Uncovering the interactions between *Phytophthora cactorum* and the strawberry plant



Leather rot



Crown rot

Photos: H. Eikemo and A. Stensvand

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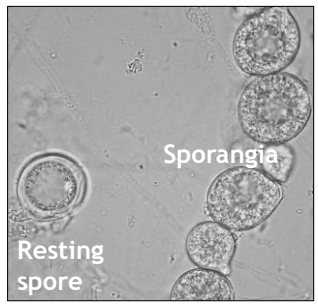
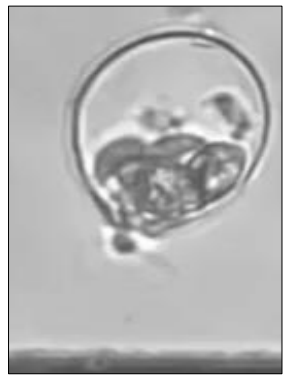
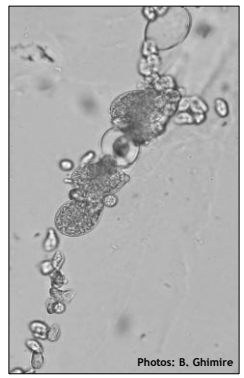
Phytophthora cactorum





Photos: B. Ghimire

Forms thick-walled resting spores (oospores) and zoospores in sporangia; zoospores move in water

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Leather rot



Photo: M. Ellis

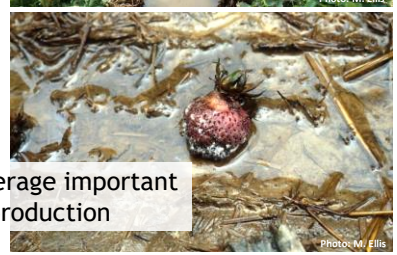
Photo: M. Ellis

Well drained soil and good straw coverage important to prevent leather rot in open-field production

Photo: A. Stensvand

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Crown rot



Photos: A. Stensvand


Crown rot is problematic if it follows the planting material

Here from imported plants with about 30% plant and yield loss

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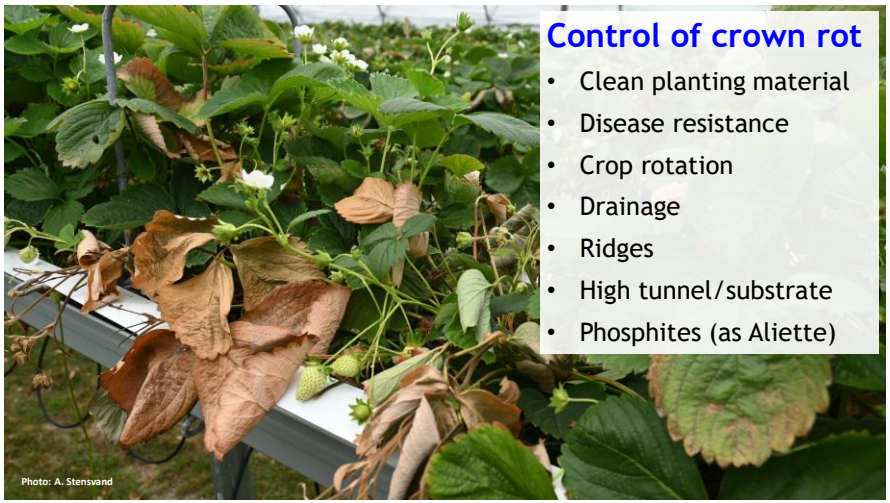

Control of crown rot

- Clean planting material
- Disease resistance
- Crop rotation
- Drainage
- Ridges
- High tunnel/substrate
- Phosphites (as Aliette)

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Resistance to crown rot

Varies greatly with cultivars

\+ = high resistance

+++++ = high susceptibility

(Eikemo et al. 2003)

Many new cultivars moderately to highly susceptible

Cultivar	Susceptibility
Senga Sengana	+
Glima	+(+)
Bogota	++
Bounty	++
Calypso	++
Honeoye	+++
Rita	+++
Korona	+++
Lambada	+++
Zephyr	++++
Polka	++++
Elsanta	++++
Evita	++++
Tamella	+++++

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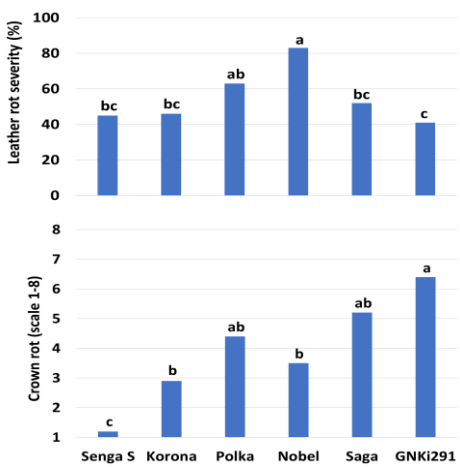
Crown rot *vs.* leather rot

Resistance to crown rot (lower graph) not correlated with resistance to leather rot (upper graph)

(Eikemo & Stensvand, 2015)



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Three PhD students that have worked or are working on mechanisms of virulence ("infection strategies") of the pathogen and defence responses in the strawberry host

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Infection by *P. cactorum*

Phytophthora species secrete effector proteins to facilitate the infection

Effector proteins enter different parts of the plant cell

Effectors interact with plant proteins to promote infection in the plant

or

Are recognised by plant resistance proteins that initiate cell death to stop the pathogen

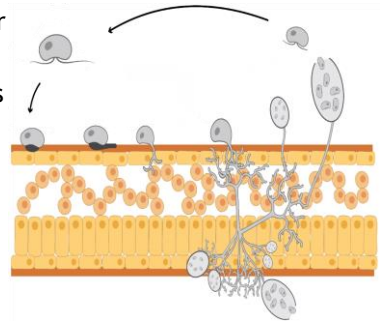

Figure: B. Ghimire

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Effector candidates

RxLRs are the most studied effectors in species of *Phytophthora*

They target a wide range of cellular processes, including immune responses in plants

Specification	Numbers
No. of transcripts with ≥ 99% identity to *P. cactorum* genes	4665
Secreted proteins	539
Uncharacterized proteins	216
Carbohydrate active enzymes	120
RxLRs	40
Proteolytic enzymes	23
Elicitins	9
Cysteine-rich proteins	7
Necrosis inducing proteins	7
Protein with kinase-like domain	5
Transglutaminase elicitors	4
Crinklers	3
Others	105

(Ghimire et al., unpublished)

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Cloning and infiltration

18 RxLRs were cloned into a plant expression vector

Agrobacterium (AGL1) containing the cloned construct infiltrated into leaves of tobacco (*Nicotiana benthamiana*) - five of the effectors induced cell death

Photo: B. Ghimire

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Agroinfiltration in *N. benthamiana*

Photo: B. Ghimire

Left leaf sides: RxLR effectors (1-5) inducing cell death (= resistance reaction)
Right leaf sides: Negative control (upper), positive control (lower)

Positive control: A known elicitor gene for cell death of *P. infestans*
Negative control: An empty vector

(Gogoi et al., unpublished)

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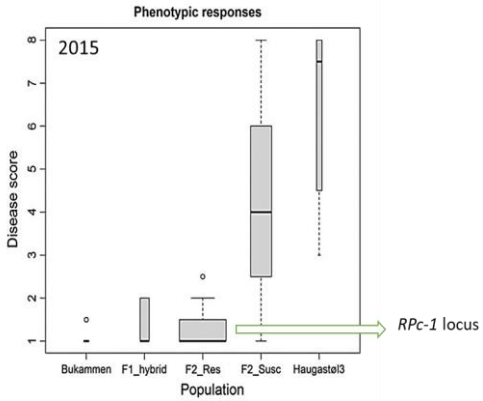
A locus for crown rot resistance

A single major gene locus called *Resistance to Phytophthora cactorum 1* (***RPc-1***) was identified in diploid strawberry with resistance to crown rot

It contains 69 putative disease resistance genes



(Davik et al., 2015)

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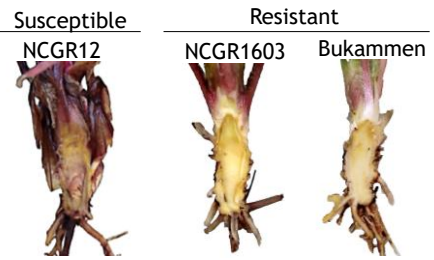
Resistance in wild strawberry

To further understand the expression level of these genes, RNA-sequencing of a susceptible and two resistant *Fragaria vesca* genotypes was performed after infection of *P. cactorum*

(Gogoi et al., 2023)



Photos: A. Gogoi

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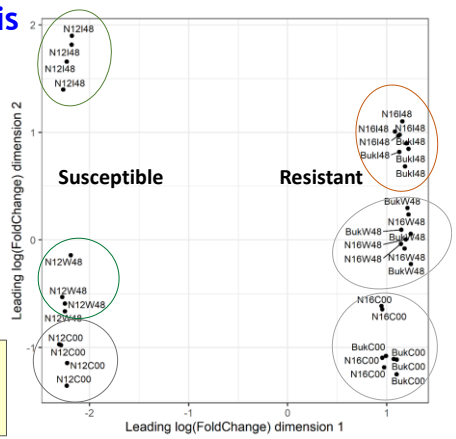
Gene expression analysis

The two resistant genotypes were clearly separated from the susceptible genotype, thus showing difference in gene expression between resistant and susceptible genotypes (Gogoi et al., 2023)



Treatment
C: Untreated control
W: Wounded (W48)
I: Wounded-inoculated (I48)

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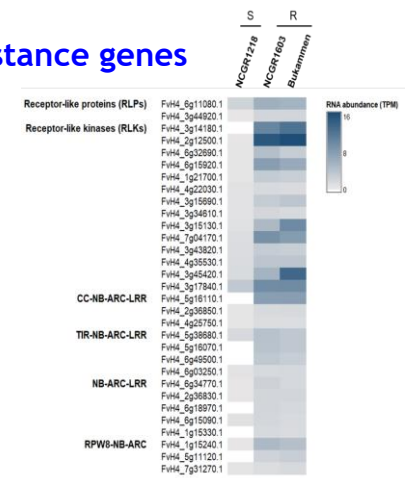
Putative disease resistance genes

Genes present in the two resistant (R) and the susceptible (S) genotypes

Darker box indicates higher expression of mRNA

Several genes with potential role in plant defence

(Gogoi et al., 2023)



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A new gene associated with disease resistance

Found in disease resistant genotypes of *F. vesca*

Induces cell death when expressed in leaves of *N. benthamiana*

(Gogoi et al. 2023)

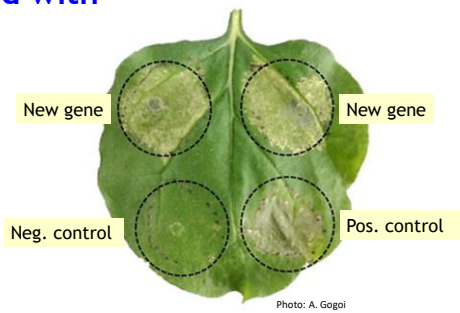

Photo: A. Gogoi

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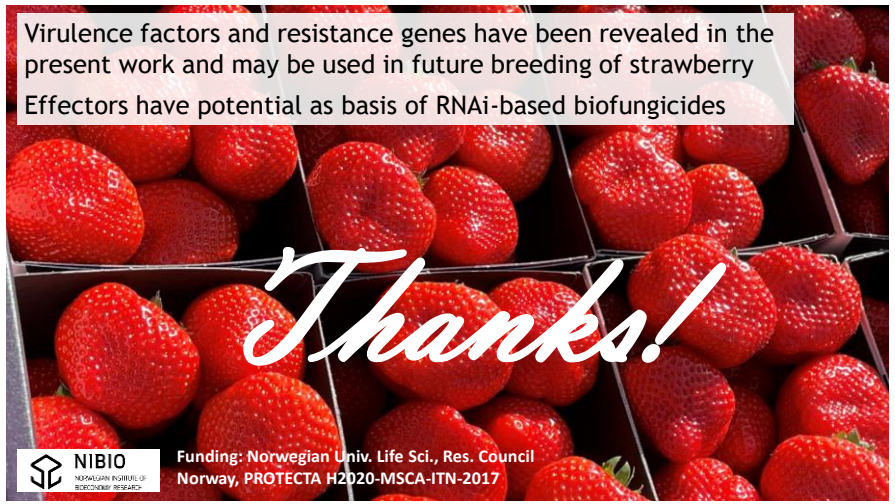
Virulence factors and resistance genes have been revealed in the present work and may be used in future breeding of strawberry

Effectors have potential as basis of RNAi-based biofungicides



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