestolz
Bintje
Urgenta
Iroise
Lady Rosetta
Santana
Amandine
Christa
Stella
Eba
Sirtema
Ostara
Granola
Markies
Nicola
Désirée
Hermes
Ratte
Panda
Saturna
Appell
Charlotte
Ditta
Gladiator
moyenne

The Cultivar: Cultivar List Switzerland

Anfälligkeit	Anfälligkeit	Anfälligkeit für Viruskrankheiten		Bemerkungen zu besonderen Sortenmerkmalen und Verhalten gegenüber anderen Krankheiten und Schädlingen	Sortenname
emeiner für Schorf	für Pulverschorf	Blattroll (PLRV)	Mosaik (PVY)		
mittel	mittel	mittel	mittel	grossknollig, regelmässig; sehr kurze Keimruhe, frostempfindlich	Agata
gering	gering	mittel	hoch mittel PVY^{NTN}	festkochend, feinkörnig; grosse Knollen ergrünen rasch; sehr kurze Keimruhe; sensibel auf das physiologische Alter. *Vertragsproduktion mit Vermarktungsschutz	Amandine*
mittel	gering bis mittel	gering	mittel hoch PVY^{NTN}	festkochend, feinkörnig; kurze Keimruhe	Annabelle
gering	mittel	gering	hoch	festkochend, feinkörnig *Vertragsproduktion mit Vermarktungsschutz	Celtiane*
mittel	gering	mittel	hoch	festkochend, feinkörnig; grosse Knollen ergrünen rasch; Eisenfleckigkeit vor allem auf leichten Böden; resistent gegen Virus A	Charlotte
gering	gering	mittel	mittel hoch PVY^{NTN}	festkochende Speisesorte, mässige N-Düngung; anfällig auf Tabak-Rattle-Virus	Ditta
gering	mittel	gering	gering gering Y^{NTN}	festkochend, feinkörnig	Erika
ittel bis gering	mittel bis hoch	mittel	hoch	festkochend; ziemlich anfällig für Eisenfleckigkeit; anfällig gegen Virus X, resistent gegenüber Virus A, sensibel auf das physiologische Alter	Gourmandine
ittel bis gering	hoch	hoch	hoch gering Y^{NTN}	festkochend, *Vertragsproduktion mit Vermarktungsschutz	Gwenne*
gering	hoch	mittel	gering	Tendenz zum Ergrünen; ziemlich anfällig für Eisenfleckigkeit und Hohlherzigkeit	Lady Christl
gering	élevée	mittel	gering	vereinzelt Eisenflecken	Marabel
ittel bis gering	mittel	gering	gering	festkochend, feinkörnig	Venezia

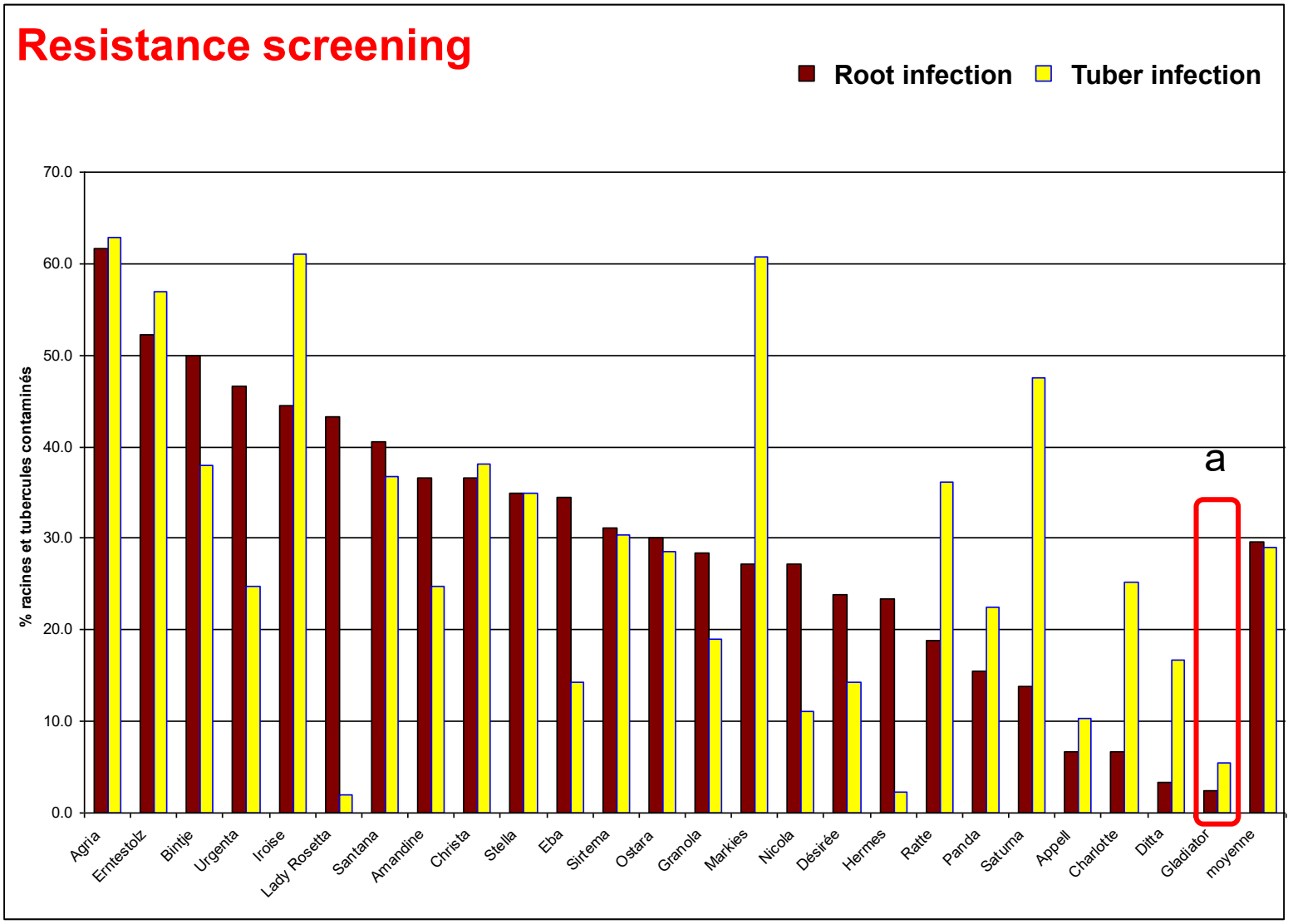
Danger! Cultivars with high susceptibility to root infection and low to tuber infection



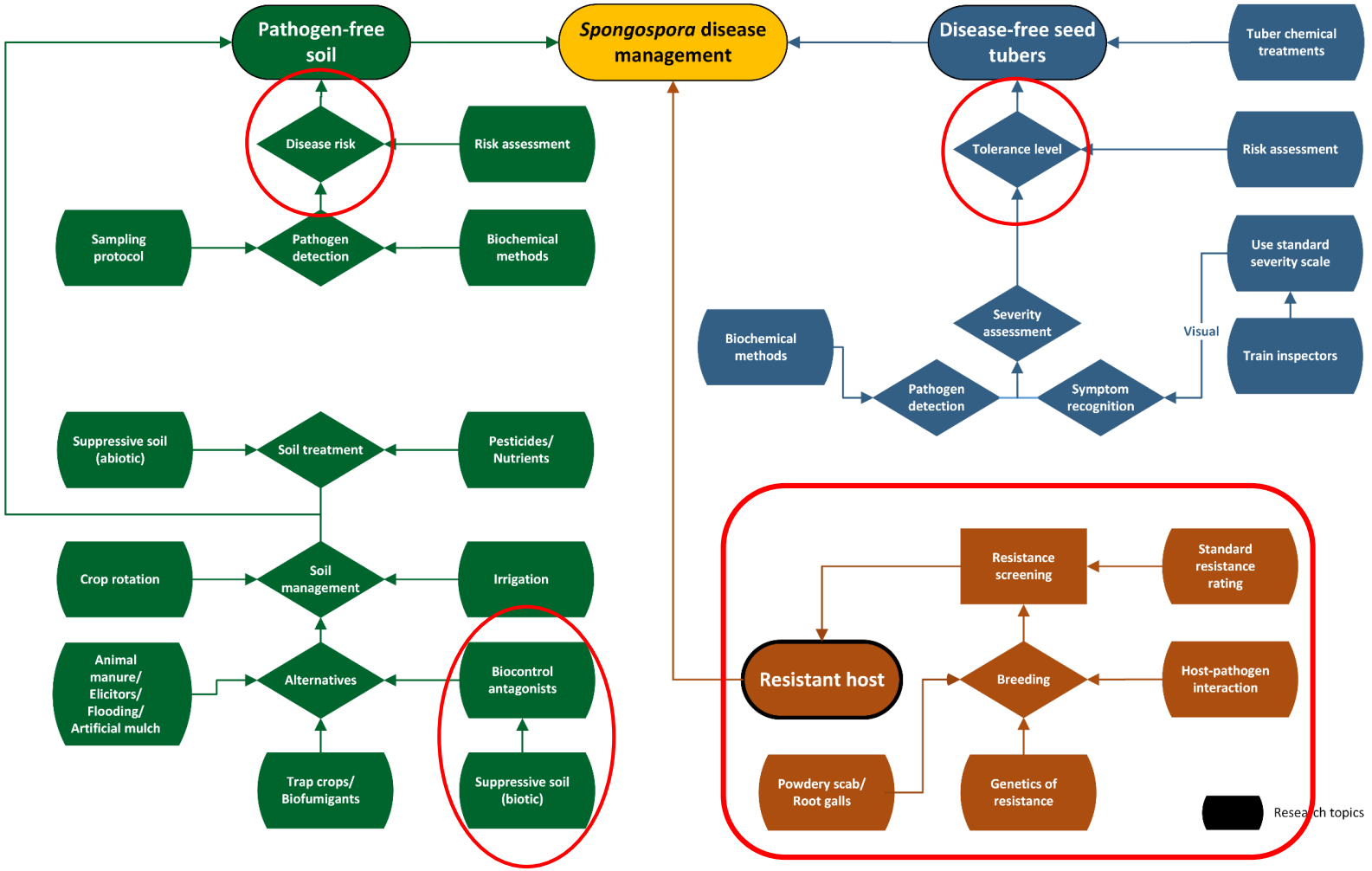
Colombia: *S. phureja* / *S. tub*. ssp. *andigena*

Massive attack with root galls

Resistance screening



We also outlined key areas of research where knowledge is lacking

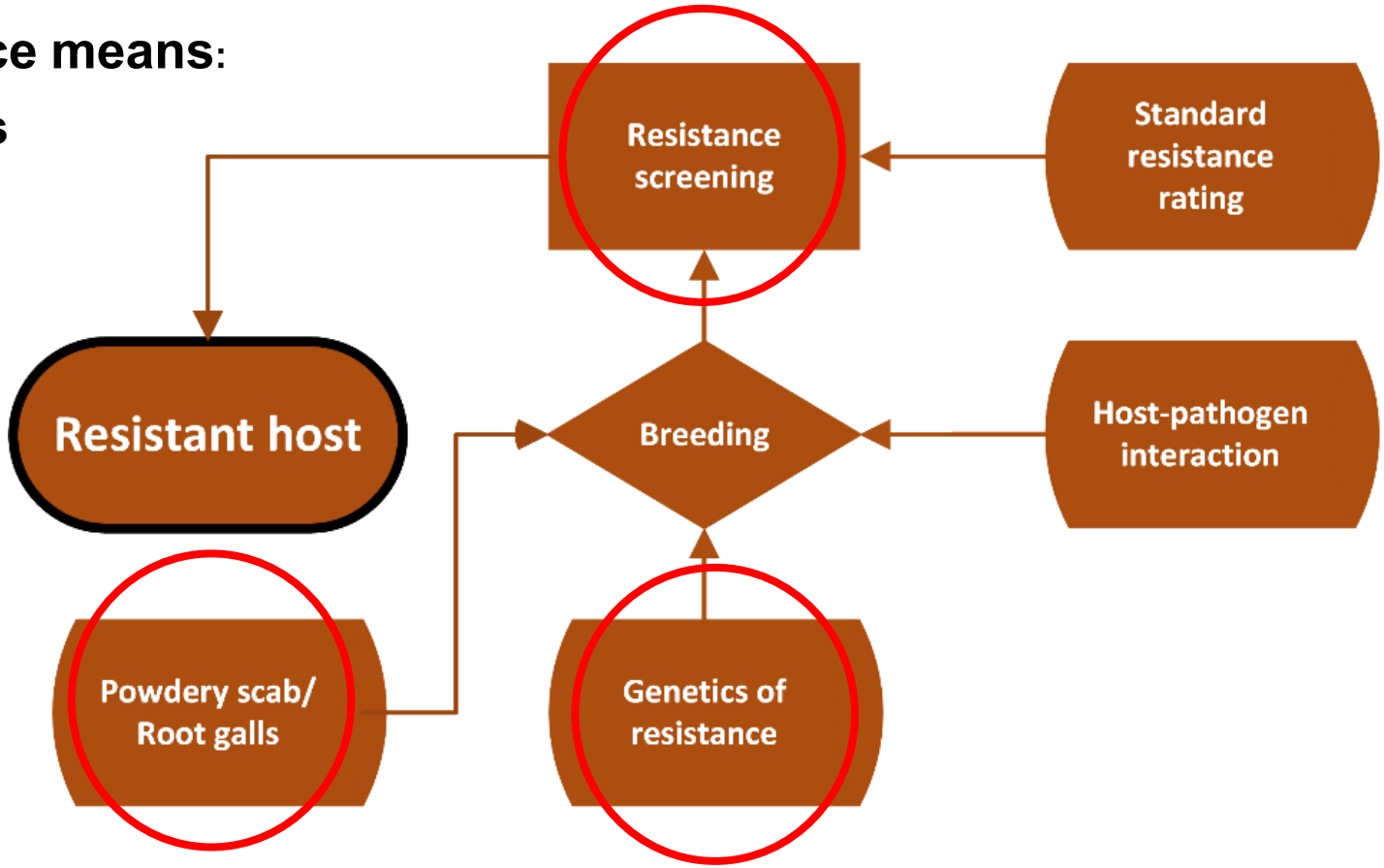


Merz U. and R.Falloon eds. (2017). Proceedings of the 3rd International Powdery Scab Workshop: Einsiedeln, Switzerland, July 18–21, 2016. Potato Research 60(2), 195-215

Resistance breeding – The longterm solution

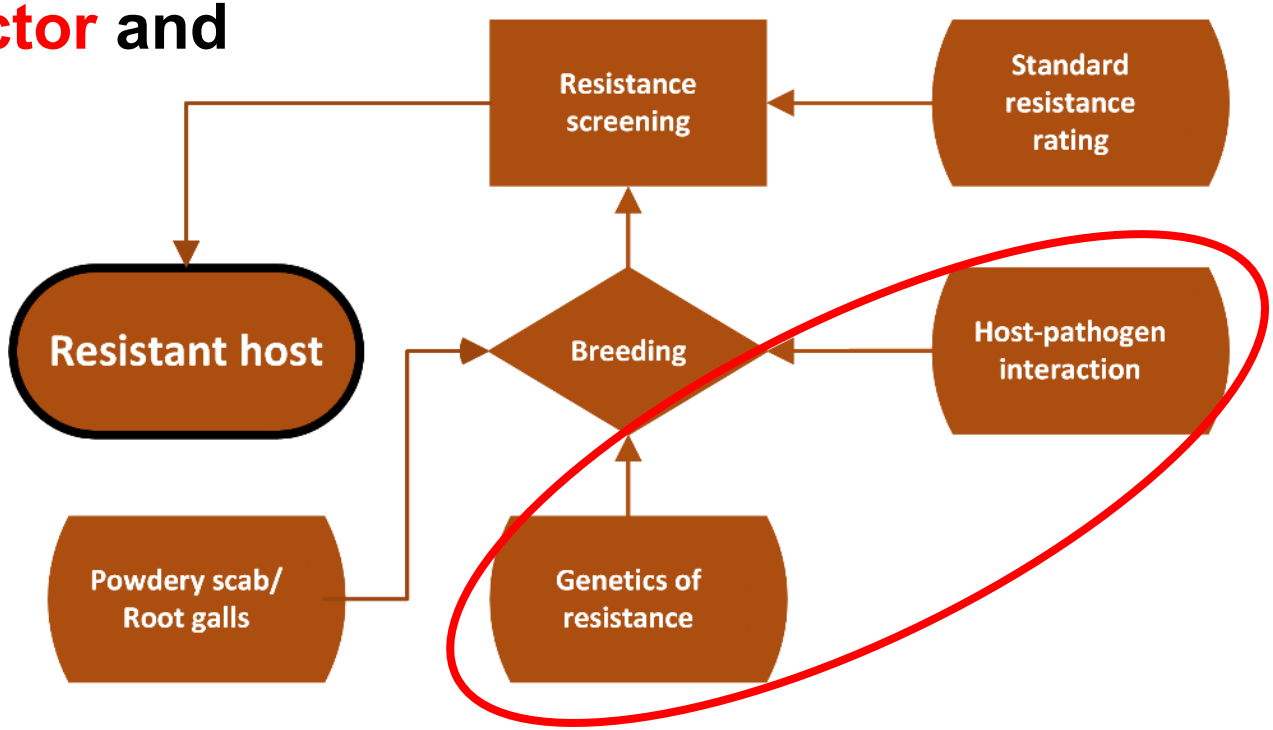
Host resistance means:

- **Two diseases**
- **Two genetics**



Resistance breeding: Need for more research

aspects of pathogen genetics, biology and disease epidemiology, the role as a vector and host resistance mechanisms



Resistance breeding: Pathogen genetics

Molecular Plant-Microbe Interactions®

Editor-in-Chief: Jeanne M. Harris
Published by APS PRESS in cooperation with the
International Society for Molecular Plant-Microbe Interactions

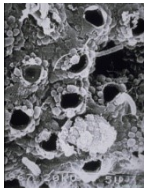
December 2018, Volume 31, Number 12
Pages 1227-1229
https://doi.org/10.1094/MPMI-06-18-0163-A

RESOURCE ANNOUNCEMENT

Draft Genome Resource for the Potato Powdery Scab Pathogen *Spongospora subterranea*

Stefan Ciaghi,[1] **Sigrid Neuhauser,**[1] and **Arne Schwelm**[2,†]

Zoospore release and attraction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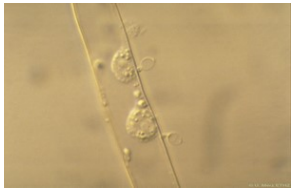
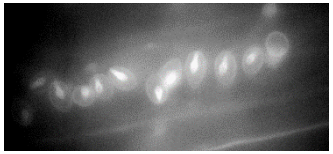
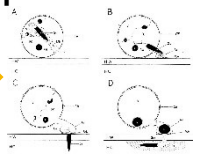


Resistance breeding: Pathogen biology

Penetration and plasmodial development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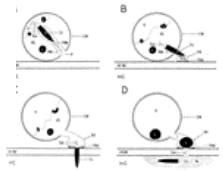
Host tissue determination


?

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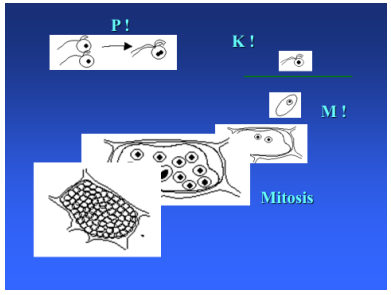
Recombination, population genetics and virulence



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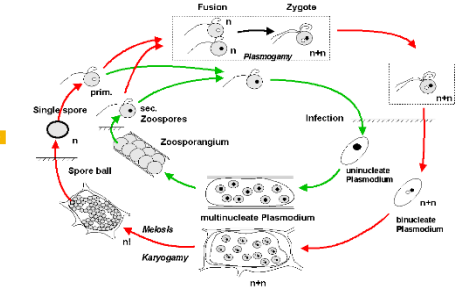

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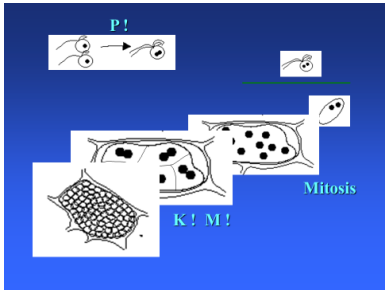
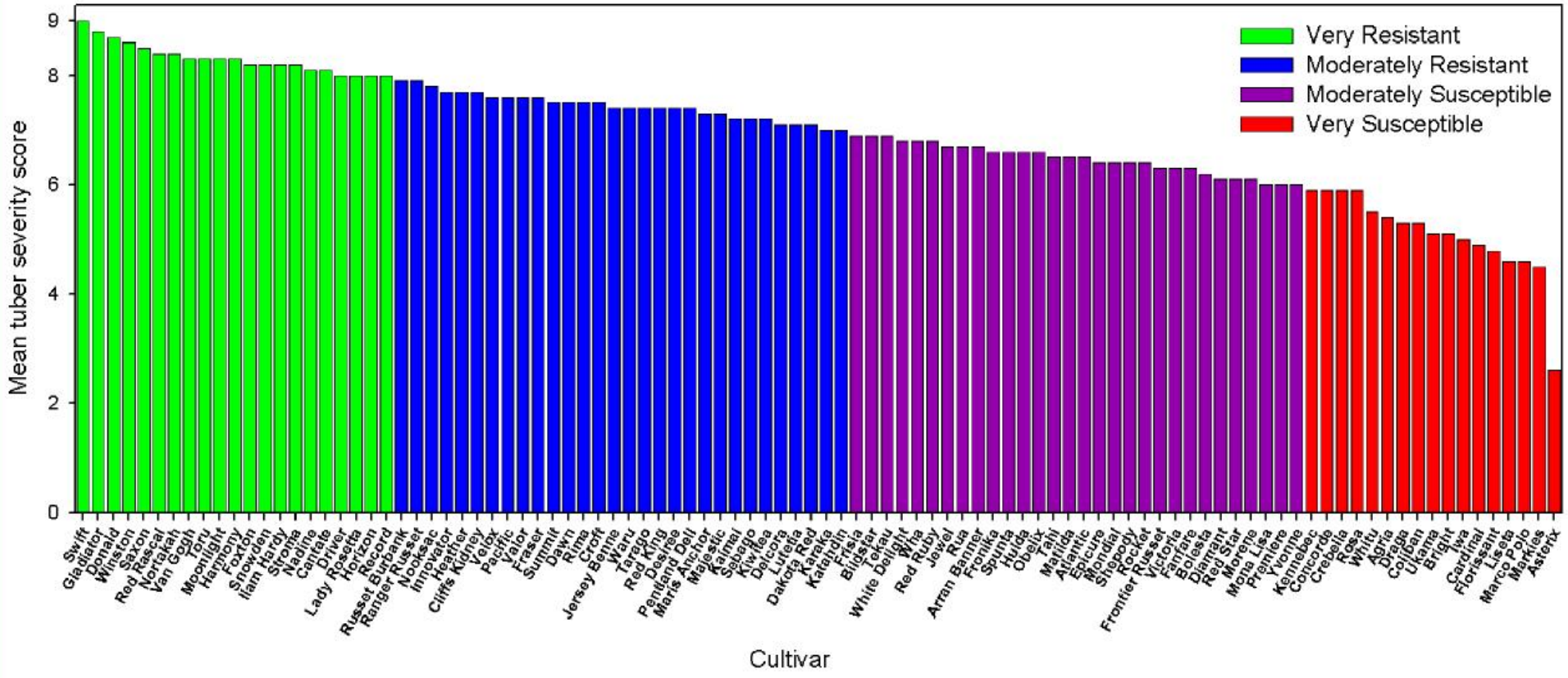


Resistance breeding: Host resistance genetics

Multi-Gene Resistance?

C&F, NZ, resistance screening



Resistance Breeding – Host resistance markers

American Journal of Potato Research
June 2014, Volume 91, Issue 3, pp 233–245 | Cite as

Relationship Between Tuber Storage Proteins and Tuber Powdery Scab Resistance in Potato

Authors | Authors and affiliations

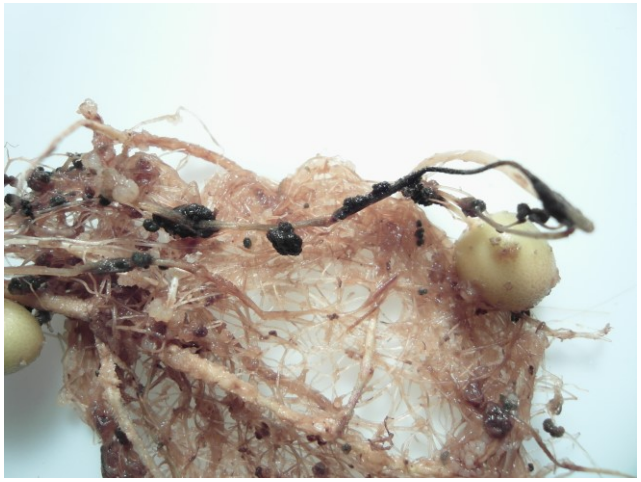
Venu Perla, Sastry S. Jayanty, David G. Holm, Robert D. Davidson

Article
First Online: 03 October 2013

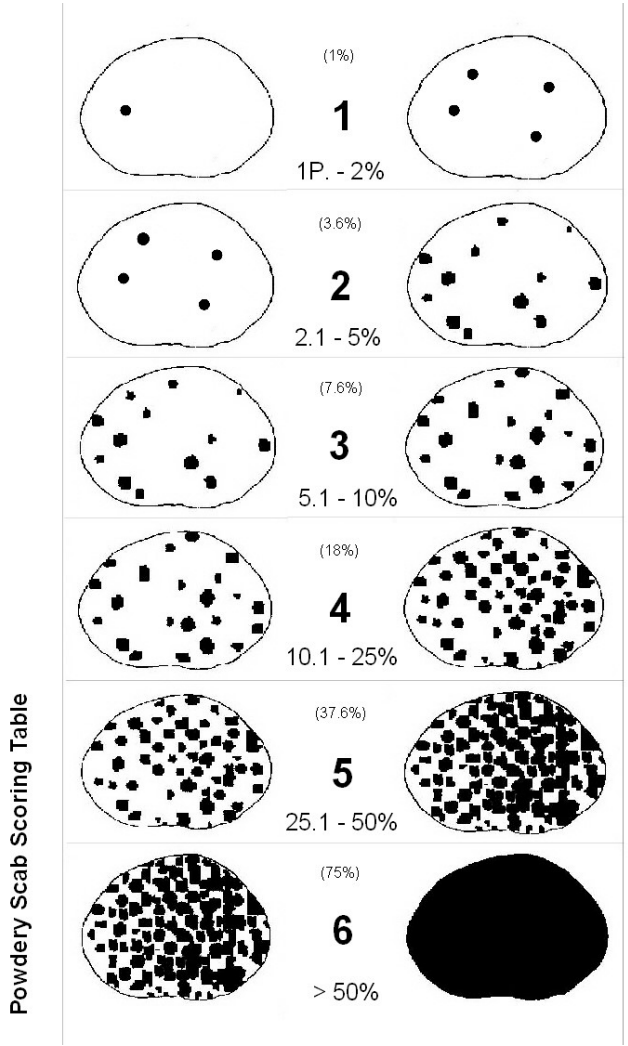
4 Citations

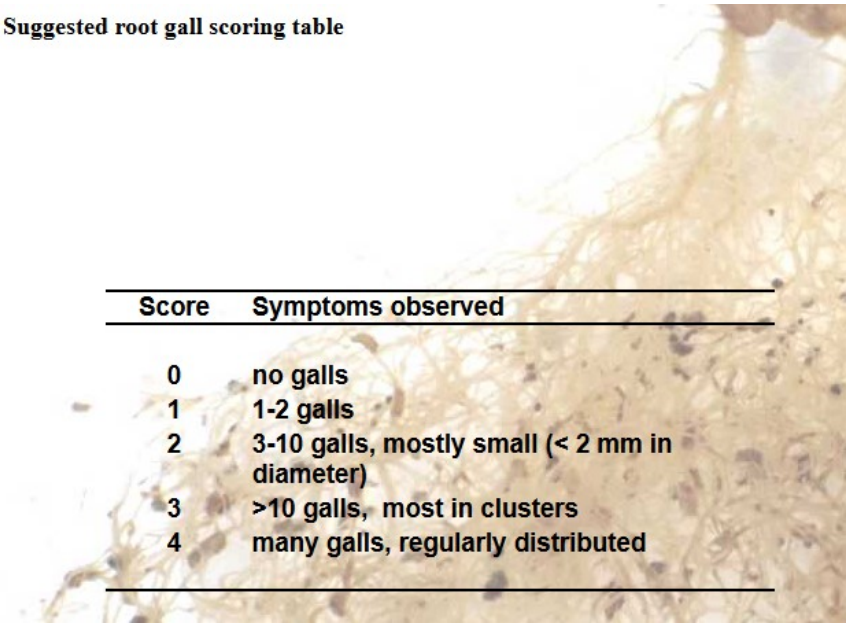
.... The physiological levels of LOX protein can be considered as a useful marker for powdery scab resistance in potato breeding programs....

Resistance Breeding – Rapid screening micro-bioassay



Resistance screening – Assessment standards





http://www.spongospora.ethz.ch/LaFretaz/index.htm
2002

The Cultivar:

Resistance is the best longterm control solution

Tubers and root have different resistance backgrounds

Resistance screening needs to assess both resistance levels

Breeding for effective resistance to powdery scab and root galls is possible and urgent

Take-home Message

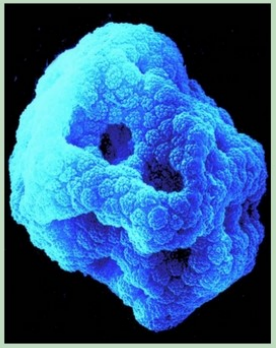
- Seed tubers are most important for disease spread and should have low or no powdery scab infection: **certification**
- Soil, once contaminated, stays infectious for longtime and is very difficult to get disease-free again: **prevention**
- To use resistant/tolerant cultivars is the best longterm control measure: **host resistence**

www.spongospora.ethz.ch

WELCOME TO THE

SPONGOSPORA COMPETENCE CENTER

All about *Spongospora subterranea,* member of the Plasmodiophorid family



This project has started in September 1995. The intention was to establish a site for INFORMATION and ORIENTATION on different aspects of the pathogen *Spongospora subterranea* f.sp. *subterranea* and to encourage people to network with other researchers.

As the webmaster has retired since October 2018, this site will be slowly moved to a new (private) URL: www.spongospora.net

Your host: U. Merz

CONTENT:

General Description of the Genus *Spongospora* | Members of the Genus *Spongospora* | References | Places and People | Slide-Shop

Spongospora Workshops

1st European Powdery Scab Workshop, Aberdeen, Scotland, UK, July 20-22, 2000
Powdery Scab Scoring Workshop, La Fretaz, CH, August 26-27, 2002
1st International *Spongospora* Workshop:Scottsbluff, NE, USA, August 8-12, 2004
2nd European Powdery Scab Workshop, Langnau, Switzerland, August 29-31, 2007
3rd European Powdery Scab Workshop, Boldern, Switzerland, July 11-13, 2011
2nd International Powdery Scab Workshop, South Africa, July 29 - August 1, 2014
3rd International Powdery Scab Workshop, Switzerland, July 18 - 21, 2016
2nd International *Spongospora* Workshop, Switzerland, September 5, 2019
(after the EAPR Pathology & Pests Section Meeting, September 2-4, 2019)