A plague on all our houses: Plant viruses

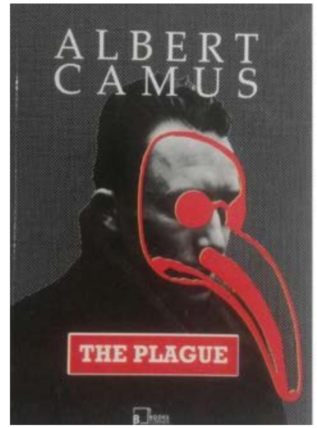
Jonathan Griffiths, Ph.D.
Research Scientist, Plant Virology
Jonathan.Griffiths@agr.gc.ca

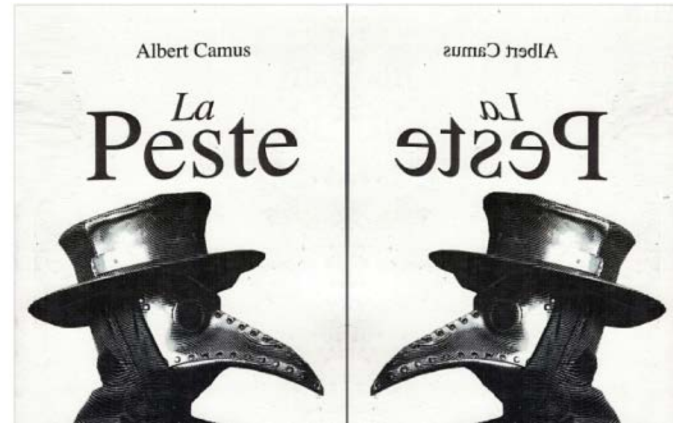
Plagues: an Overview

- Nearly half of plant disease epidemics are caused by viruses – Jones 2022
- Viruses and plagues
- Tomatoes, grapes, blueberries, tree fruits
- Individuals to ecosystems
- Resistance
- Biovigilance

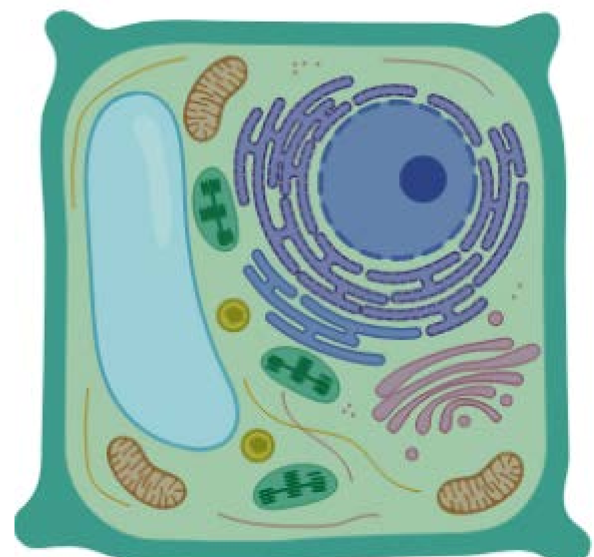
Plagues come in all shapes and sizes

- Plagues: Epidemic, pandemic, endemic





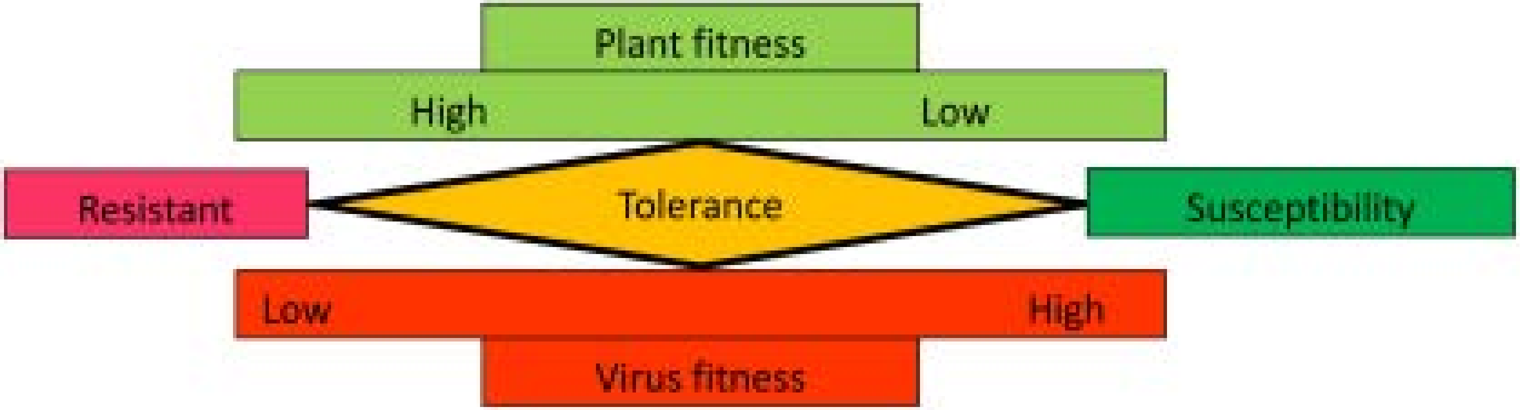
- COVID and plants
- Origins
- Transmission
- Host range
- Preventative measures
- Molecular virus-host interactions



Biorender

Plant-Virus Interactions

- Susceptible
- Tolerant
  - Co-existence
- Resistant
  - Lack of viral replication or movement
- Individuals vs populations



Paudel and Sanfacon, 2018

So many plagues

Greenhouse Tomatoes

Blueberries

Grapes

Tree fruits

Viral Plagues of Tomato

Rugose

PepMV

- Tomato brown rugose fruit virus - Tobamovirus
- Pepino mosaic virus – Potexvirus

- Easily transmissible, stable in the environment
- Similar characteristics, unrelated, completely different plague

Plagues of grapes

- Many viruses ~70
- GRBV and GLRaV
- Reddening of leaves
- Reduced fruit quality
- Persistent/Crop cycle
- Vectors
- Clean plant program

Virus plagues of blueberry

- BlScV – Carlavirus
- BlShV – Ilarvirus

- Persistent vs recovery
- Aphid vs pollen

Viral plagues of tree fruits

- Apple decline, Prunus decline
- Peach and nectarine, plum, apricot, cherry, apple
- PNRSV, PDV, CVA, ASGV, ASPV, ACLSV

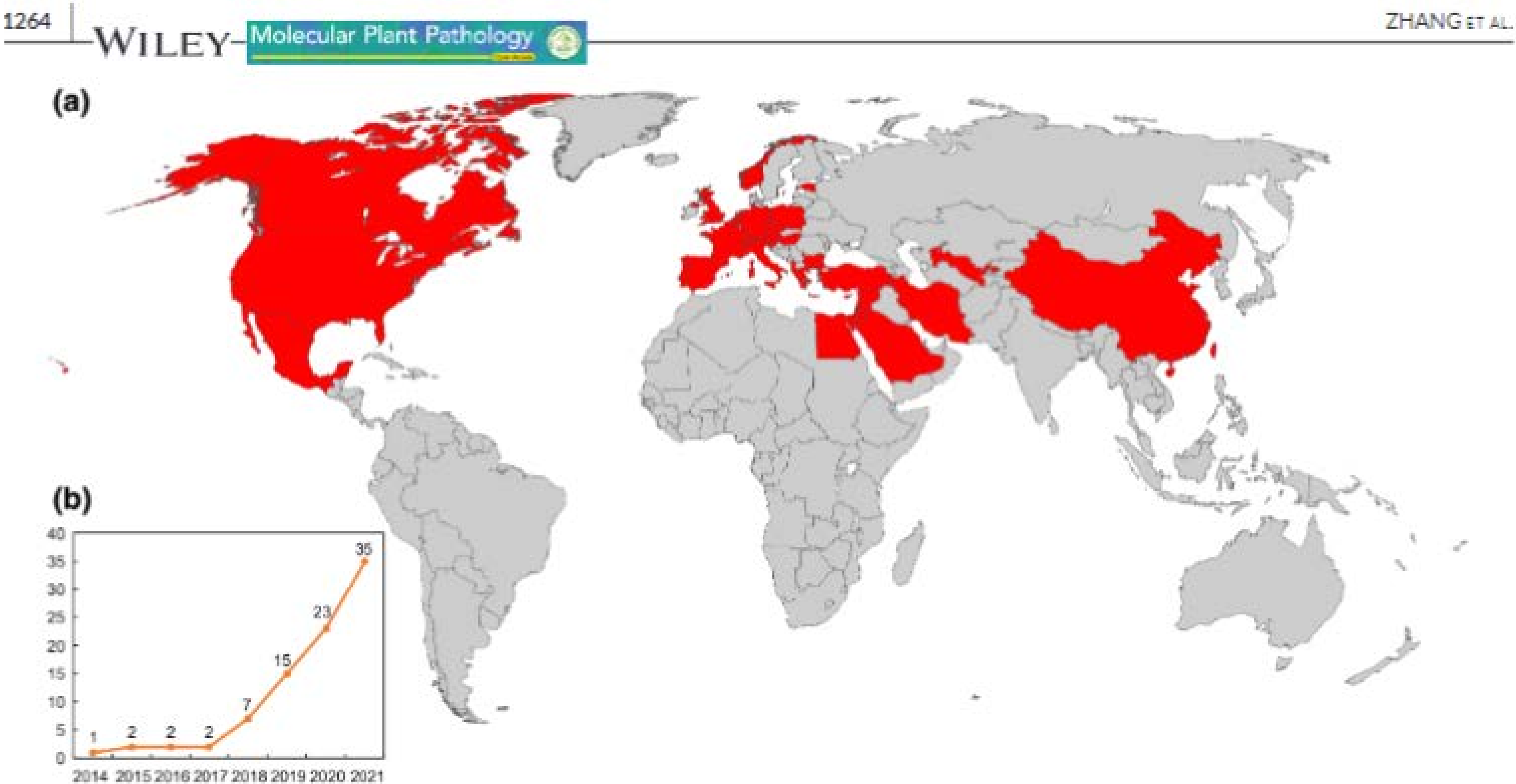
How to combat plagues

Genetic resistance

Monitoring

Clean plants

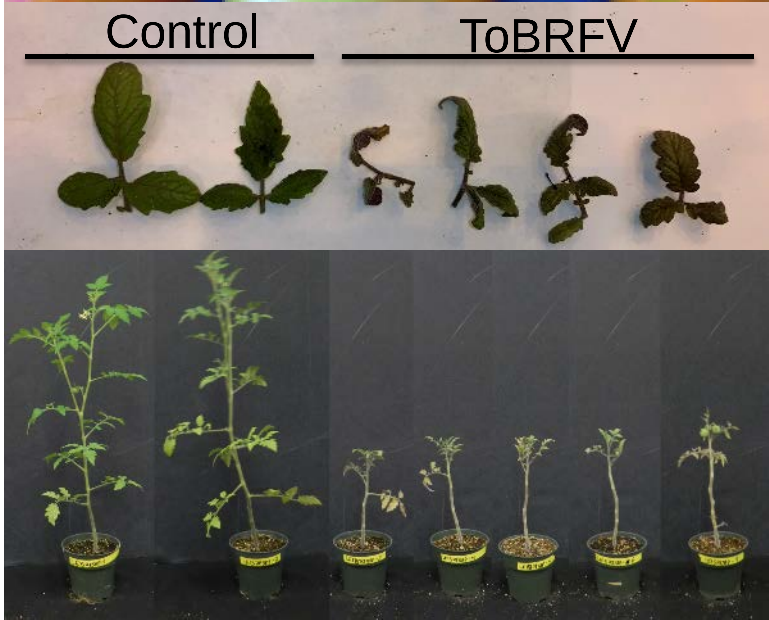
Origins of a plague: rise of rugose



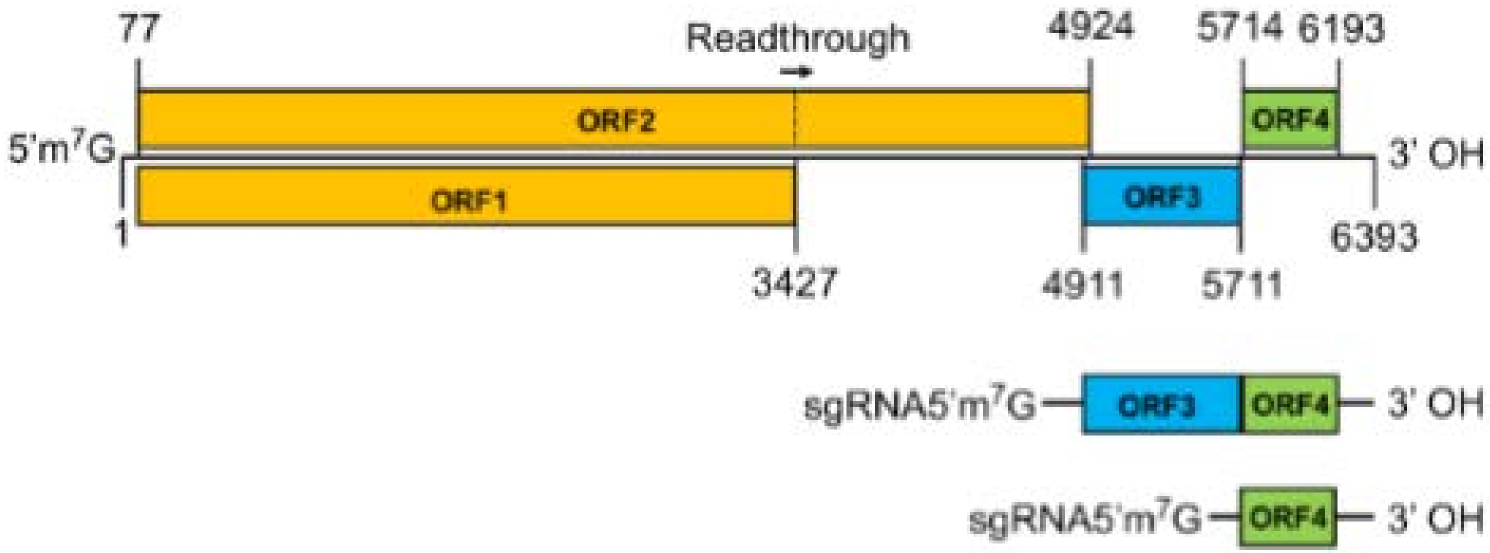
The Plague of Rugose

- Easily mechanical transmitted
  - Low seed transmission
- Stable/persistent
- Leaf mosaic, deformation
- Yellow/brown fruit
- Necrotic flowers
- Rapid decline in production

- Evades *Tm-2*^{2} resistance

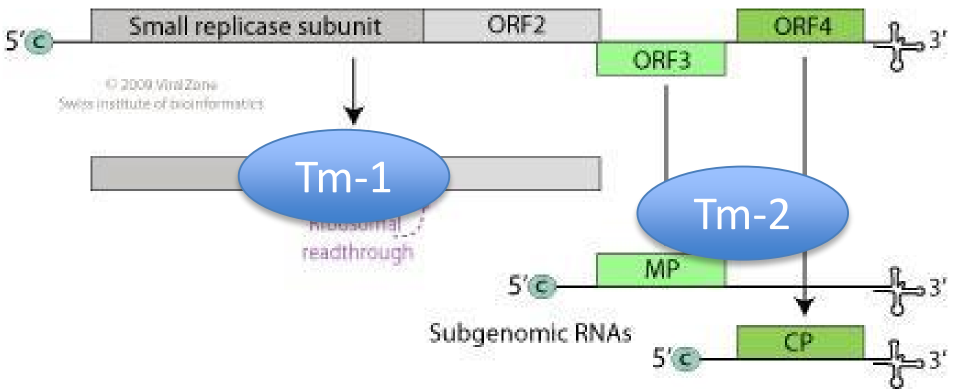


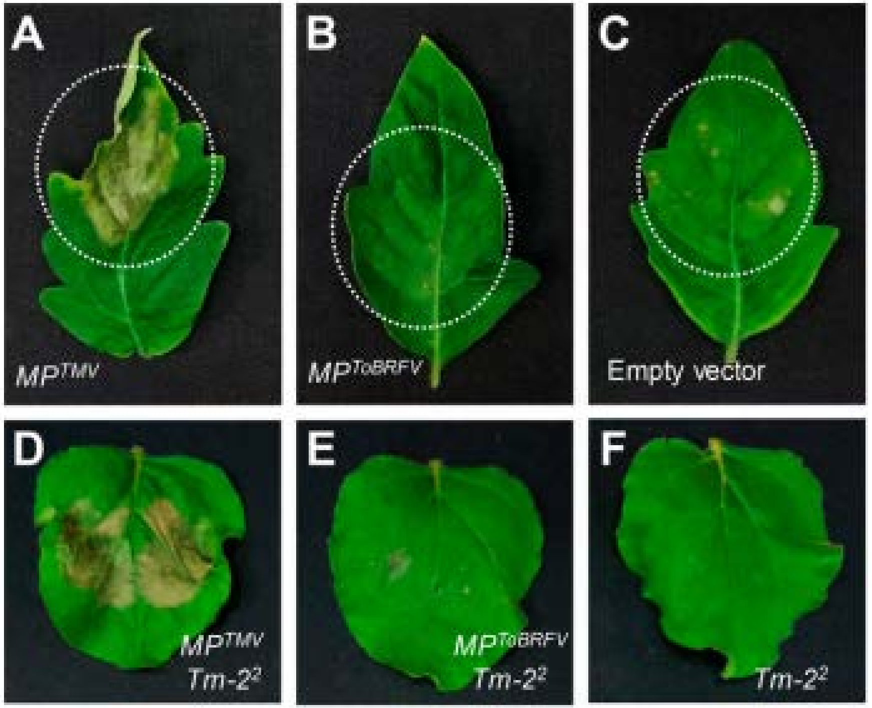
ToBRFV Genome and Weapons



- ORF1/2 Large and small replicase
- ORF3 Movement protein
- ORF4 Coat protein

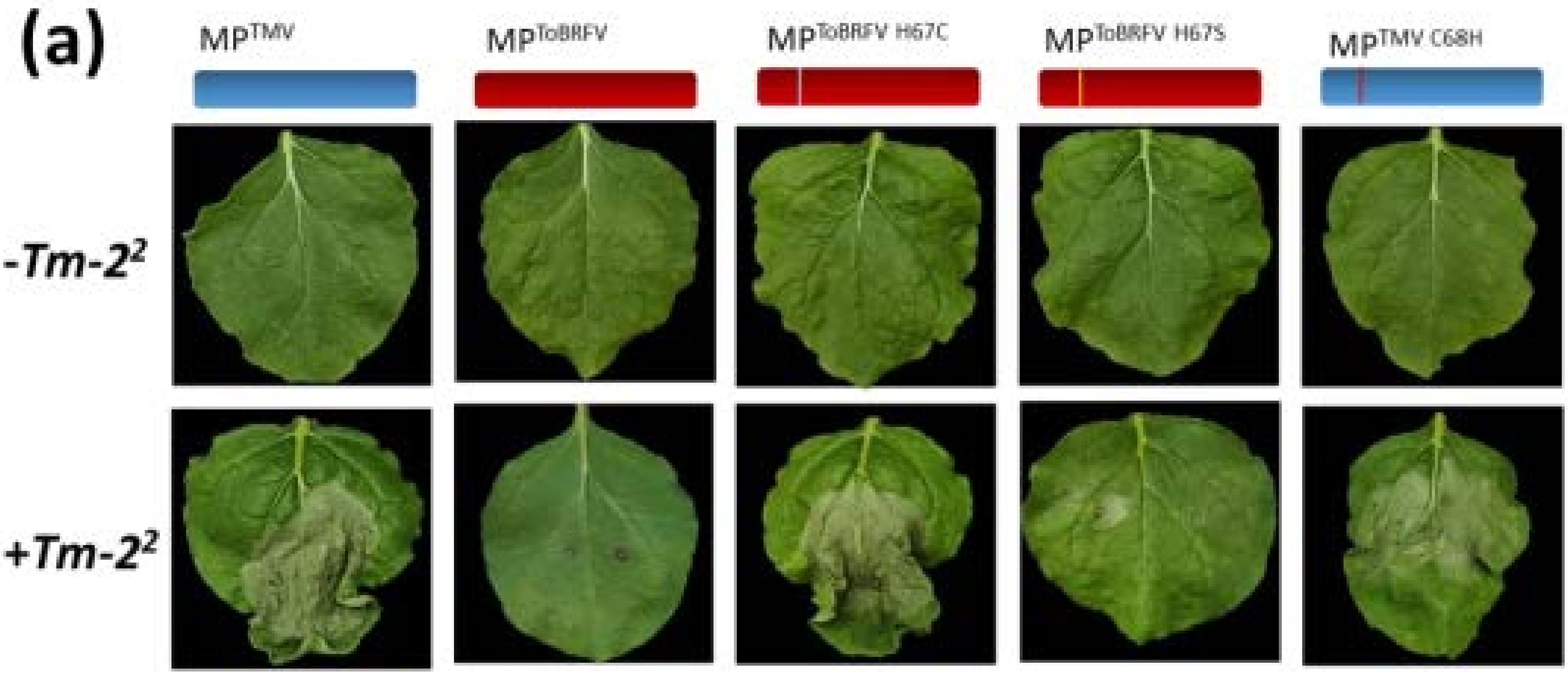
ToBRFV evades *Tm-2*^{2} mediated resistance





Hak and Spiegelman, 2021

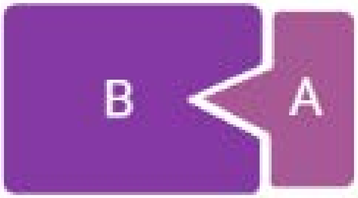
One AA residue mediates resistance

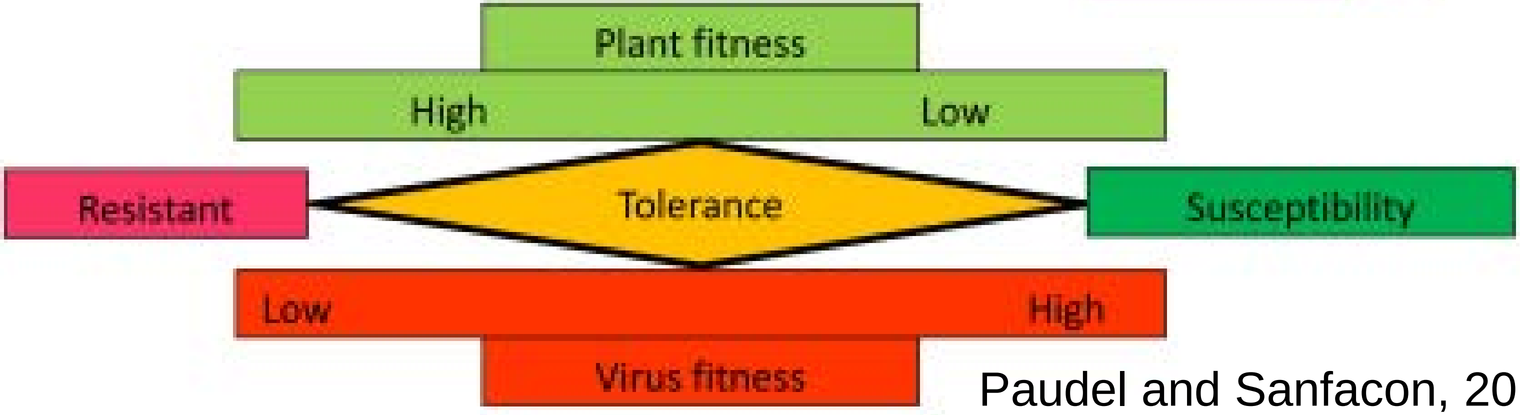


Hak et al., 2022

Plagues and resistance

- Arms race
- Antagonistic co-evolution
- Specific molecular interactions
- Resistance escape
- Novel resistance





Paudel and Sanfacon, 2018

Genetic resistance and the industry

- *Tm-1* and *Tm-2*²
  - *Tm-1* and novel locus (Zinger et al., 2021)
- Intermediate resistance
- Resistance escape
- Further screening

Global
This is Bayer

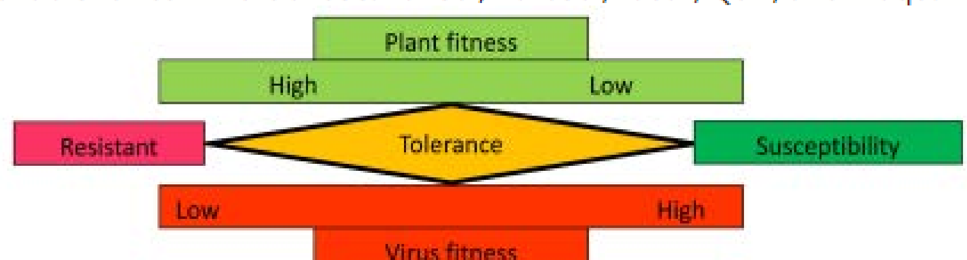
May 19, 2021

Bayer launches additional commercial varieties with intermediate resistance to Tomato Brown Rugose Fruit Virus (ToBRFV) and announces new tomato varieties with high resistance in pipeline

syngenta
Vegetable Seeds Global

More Resistance Varieties Are In Development

Syngenta currently has the following five varieties with ToBRFV resistance available for commercial use: Lansor, Barosor, Ibeth, Quri, and Waqu.



HREZ: High Resistance by Enza Zaden

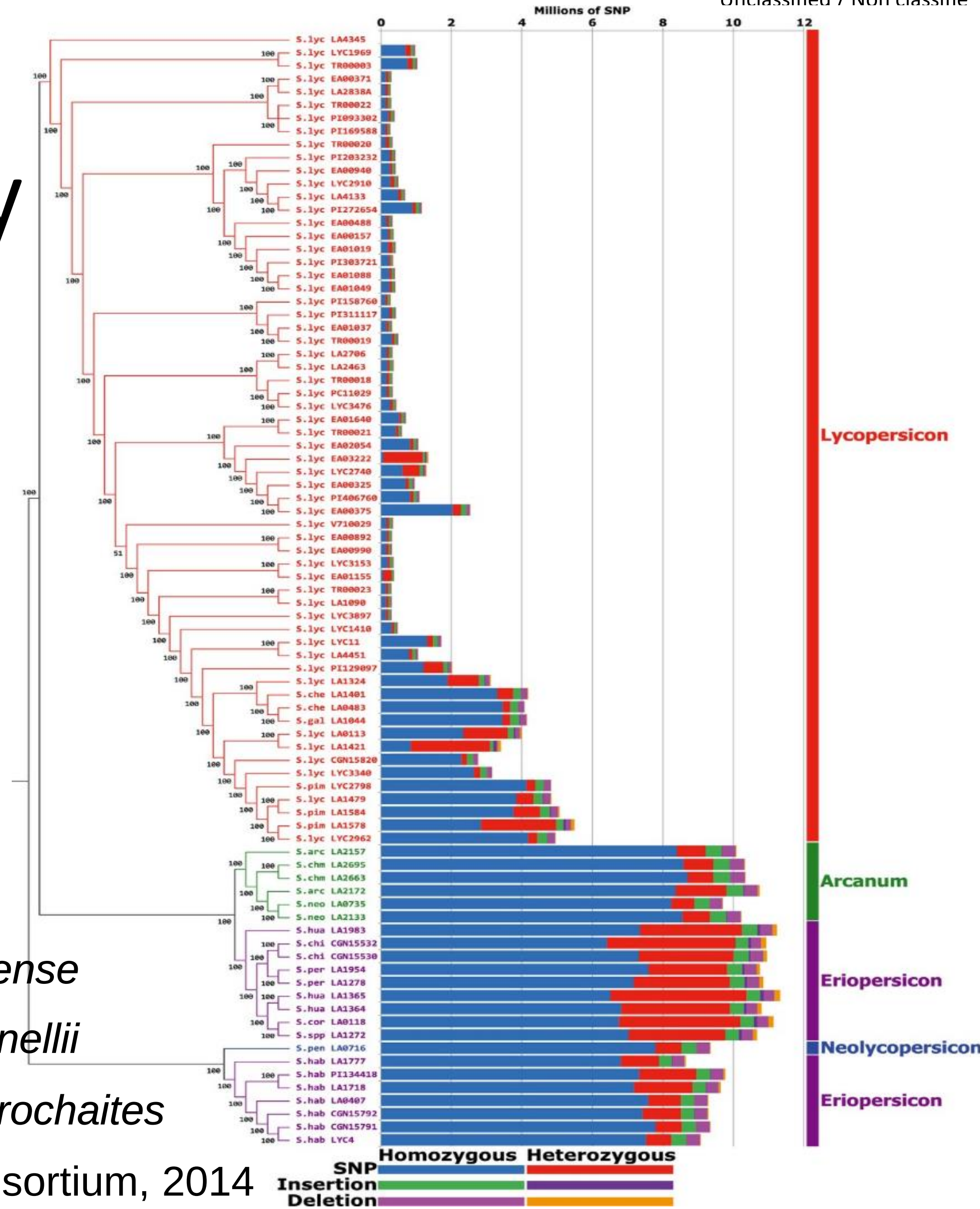
We have developed tomato varieties with High Resistance against Tomato Brown Rugose Fruit Virus (ToBRFV) – strong and

Resistance escape and evolution

More plague pictures

High natural genetic diversity in tomato

- Genetic variation
- Natural variants
- Mutation
  - EMS



S. chilense

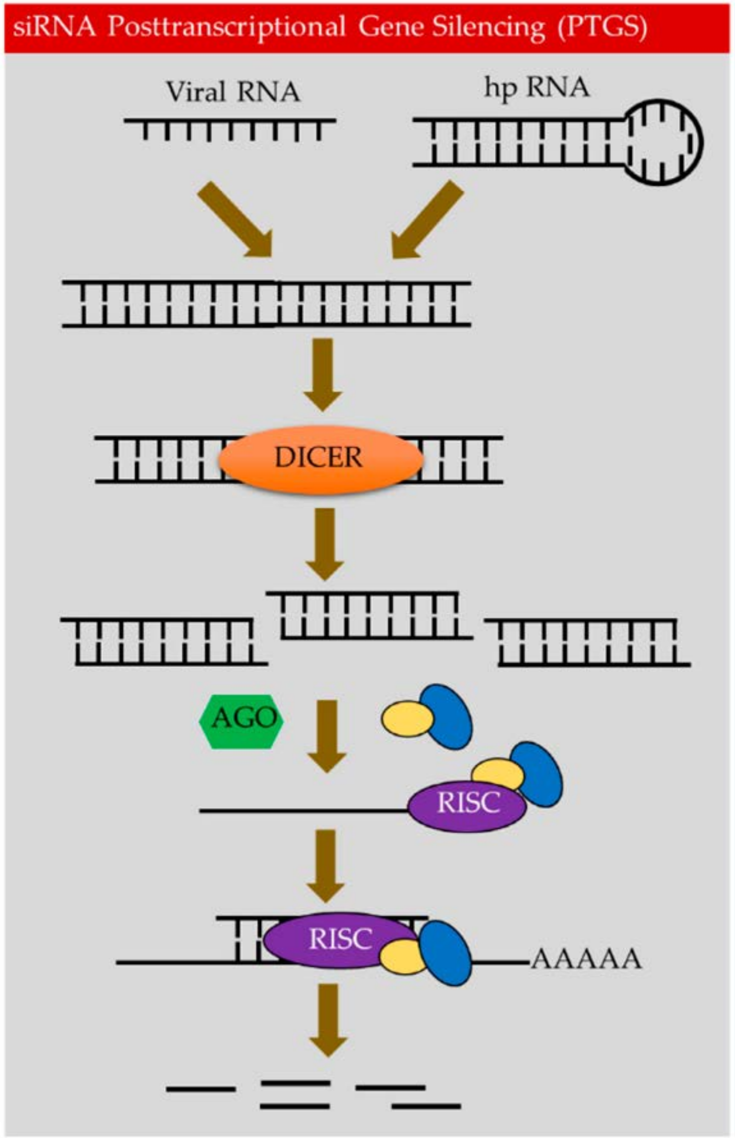
S. pennellii

S. habrochaites

100 tomato genome sequencing consortium, 2014

RNA based technologies

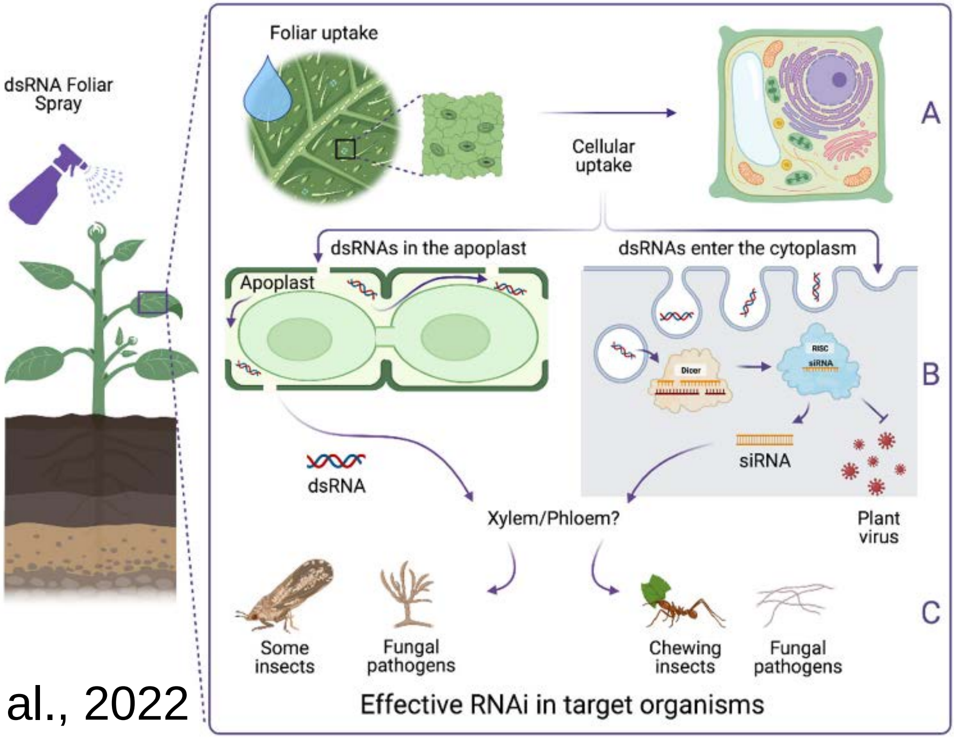
- Human vs plant
- Antibodies vs RNAi
- Resistance genes vs RNAi
- Vaccination - mild PepMV
- Transgenic
  - Papaya ringspot virus
  - Hawaii
- Topical or Spray RNAi



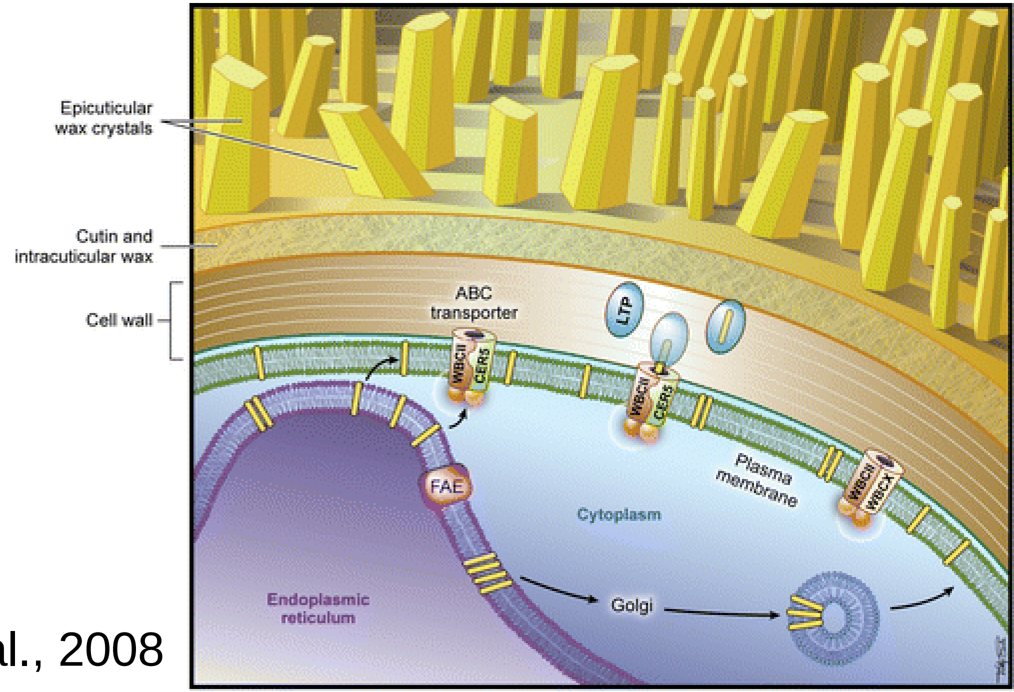
Singh et al., 2019

Topical RNAi

- Powerful
- dsRNA
- Production
- Uptake
- Signal transmission
  - Longevity
  - Strength
- Industrial level
- Resistance

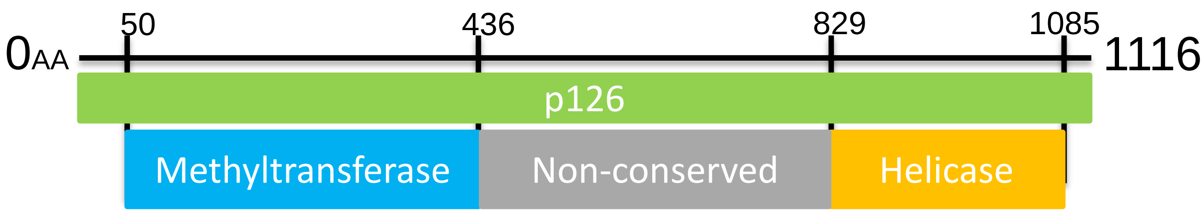


Hoang et al., 2022



Samuels et al., 2008

ToBRFV p126 is multifunctional



- p126 conserved in tobamoviruses
  - ToBRFV, ToMV, and TMV (>93%)
- Methyltransferase
- Helicase
- RNA replication, and in RNA silencing suppression
- Characterize small RNAs

MSc Greg Fougere

How to combat plagues

Genetic resistance

Monitoring

Clean plants

Controlling plagues: clean planting stock

- BCWGC, GGO, GGANS, CVQ
- AAFC CAP, AgriAssurance
- Since 2017, $2.3 million
- Virus tested, disease free

Canadian Grapevine Certification Network

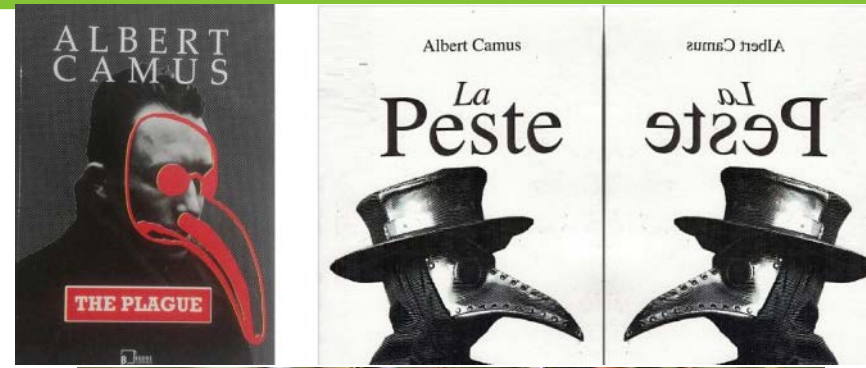
CGCN · RCCV

Réseau canadien de certification de la vigne

Monitoring plagues

- What viruses are in the environment?
- How do you detect new and emerging pathogens?
- How can we easily collect samples from a wide area?
- How do viruses get transmitted?

- Pollination



Plant virus monitoring using bees

- Pollination is a major virus transmission pathway
- Commercial honey bee pollination
- *Apis mellifera*
- 1-2km foraging range
- Visit hundreds of flowers and multiple individual plants in one trip
- Area-wide virus detection
- Viral diversity

Comparing apples and oranges

Blueberries

n = 2
Lee et al., 2023

Apples

n = 3

Cherries

n = 3

BC blueberry pollen-associated virus profile

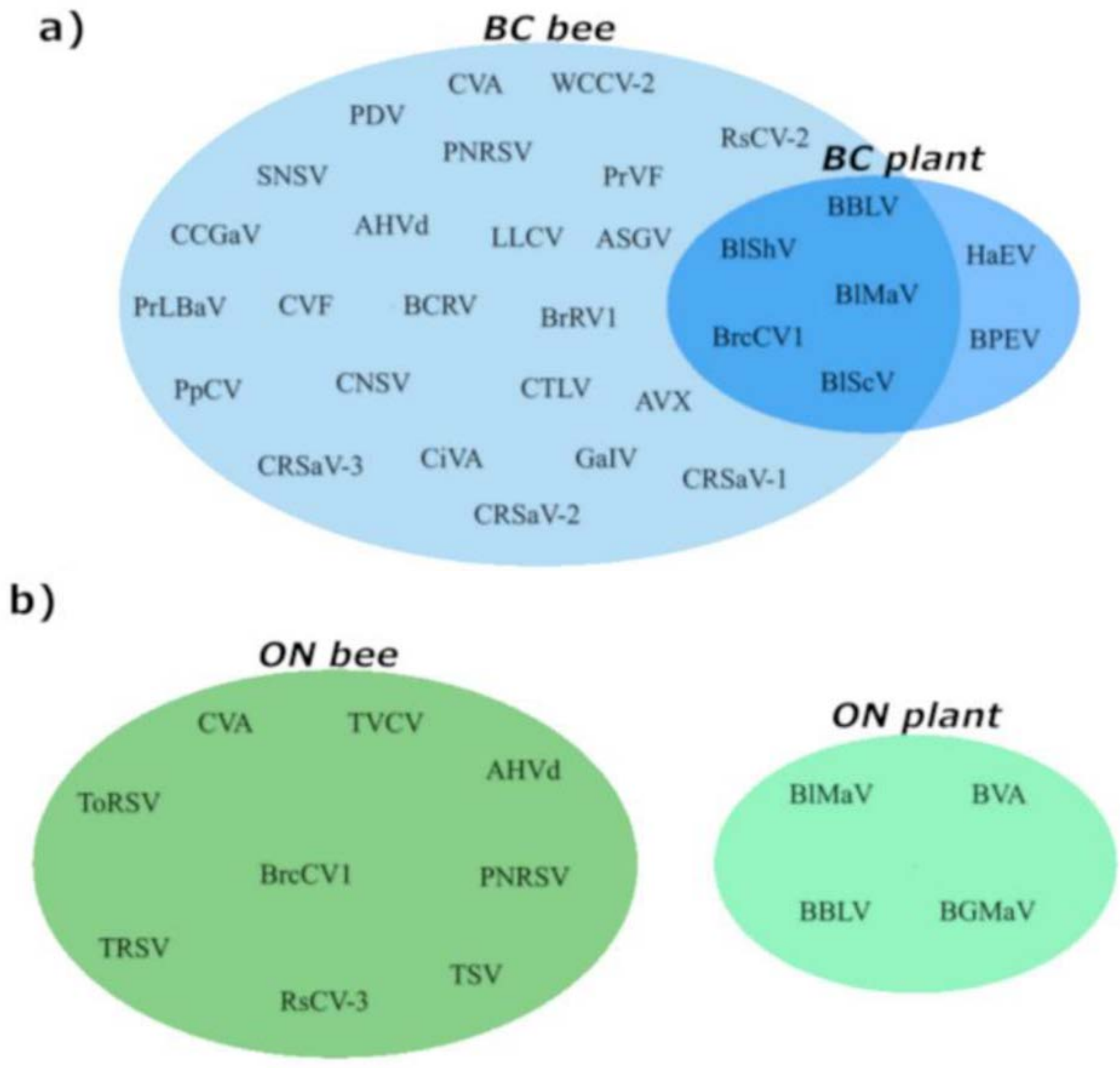
- 29 Viruses Detected, top 16 shown

Plant Virus	Family/Genus	Frequency (%) BC site 1 n=4: Bee bread	BC site 1: Forager	BC site 1: Hive	BC site 1: Pollen	BC site 2 n=4: Bee bread	BC site 2: Forager	BC site 2: Hive	BC site 2: Pollen	Average Viral Transcripts per Million	Average Genome coverage (%)	% positive
Blueberry shock virus	Ilarvirus	75	50	50	50	100	100	100	100	425	57.5	78
Prune dwarf virus	Ilarvirus	100	50	75	50	100	50	100	50	356	52.3	72
Strawberry necrotic shock virus	Ilarvirus	75	25	0	75	50	50	50	75	281	56.6	50
Cherry virus A	Capillovirus	75	25	25	0	100	50	75	0	176	63.2	44
Brassica campestris chrysovirus 1	Alphachrysovirus	50	0	0	0	50	25	75	75	24	52.8	34
Prunus necrotic ringspot virus	Ilarvirus	50	25	25	0	100	0	0	0	290	62.9	25
White clover cryptic virus 2	Betapartitivirus	0	0	50	50	0	0	75	25	43	24.5	25
Apple hammerhead viroid	Pelamoviroid	75	0	0	25	25	25	0	25	606	58.6	22
Blackberry chlorotic ringspot virus	Ilarvirus	25	0	0	0	25	25	50	50	0	17.4	22
Blueberry mosaic associated virus	Ophiovirus	0	25	0	0	0	75	25	0	40	34.3	16
Brassica rapa virus 1	Unassigned	50	0	0	25	0	0	0	0	93	17.2	9
Citrus concave gum-associated virus	Coguvirus	25	0	0	0	50	0	0	0	143	29.6	9
Lilac leaf chlorosis virus	Ilarvirus	0	0	0	0	50	0	0	25	230	35	9
Prunus virus F	Fabavirus	50	0	0	0	25	0	0	0	16	77.7	9
Blueberry latent virus	Amalgavirus	0	0	0	0	25	25	0	0	3	25.5	6
Blueberry scorch virus	Carlavirus	0	25	0	0	0	25	0	0	147	42.3	6

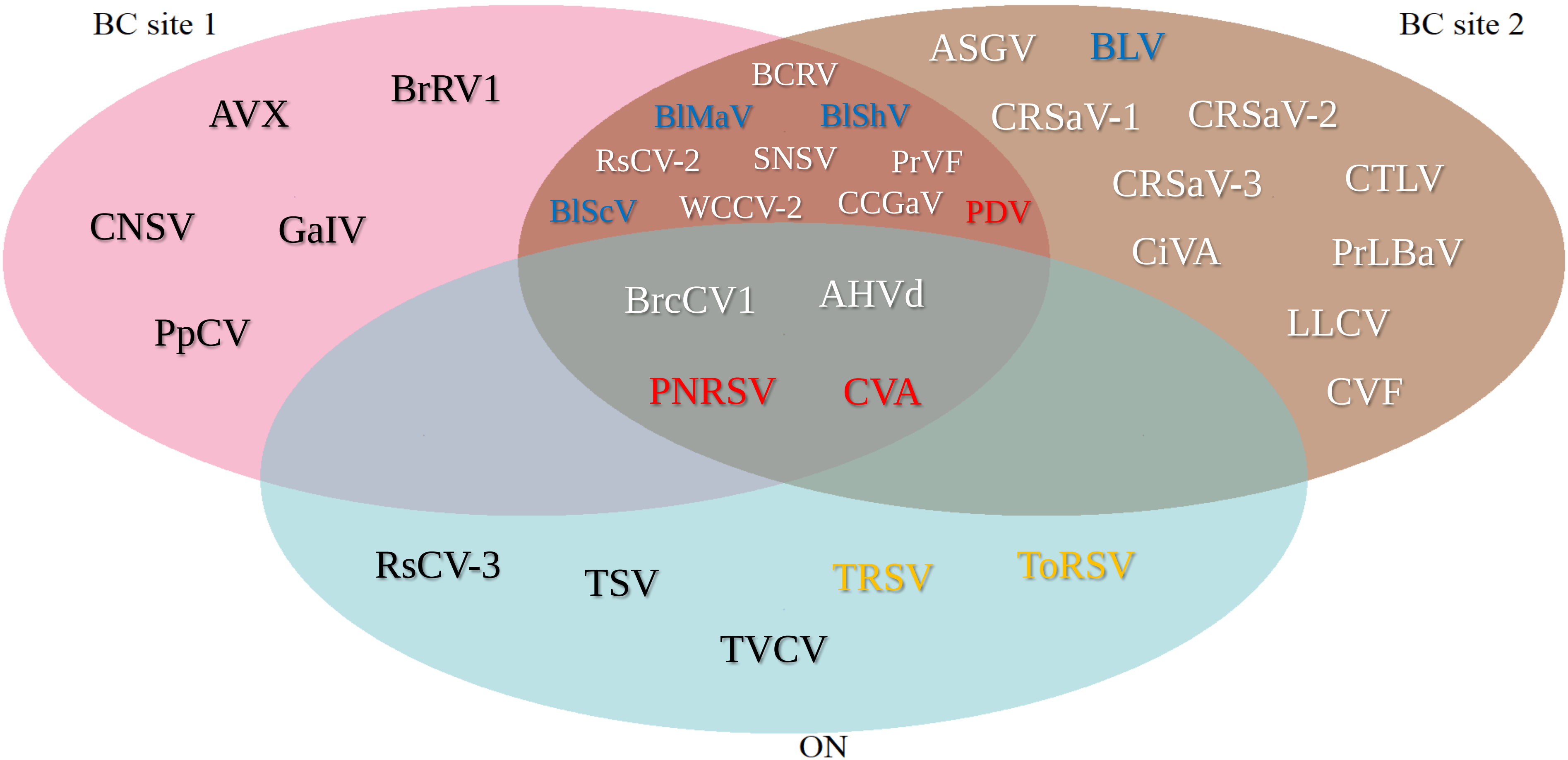
- Scorch vs Shock

BC vs ON blueberry production

- Pollen vs plant
- BC vs ON

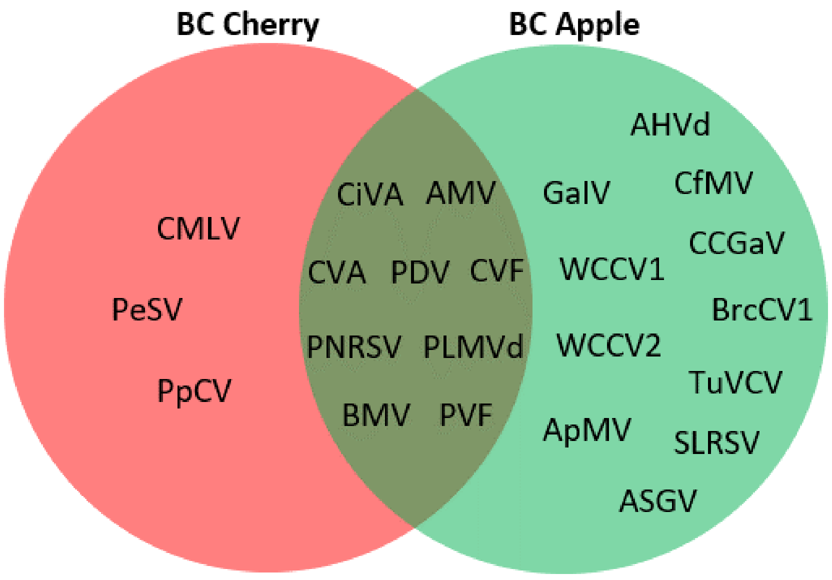


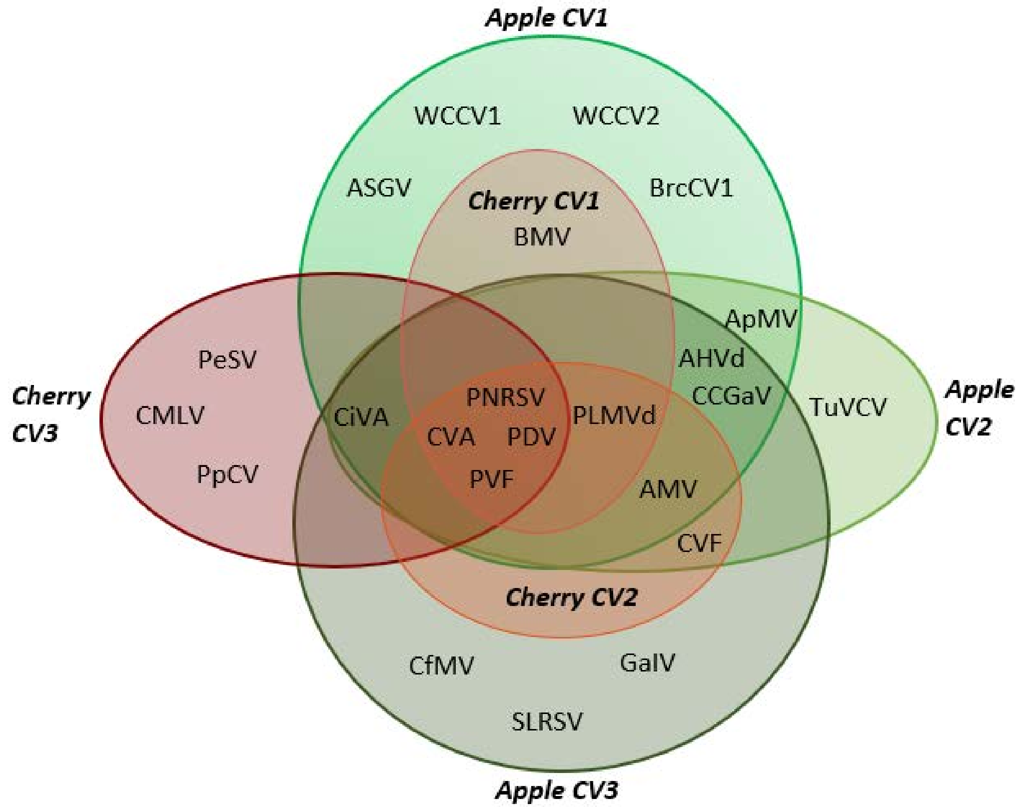
Site-specific and regional viral profiles



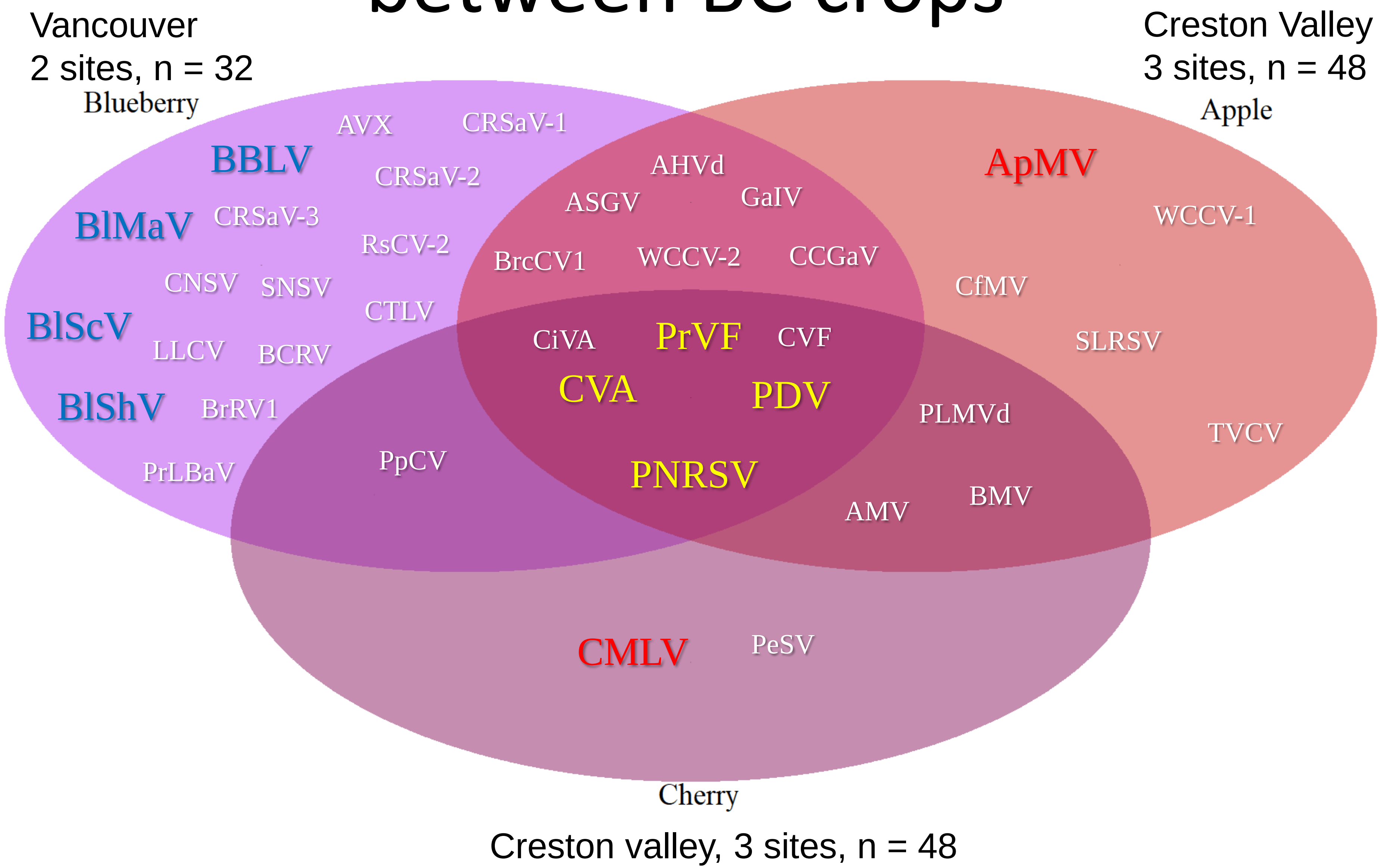
Comparing BC Apples and Cherries

- 3 sites apples and cherries
- 12 viruses in cherry, 20 in apple



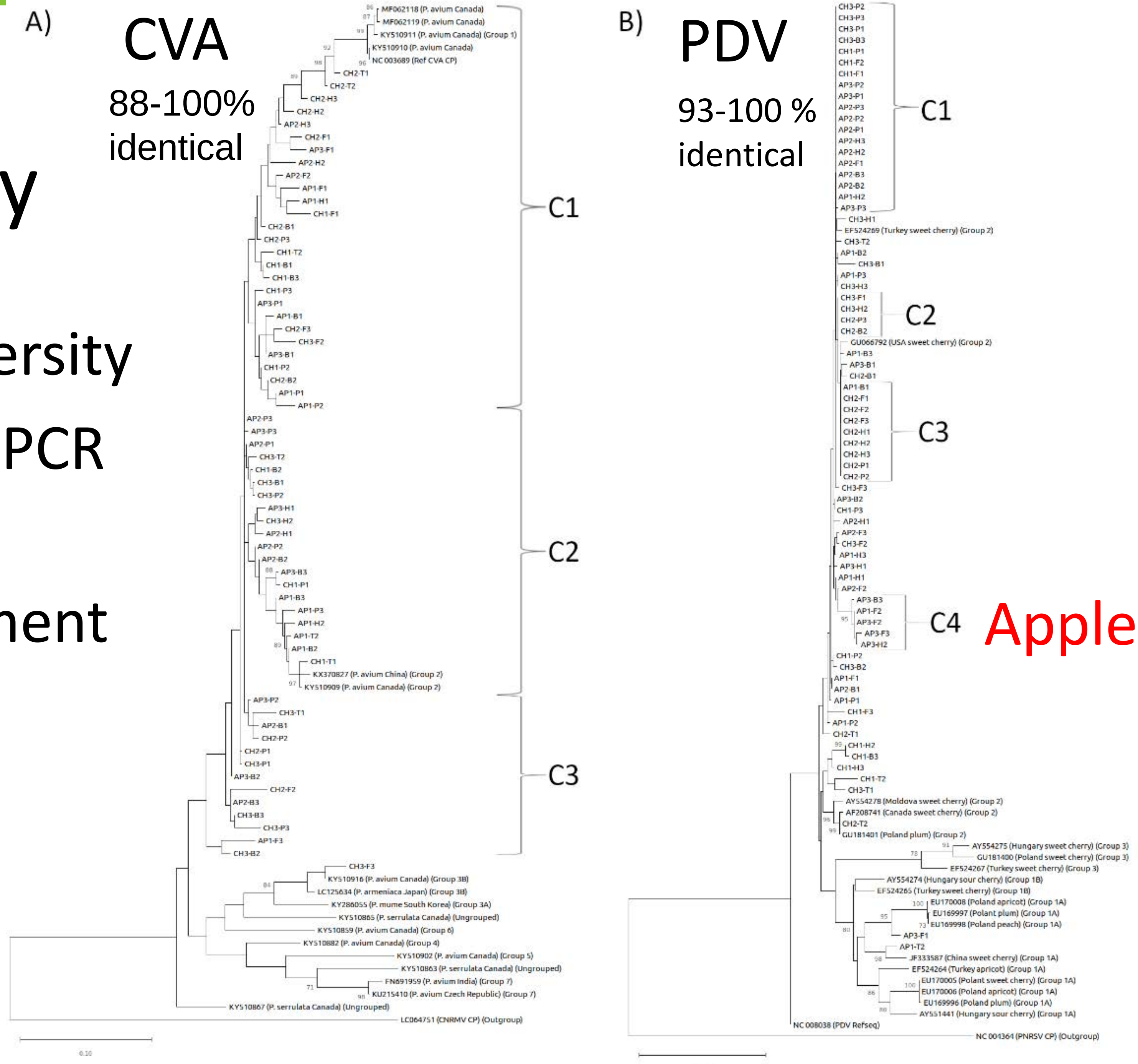


Comparing pollen viral profiles between BC crops



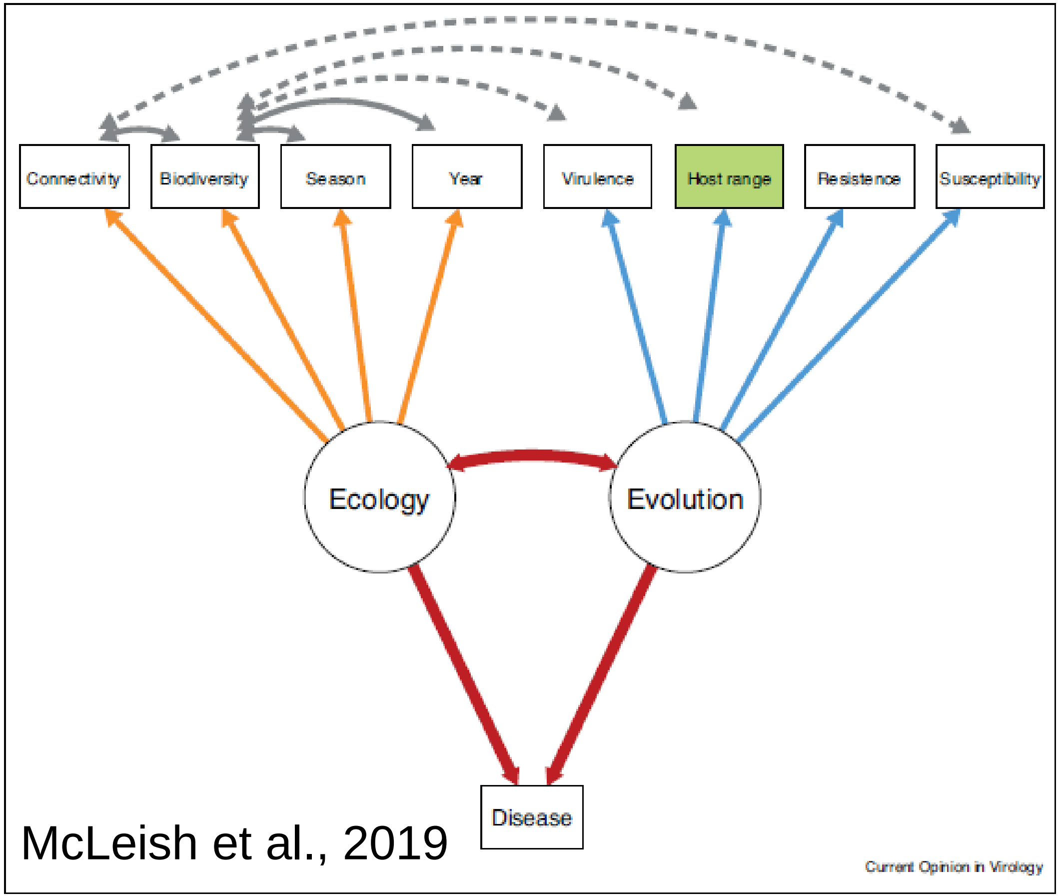
Virus diversity

- Huge diversity
- Targeted PCR
- Informed management



Emergence of viral plagues

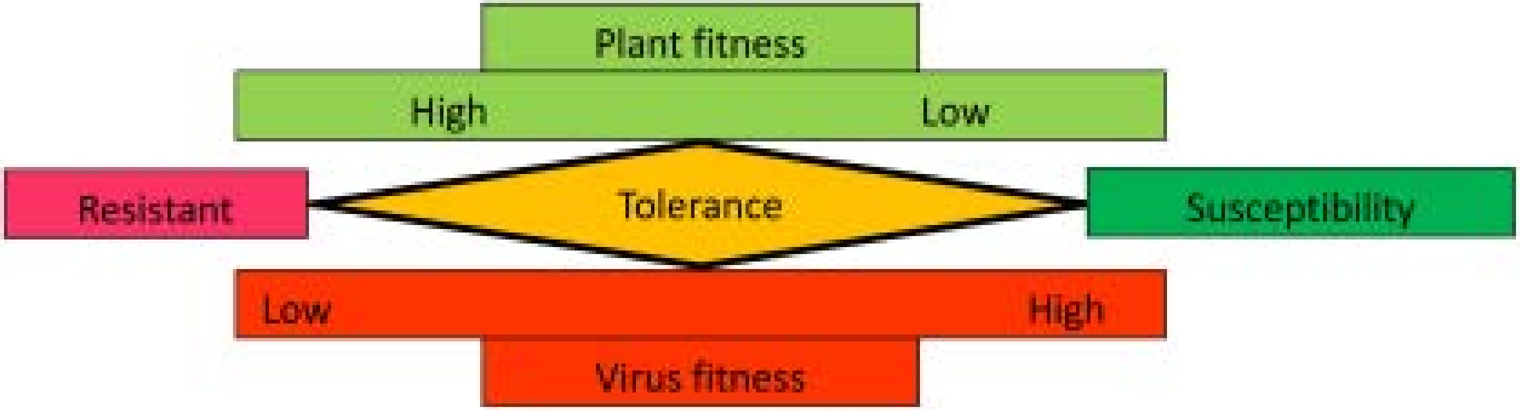
- Huge diversity of viruses
- Emergence can be due to single mutations
- Complex interactions
  - Opportunity
  - Host range
  - Susceptibility



McLeish et al., 2019

Controlling viral plagues

- Clean plants
- Biovigilance/monitoring
- Cultural practices
- Genetic resistance
- Transgenic resistance



Paudel and Sanfacon, 2018

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