Resistentieveredeling: Waar staan we nu?

Yuling Bai

Plant Breeding, Wageningen University & Research

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100years 1918 — 2018

KNPV

Afweermechanismen van de plant

Plant defence strategies

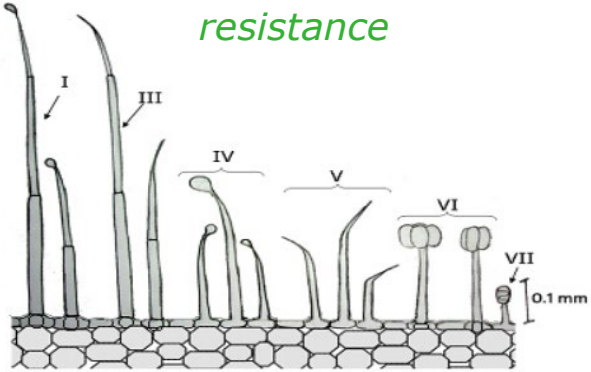
- Vermijden: Planten vermijden contact met insecten door componenten te gebruiken waar insecten niet tegen kunnen

Avoidance: plant's capacity to avoid intimate contact with a potential attacker, usually by a particular morphology like smell, colour, etc

lotte.caarls@wur.nl

De trichomen van de tomaat dragen bij aan resistentie voor witte vlieg

Tomato trichomes contribute to whitefly resistance



EU project

https://www.virtigation.eu/partners/

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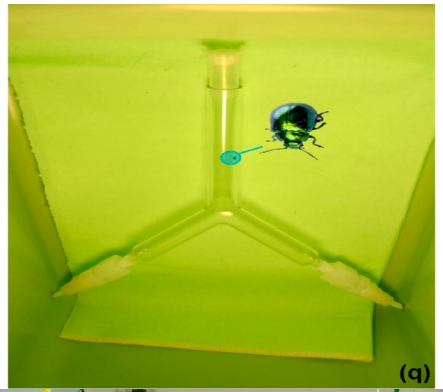
Afweermechanismen van de plant

Plant defence strategies

- **Vermijden:**

Avoidance:

lotte.caarls@wur.nl



Insect wordt aangetrokken door de geur van de plant

attracted by the smell of the plant

https://www.mdpi.com/1999-4907/11/6/638/htm

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Afweermechanismen van de plant

Plant defence strategies

- Vermijden: Planten vermijden contact met insecten door componenten te gebruiken waar insecten niet tegen kunnen

Avoidance: plant's capacity to reduce the chance of intimate contact with a potential attacker, usually by a particular morphology like *smell, colour, etc*

- Resistentie: De capaciteit van de plant om na contact de groei, ontwikkeling of reproductie van het insect te verminderen

Resistance: plant's capacity to reduce the growth/ development/reproduction of the attacker after the intimate contact)

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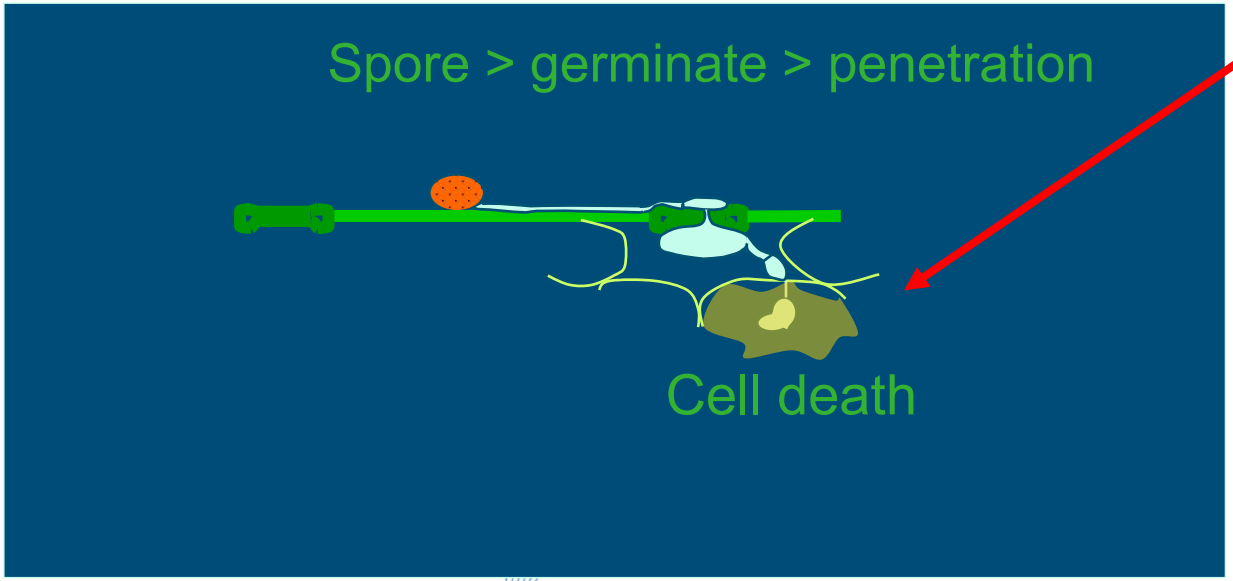
Resistentie door dominate resistentie (R) genen

Resistance via dominant resistance (R) genes

Infectie process van de roestschimmel

Infection process of rust fungi



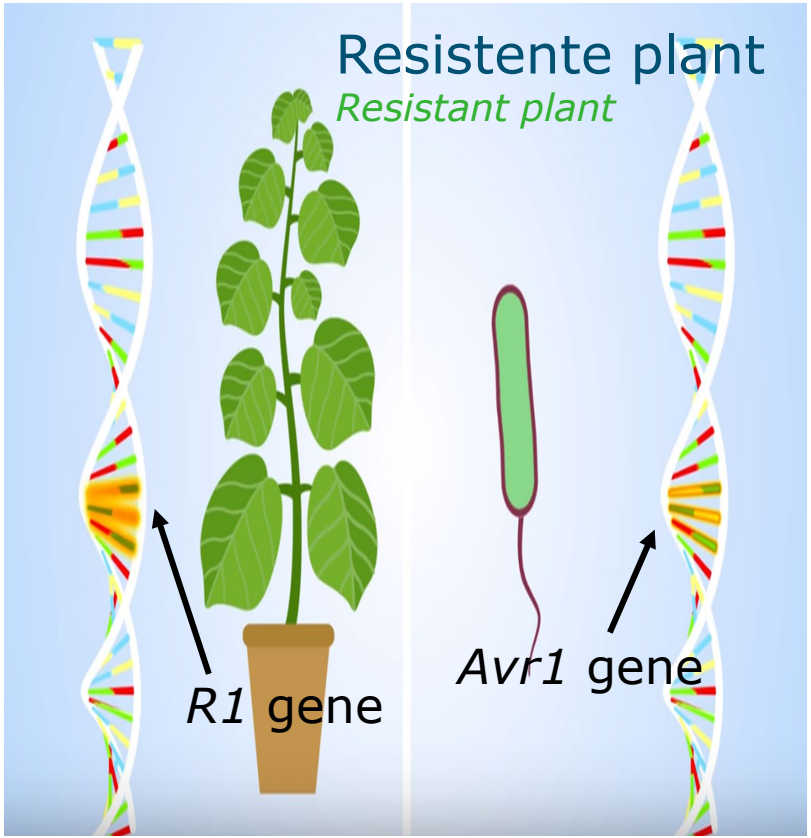
Hypersensitive response (HR):

Snelle gelokaliseerde celdood in de geïnfecteerde cel

Fast localized cell death in cells infected by pathogen.

R-gen: Gen om Gen

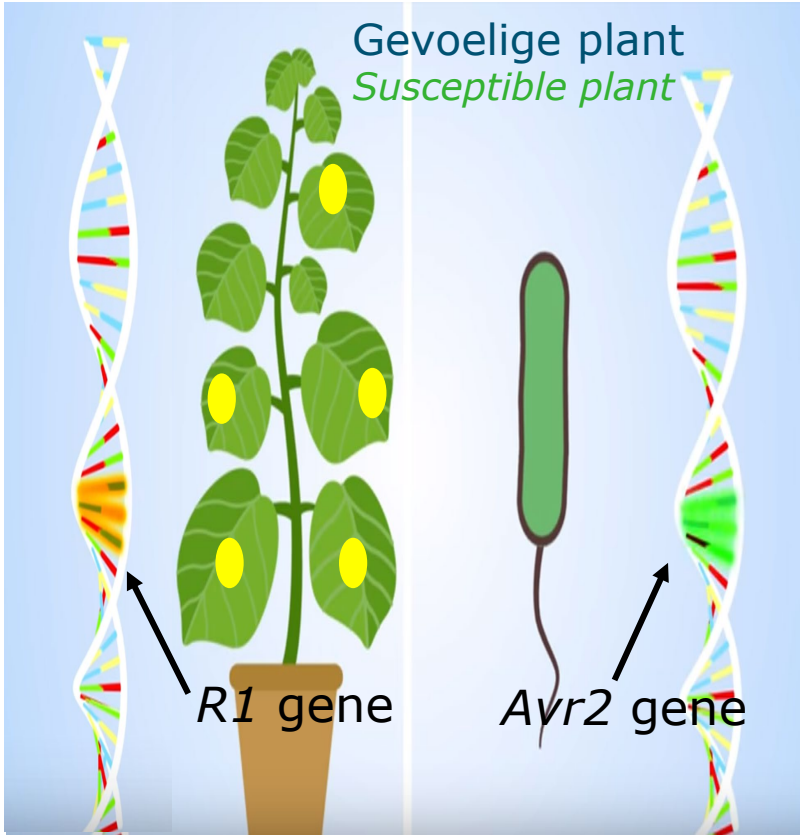
R gene: the Gene-for-Gene Model

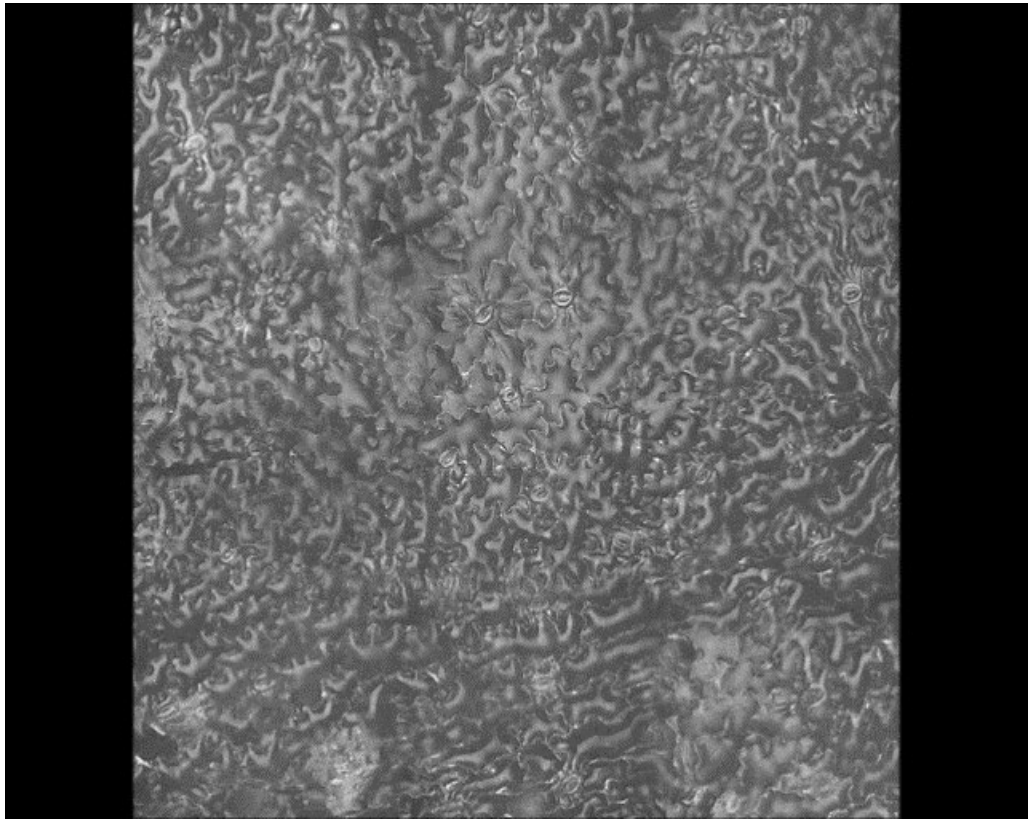


Adapted from https://www.youtube.com/watch?v=mlp2mQTEVtQ

R-gen: Gen om Gen

R gene: the Gene-for-Gene Model





Adapted from https://www.youtube.com/watch?v=mlp2mQTEVtQ

Afweermechanismen van de plant

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- Vermijden: Planten vermijden contact met insecten door componenten te gebruiken waar insecten niet tegen kunnen

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- Resistentie: De capaciteit van de plant om na contact de groei, ontwikkeling of reproductie van het insect te verminderen

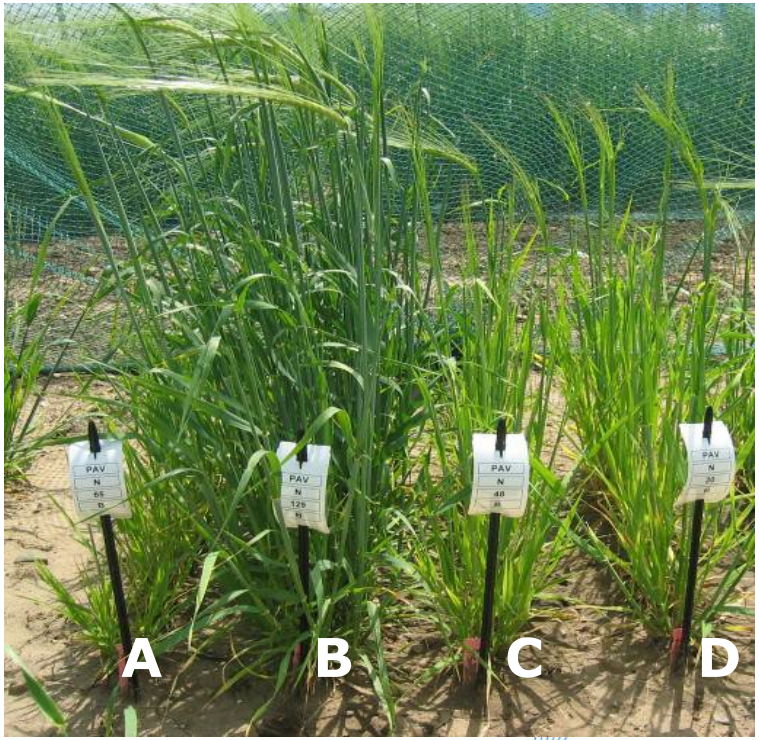
Resistance: plant's capacity to reduce the growth/ development/reproduction of the attacker.

- Tolerantie: de plant voorkomt symptoom ontwikkeling/ schade door het inperken van de infectie na contact

Tolerance: plant's ability to restrict the symptoms or damage other than by restricting the amount of infection.

Afweermechanismen van de plant

Plant defence strategies



Vier gerst rassen geïnoculeerd met gerstevergelingsvirus (BYDV)

Four barley cultivars were inoculated with barley yellow dwarf virus

Verschil in symptomen na een paar weken

After a few weeks, difference on plant growth was observed among the cultivars (see photo)

Is ras B resistant of tolerant? *Is cultivar B resistant or tolerant?*

Virussen:

- Veredelen voor resistente of tolerante rassen?
- Kan je planten vaccineren?

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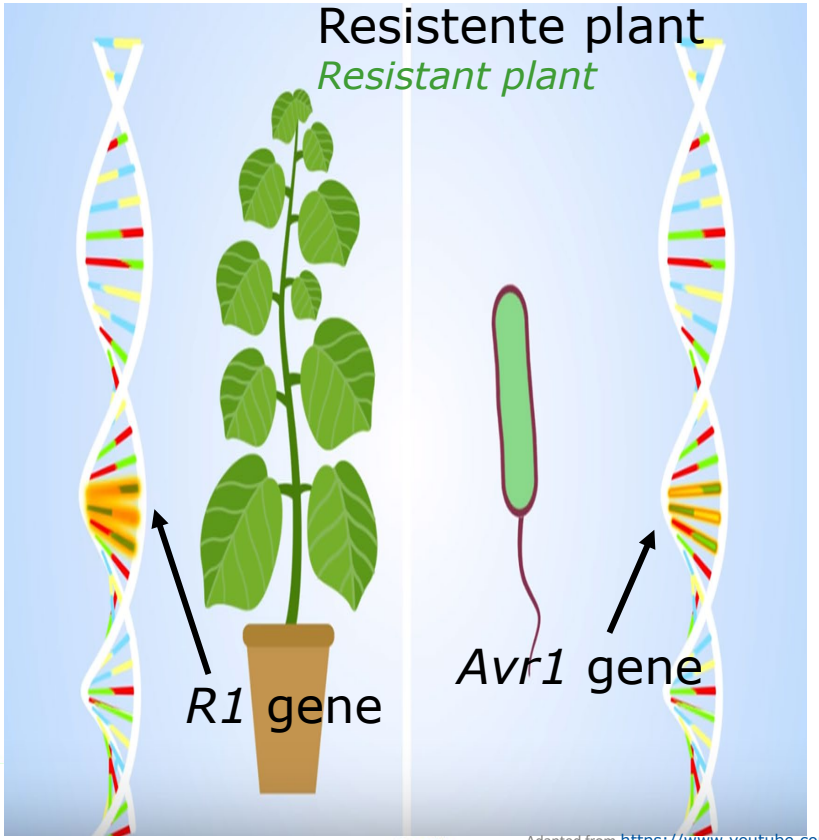
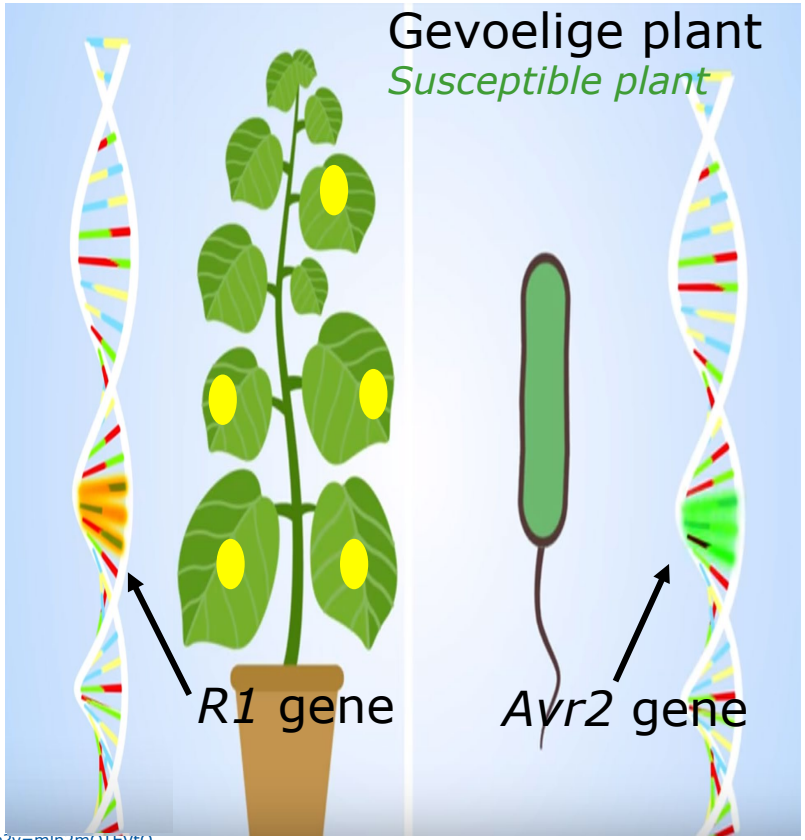
R gen: ras-specifieke resistentie (Gen-om-Gen)

R gene: race-specific resistance (the Gene-for-Gene Model)





Adapted from https://www.youtube.com/watch?v=mIp2mQTEVtQ

De wapenwedloop tussen plant en pathogeen

The arms race between plants and pathogens

Valse meeldauw in spinazie

Downy Mildew in Spinach

Correll et al, 2011, European Journal of Plant Pathology

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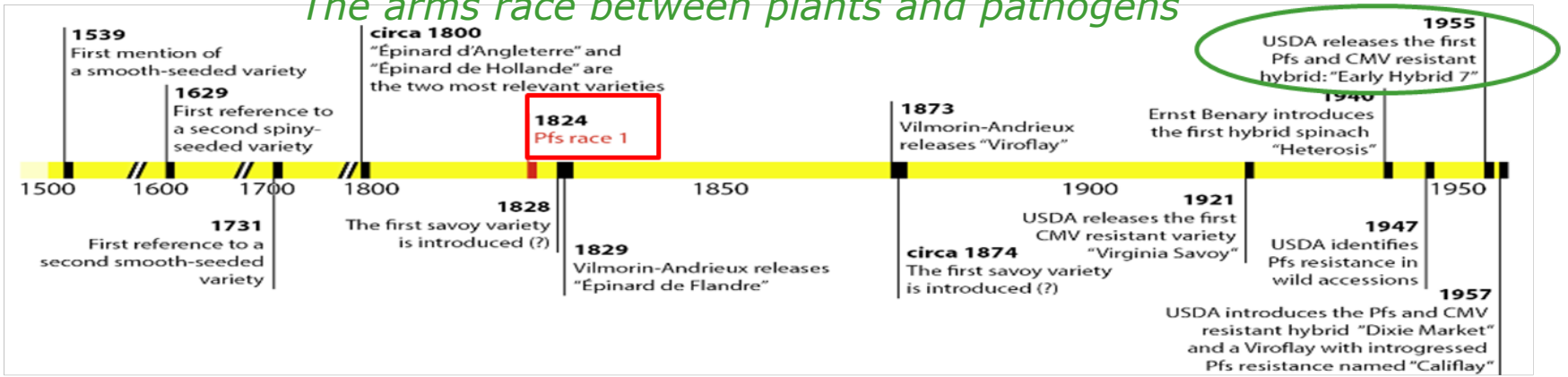
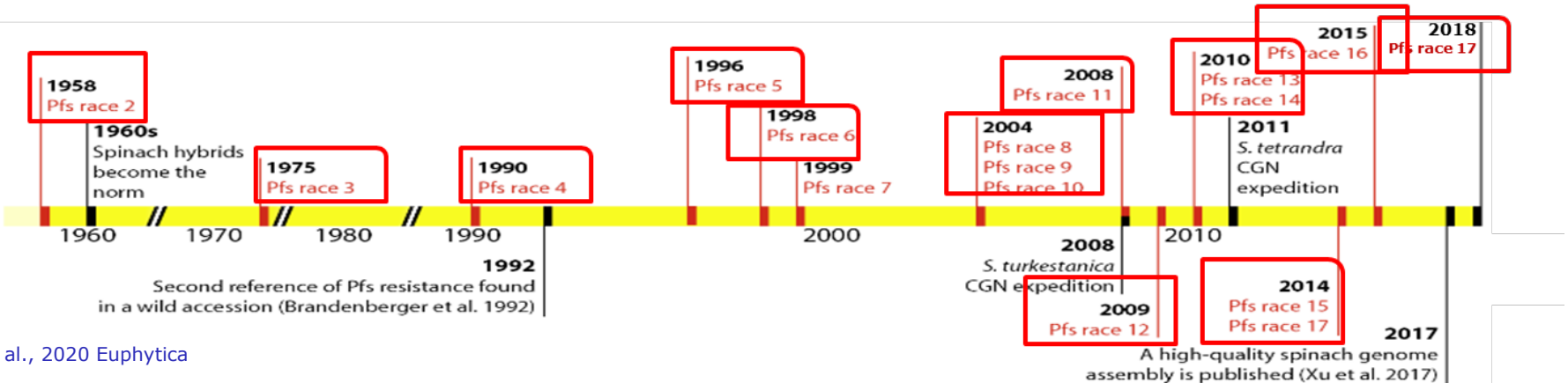
De wapenwedloop tussen plant en pathogeen

The arms race between plants and pathogens

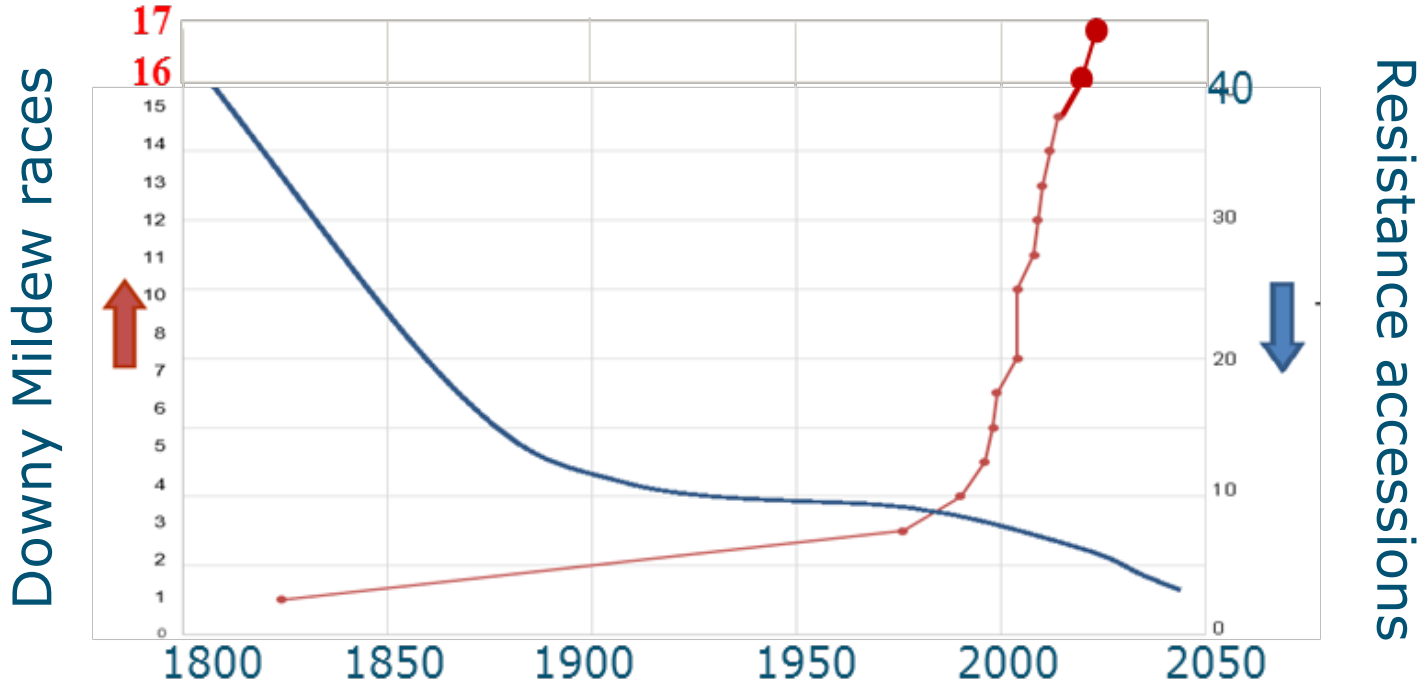




Ribera et al., 2020 Euphytica

De wapenwedloop tussen plant en pathogeen

The arms race between plants and pathogens



Correll et al, 2011, European Journal of Plant Pathology; Source: presentation Jan de Visser 2015, International Spinach Conference; Yuma, Arizona; February 24-25, 2015 (adapted)

Geen R genen voor resistentie tegen necrotrofen

No R genes for diseases caused by necrotrophs

- *e.g. Botrytis cinerea*
- Geen R-genen in wilde tomaten verwanten

No R genes discovered so far in wild tomato relatives

Gevoeligheids genen

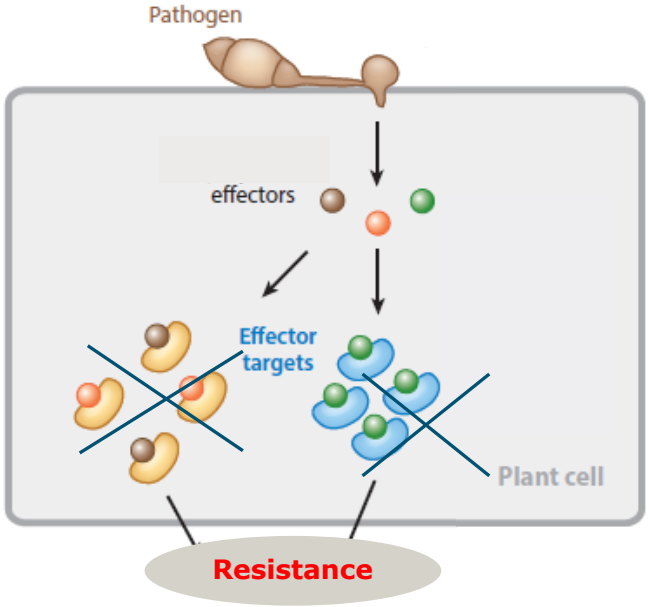
Plant susceptibility (S) genes

- **S-gen: een planten gen dat wordt gebruikt door een pathogen om ziekte te veroorzaken**

***S-gene**: A plant gene required/misused by pathogens to cause disease, e.g. genes coding effector targets*

- **Genetisch, beschadigde/afwijkende S-genen resulteren in recessieve resistentie**

***Genetically**, impaired S-genes lead to recessive resistance*



Het S-gen concept in de afgelopen 10 jaar

S-gene concept in the past 10 years

- Zijn S-genen geconserveerd tussen planten soorten?

Are S genes conserved across plant species?

- Hoe verkrijg je mutanten die niet meer functioneel zijn?

How to obtained loss-of-function mutants?

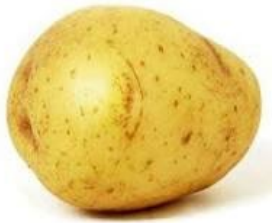
  - Natural mutations (*Mlo*, *Xa5* & *Xa13*, *eIF4E* & *eIF4G*)
  - Mutagenesis
  - RNAi and/or gene editing

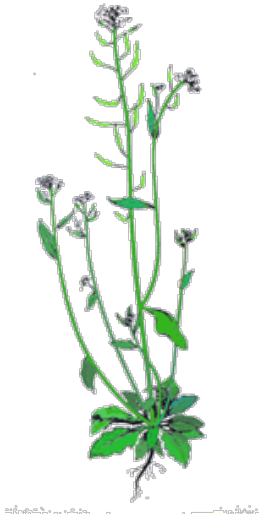
- Hoe ga je om met pleiotropie (nadelige kenmerken)?

How to deal the pleotropic phenotypes?

Zijn S-genen geconserveerd tussen planten soorten?

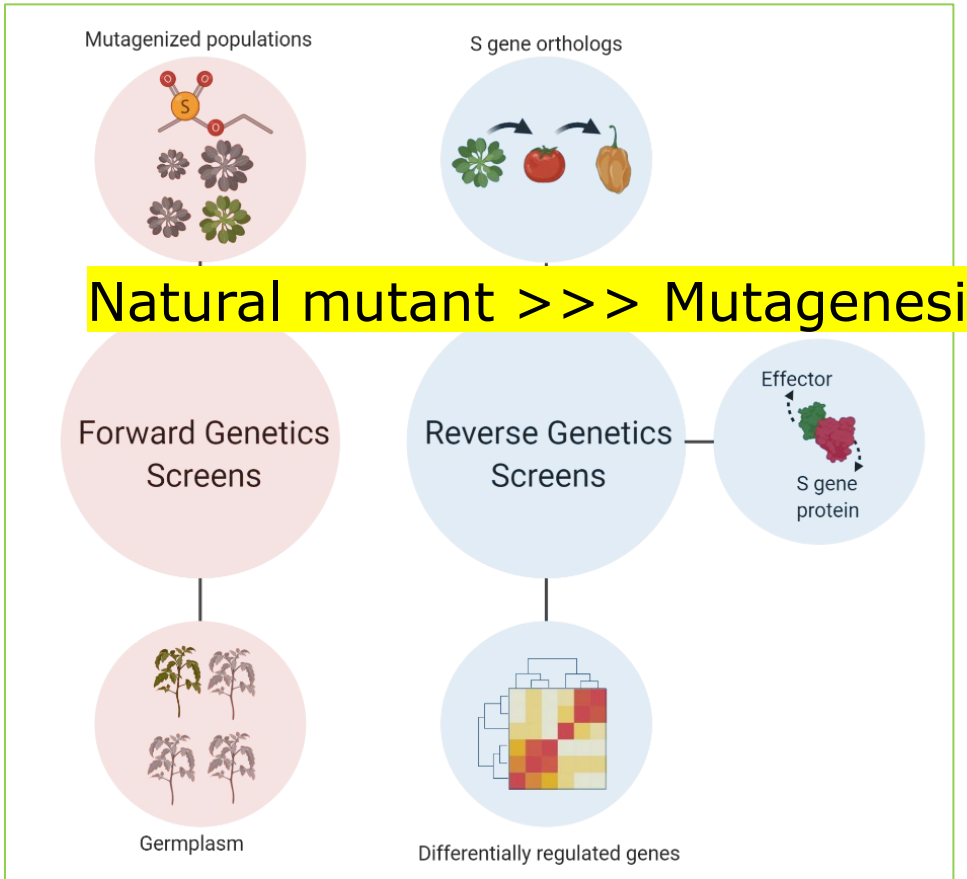
Are plant S genes conserved across plant species?

S genen van Arabidopsis	Orthologues in gewassen	RNAi/CRISPR
PMR4		Resistance to
DND1		**Powdery mildews**
DMR1		**Late blight**
DMR6 →	→	***Botrytis***
CESA3		***Clavibacter***
SR4		***Verticillium***
Many others		***……***

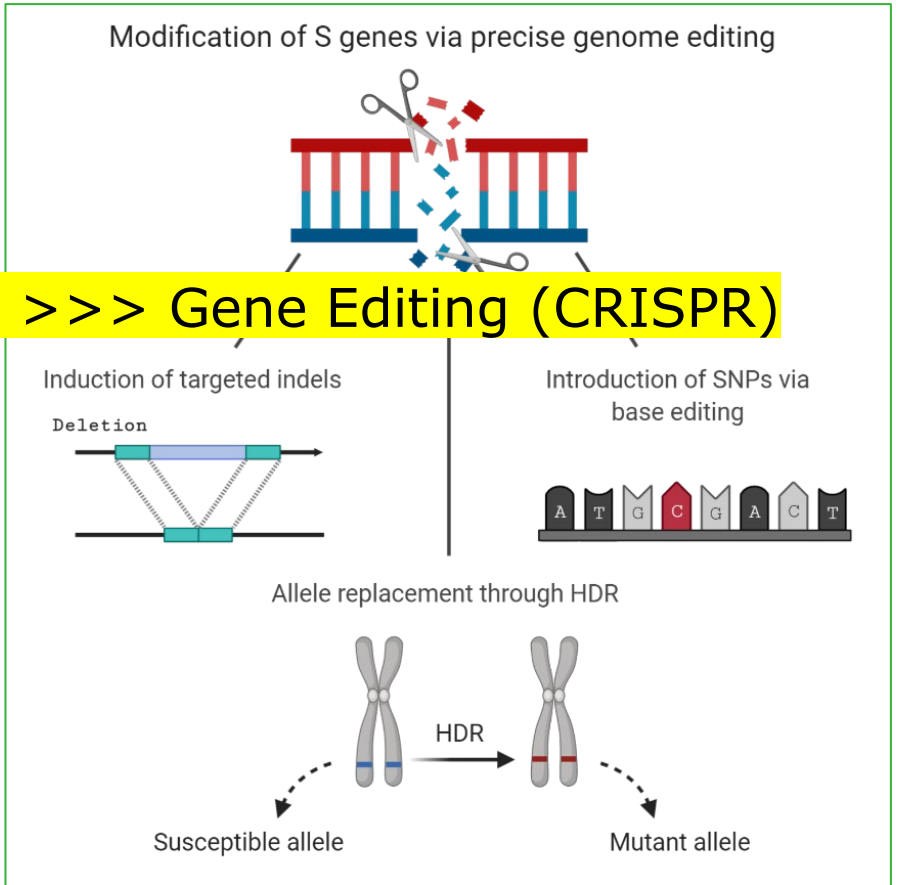


Hoe verkrijg je niet functionele mutanten?

How to obtained loss-of-function mutants?

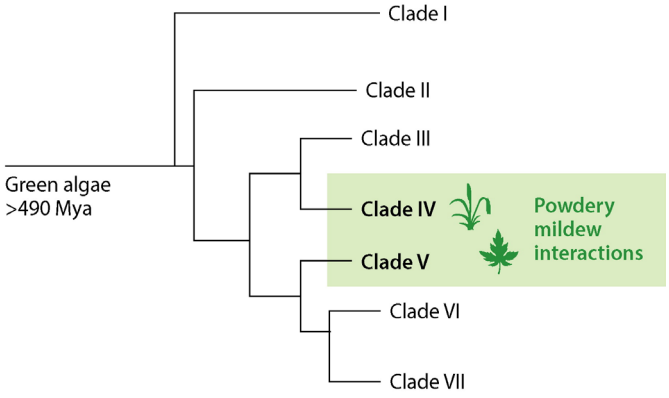


Natural mutant >>> Mutagenesis >>> Gene Editing (CRISPR)

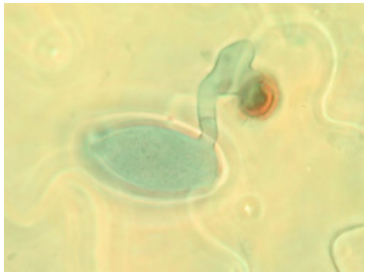


Het *Mlo*-gen: S-gen voor echte meeldauw

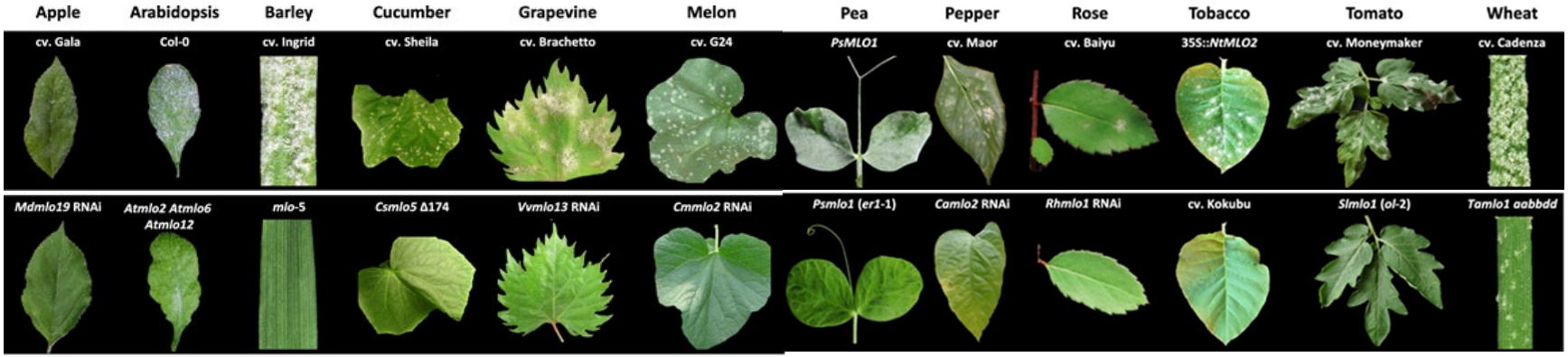
The Mlo gene: S gene for powdery mildews



Functional *Mlo* gene



Loss-of-function *mlo* mutant



Plant Biotechnology Journal
Open Access

Plant Biotechnology Journal (2023), pp. 1–3

doi: 10.1111/pbi.14127

Brief Communication

Mutation of *PUB17* in tomato leads to reduced susceptibility to necrotrophic fungi

Miguel Ramirez Gaona[1], Ageeth van Tuinen[1], Danny Schipper[1], Akihito Kano[2], Pieter J. Wolters[1], Richard G. F. Visser[1], Jan A. L. van Kan[3], Anne-Marie A. Wolters[1] and Yuling Bai[1,*]

[1]*Plant Breeding, Wageningen University & Research, Wageningen, The Netherlands*

[2]*Plant Breeding and Experiment Station, Takii & Company Limited, Konan, Japan*

[3]*Laboratory of Phytopathology, Wageningen University & Research, Wageningen, The Netherlands*

Miguel Ramirez Gaona

Anne-marie Wolters

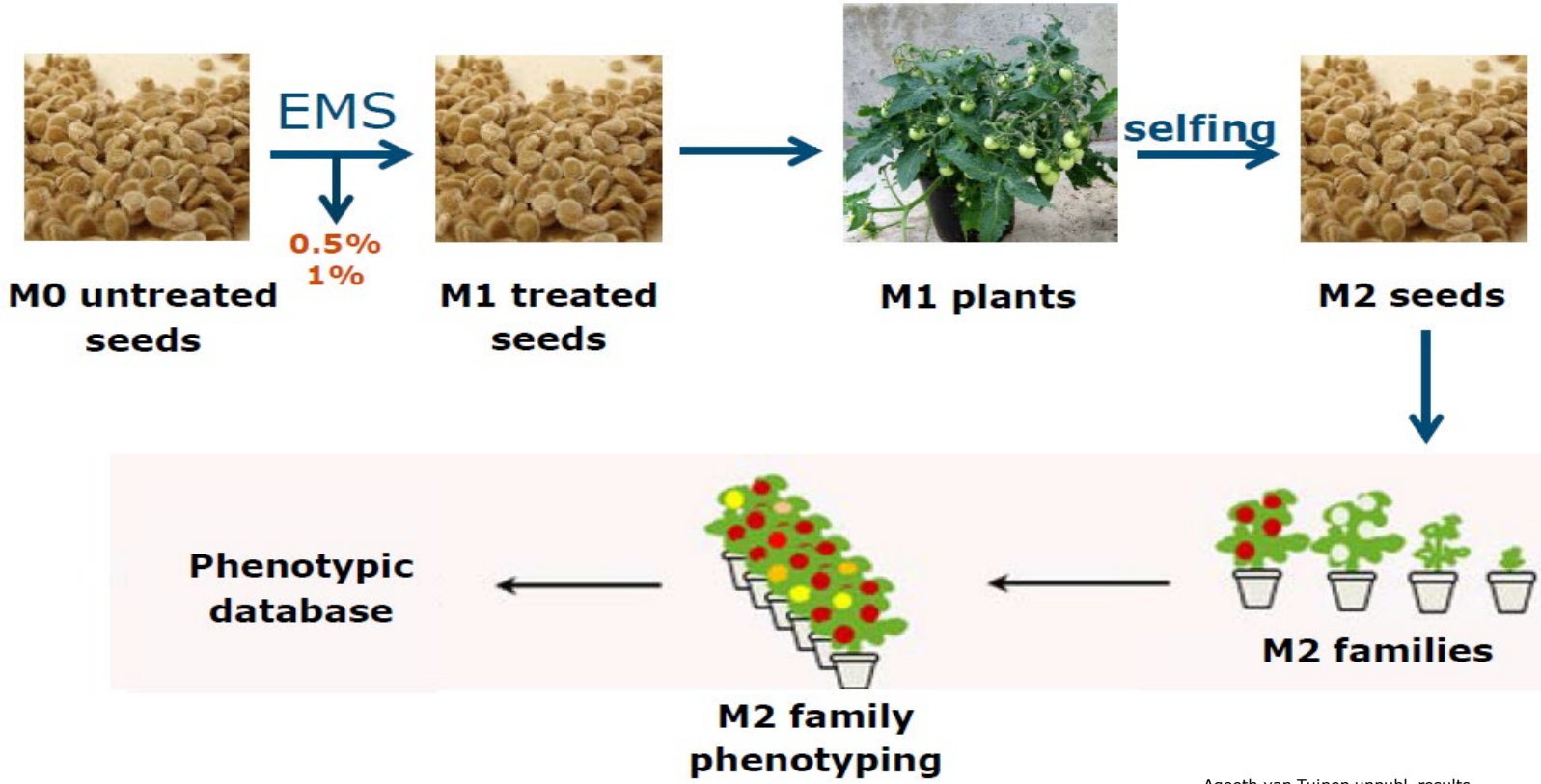
Jan van Kan

Danny Schipper

Ageeth van Tuinen

Mutagenese om niet functionele mutanten te maken

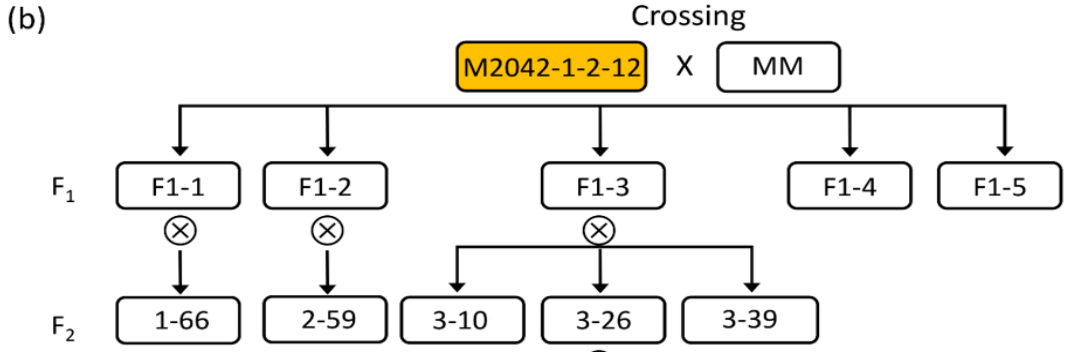
Mutagenesis to obtain loss-of-function mutants



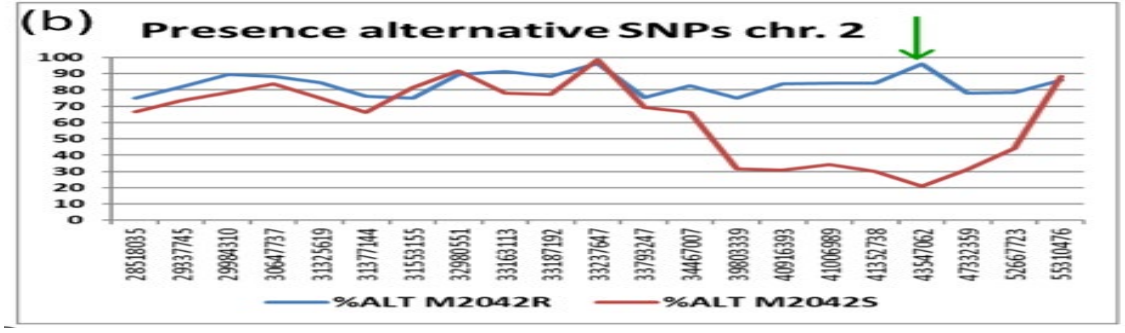
Ageeth van Tuinen unpubl. results

BSA-sequentie analyse voor gen identificatie

BSA-sequence analysis to identify the causal gene



R and S pools used in BSA: bulked segregant analysis



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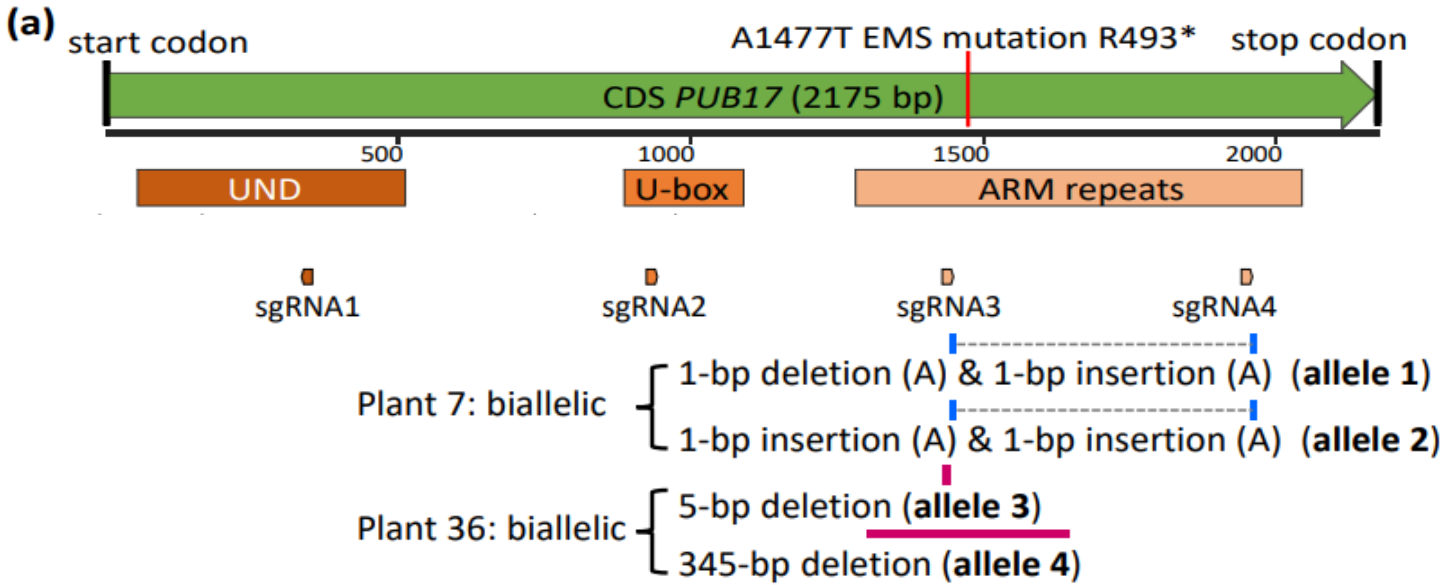
Het causale gen/*The causal gene: PUB17*

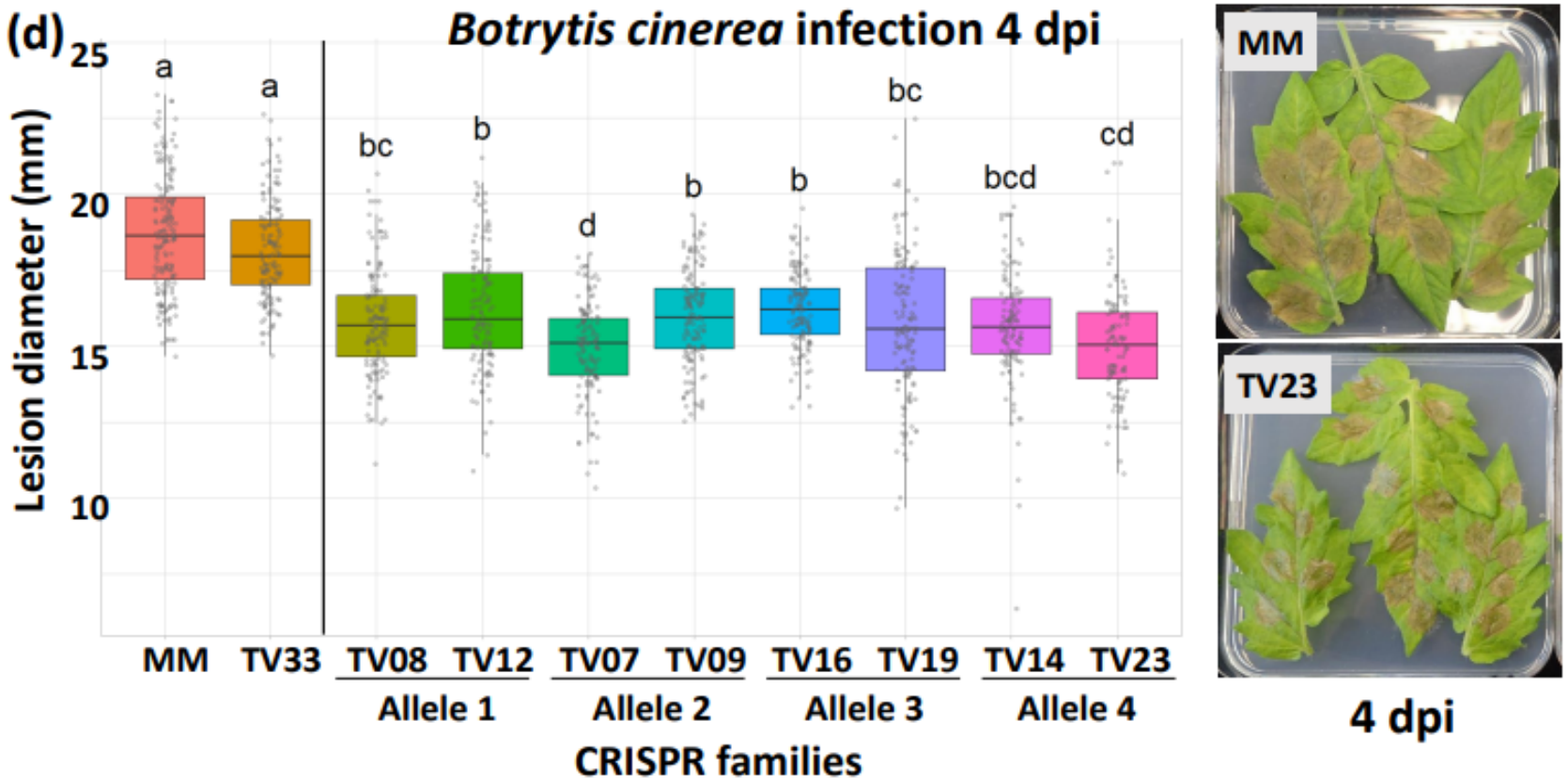
- PUB17: a U-box E3 ubiquitin ligase; mutation R493*.



UND: U-box N-terminal domain

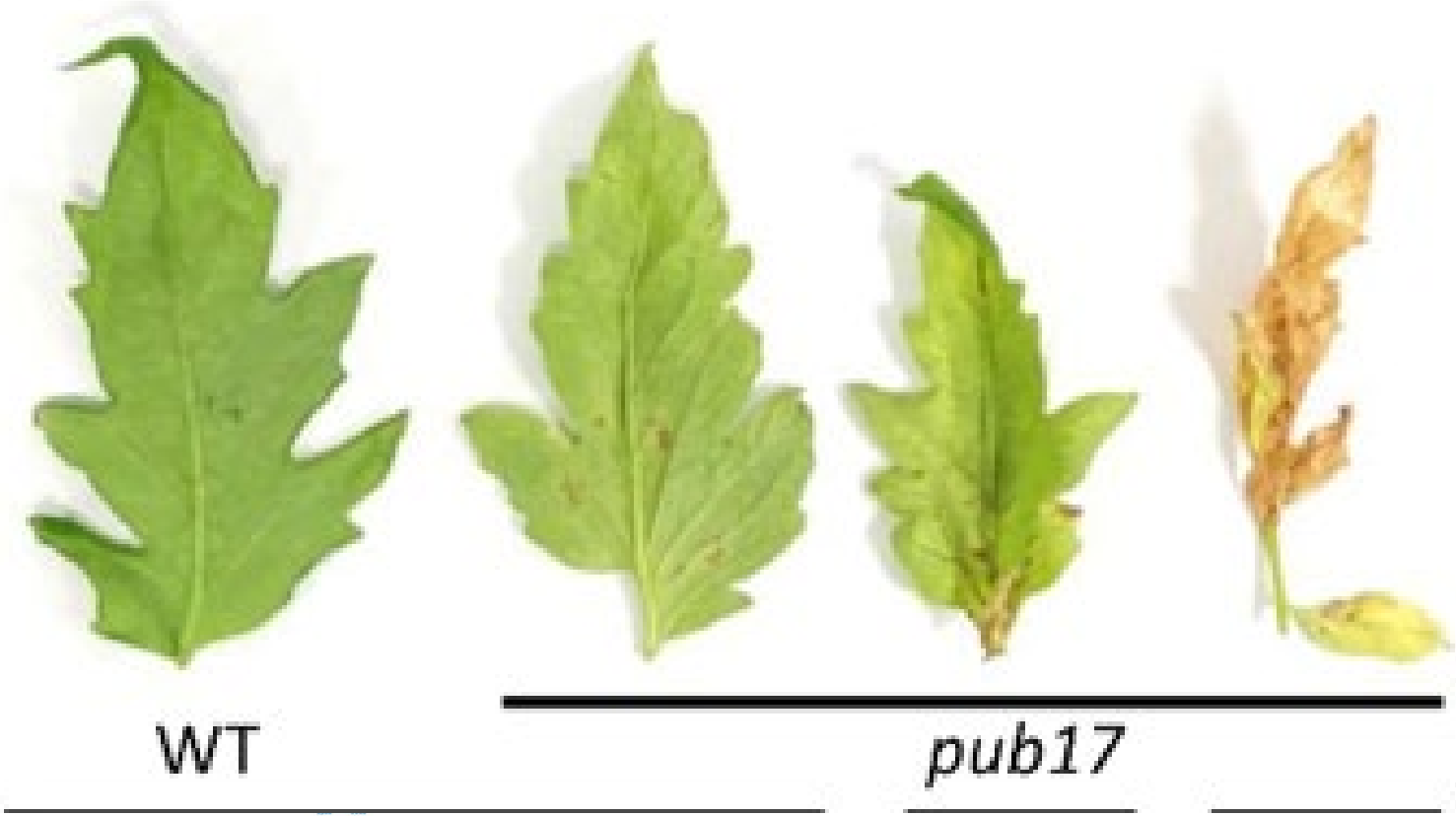
ARM: Armadillo repeat

Het causale gen/*The causal gene: PUB17*



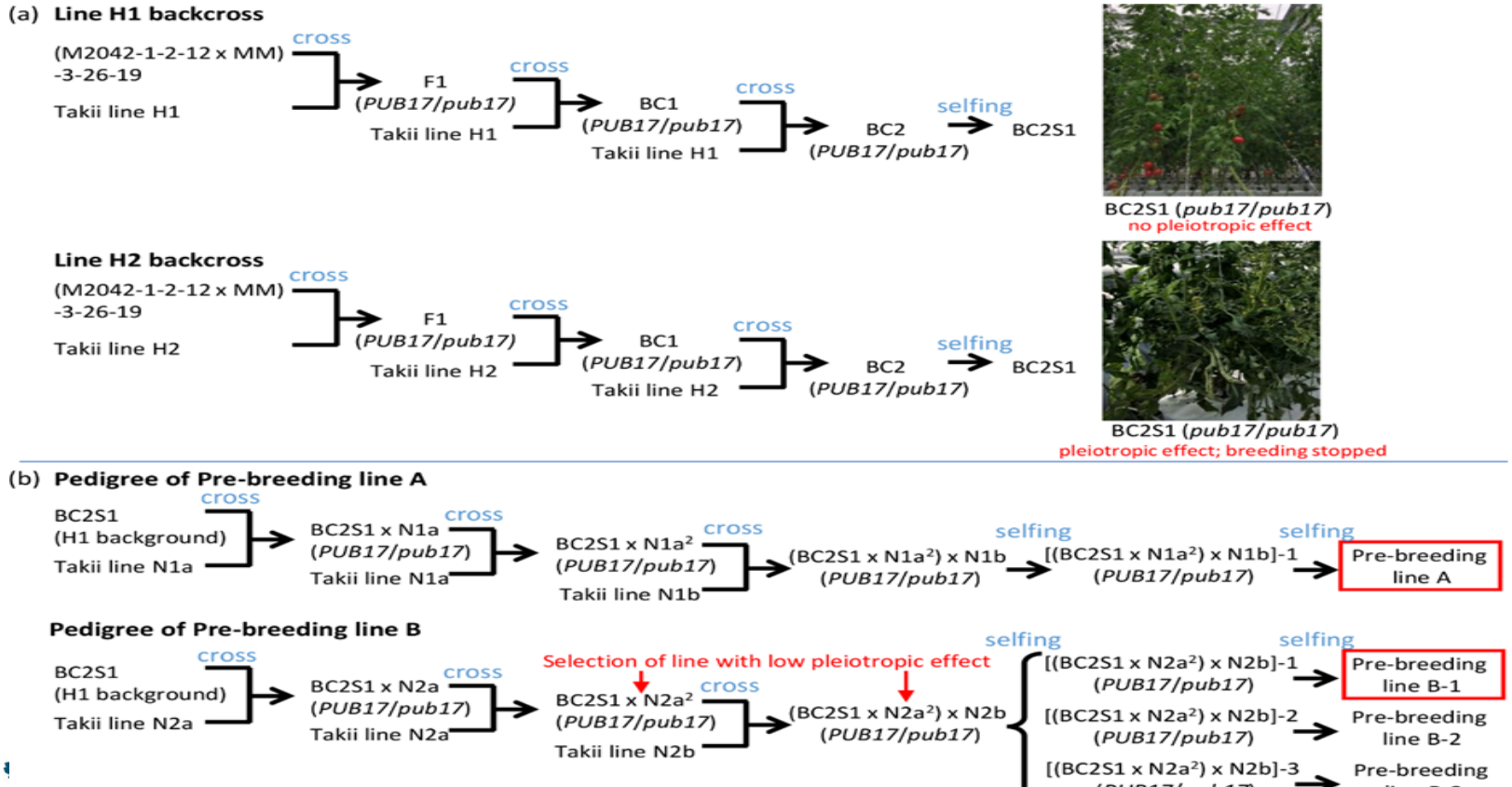
Hoe voorkom je pleiotropie?

How to deal pleotropic effect?

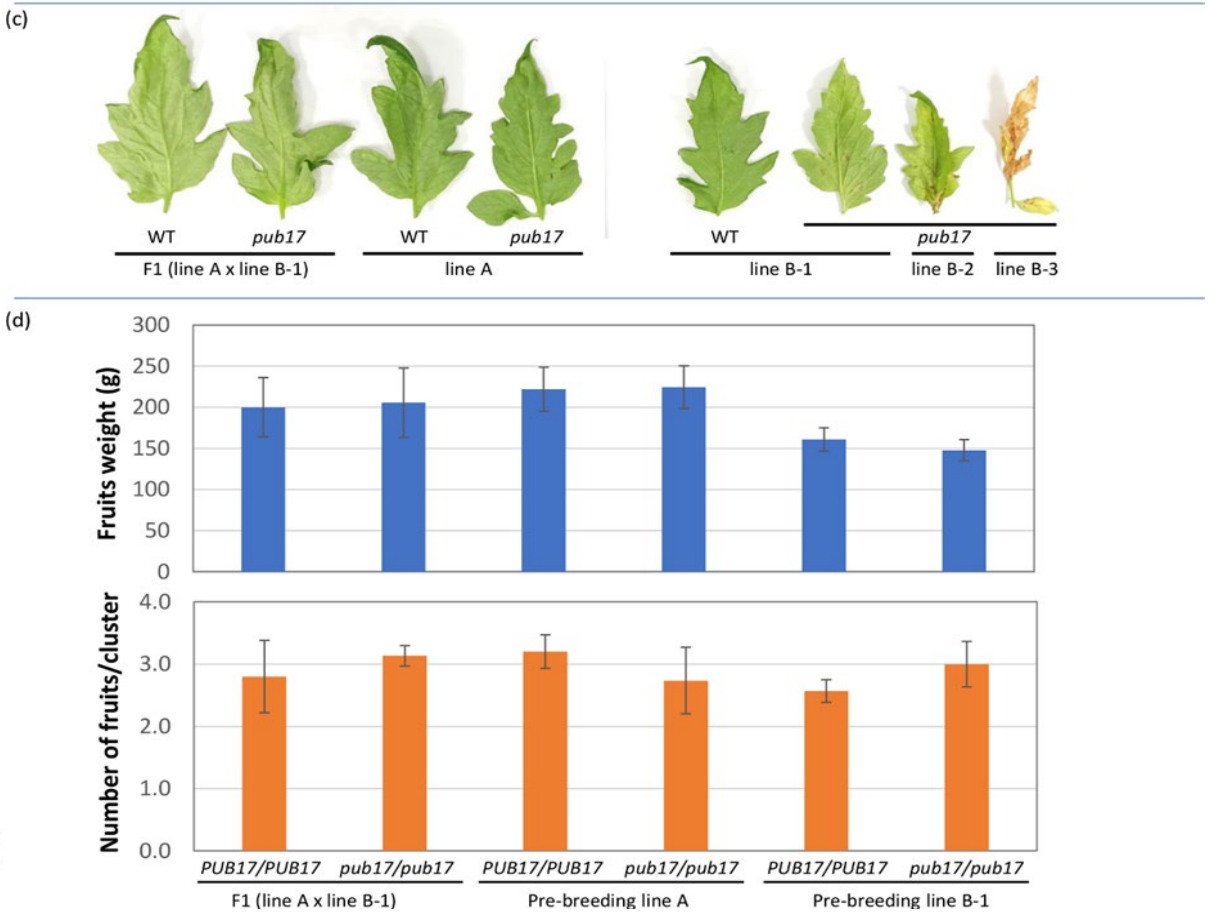


Pleiotropie is afhankelijk van de achtergrond

Pleiotropic effect is background dependent



pub17 mutatie in tomaten cultivars!



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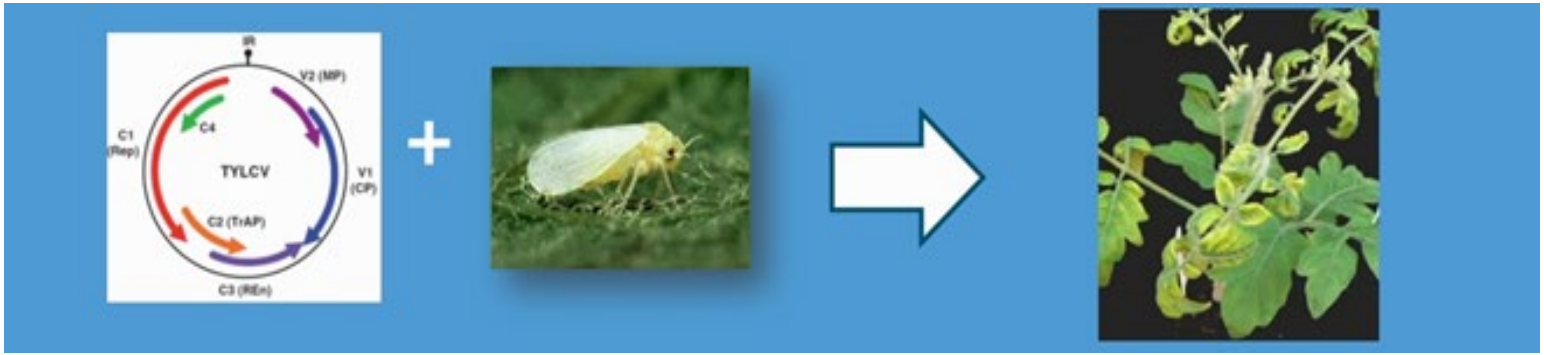
S-gen voor virus resistentie

S genes in resistance to viruses

- >50% zijn recessieve resistentie genen
  - Virussen hebben weinig genen
  - Ze hebben hulp nodig van de plant



TYLCV: tomato yellow leaf curl virus, ~ 6 genen

Pril een S-gen voor geminivirusen

PriL as an S-gene for geminiviruses

DNA primase large subunit is an essential plant gene for geminiviruses, putatively priming viral ss-DNA replication

Lampros Siskos[1], Maria Antoniou[1], Jose Riado[2], Montserrat Enciso[2], Carlos Garcia[2], Daniele Liberti[3], Danny Esselink[1], Andrey G. Baranovskiy[4], Tahir H. Tahirov[4], Richard G. F. Visser[1], Richard Kormelink[5], Yuling Bai[1] and Henk J. Schouten[1*]

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frontiers | Frontiers in Plant Science

Het S-gen concept in de afgelopen 10 jaar

S-gene concept in the past 10 years

- S-genen zijn **plantengenen** die worden gebruikt door pathogenen/ *plant genes that are exploited by pathogens*
  - Binnendringen/*to enter*, i.e. the *mlo* gene
  - Onderdrukken van afweer/*supress plant defence responses*, *PUB17* gene
  - Verwerven van nutrienten/ *acquire nutrients,* rice *Sweet* genes
  - Veroorzaken van symptomen/ *cause symptoms*, pepper *Upa20* gene
  - ...
- S-genen zijn plantengenen die gebruikt kunnen in de resistentieveredeling/ *S genes are plant genes can be exploited for breeding resistance to biotic stresses*

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Het S-gen concept in de afgelopen 10 jaar

S-gene concept in the past 10 years

- S-genen van planten:
  - kunnen worden geïdentificeerd/ *can be identified*
  - kunnen worden gemodificeerd/ *can be modified*
  - zijn geconserveerd/ *conserved across plant species*
  - veranderingen kunnen leiden tot pleiotropie/ *may lead to pleiotropic effect if it is impaired*
- S-genen van planten in resistentieveredeling

Plant S genes in resistance breeding

  - .....

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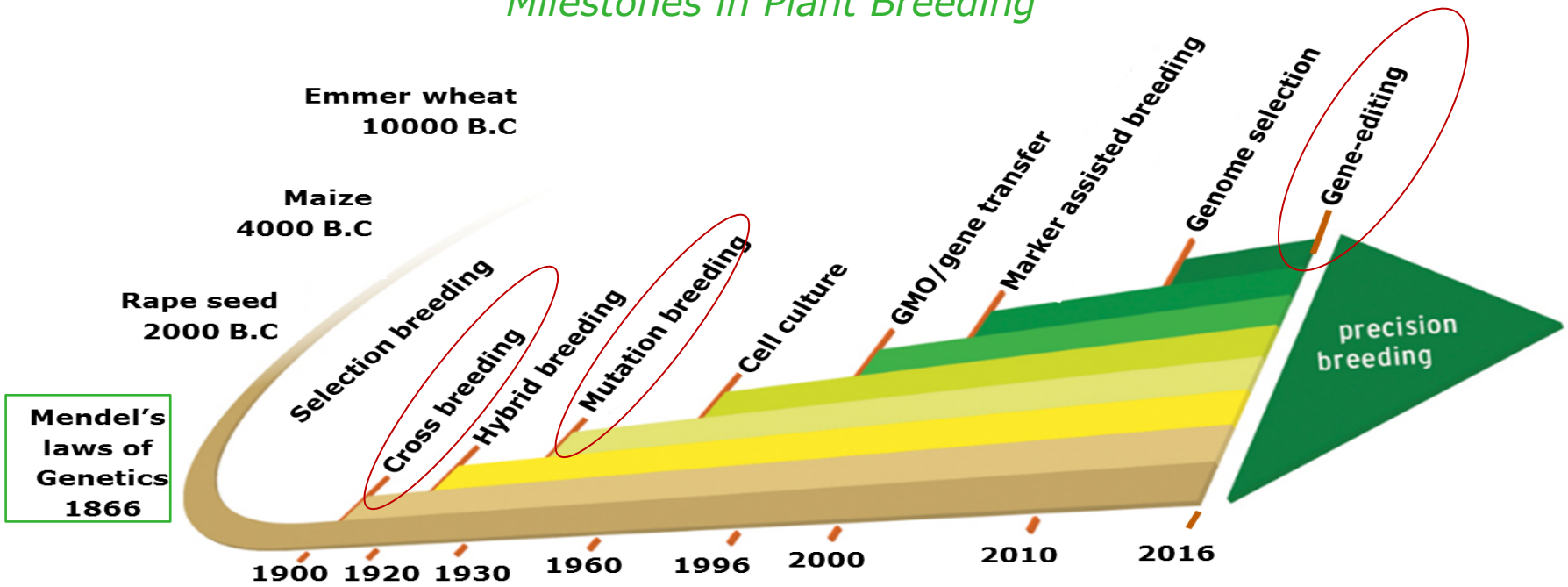
Mijlpalen in plantenveredeling

Milestones in Plant Breeding



Gene Editing belongs to New Genomic Techniques (NGT)

https://european-seed.com/2016/05/much-plant-breeding-innovation-politically-intended/

Reactiveren van R-genen & modificeren van S-genen

Repair R genes

Daniel Moninolopez

Jack Vossen

Henk Schouten

Anne-marie Wolters

Mireille van Damme

Eleni Koseoglou

S genes

Arnaud Bovy

Jan Schaart

Paul Arens

Suzan Gabriels

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Afweermechanismen van de plant

Plant defence strategies

- Resistentie voor biotische stress/ *Resistance to biotic stresses*
  - Monogene resistentie/*Monogenic resistance*
    - R & S genen
  - Polygene resistentie/ *Polygenic resistance*
    - Kwantitatieve eigenschappen/*Quantitative traits*, difficult to use in breeding
    - Nuttig voor genomics & digitale fenotypering/ *Helpful with genomics and digital phenotyping*
    - Genomische selectie/ *Genomic selection*
- Resistentie voor abiotische en gekoppelde stressfactoren *Resistance to abiotic and combined stresses*

Respons van S-genen op biotische & **abiotische** stress

*Plant S genes in responses to biotic & **abiotic** stresses*

Plant Stress 13 (2024) 100541

Contents lists available at ScienceDirect

Plant Stress

journal homepage: www.sciencedirect.com/journal/plant-stress

Knock-out of *SlDMR6-1* in tomato promotes a drought-avoidance strategy and increases tolerance to Late Blight

Alex Maioli [a], Federica De Marchi [a], Danila Valentino [a], Silvia Gianoglio [a,b], Davide Lucien Patono [a], Fabio Miloro [a], Yuling Bai [c], Cinzia Comino [a], Sergio Lanteri [a], Claudio Lovisolo [a], Alberto Acquadro [a], Andrea Moglia [a,*]

[a] DISAFA, Department of Agricultural, Forest and Food Sciences, University of Torino, 10095, Grugliasco, TO, Italy
[b] Instituto De Biología Molecular y Celular De Plantas (IBMCP) CSIC-UPV, Ingeniero Fausto Elio/n, 46022, Valencia, Spain
[c] Plant Breeding, Wageningen University & Research, 6708, PB, Wageningen, the Netherlands

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Respons van S-genen op biotische & **abiotische** stress

*Plant S genes in responses to biotic & **abiotic** stresses*

Drought stress analysis. T2_7 & WT plants growing in a greenhouse after 7 days of withholding water

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Acknowledgements

WUR:

- Jan van Kan (the *Pub17* gene)

- Richard Kormelink (the *Pril* gene)

The *mlo* mutant

Aachen University
- Ralph Panstruga

University of Bari
- Stefano Pavan
- Claudio De Giovanni
- Luigi Ricciardi

Univ. of Foggia
- Concetta Lotti

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2023 Dec.
Including
MSc thesis
students

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