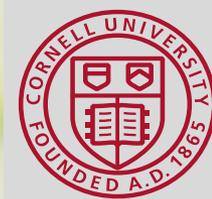


Confirming the breakdown of apple scab resistance in the key source for scab resistance breeding in North America



Awais Khan

February 4, 2020

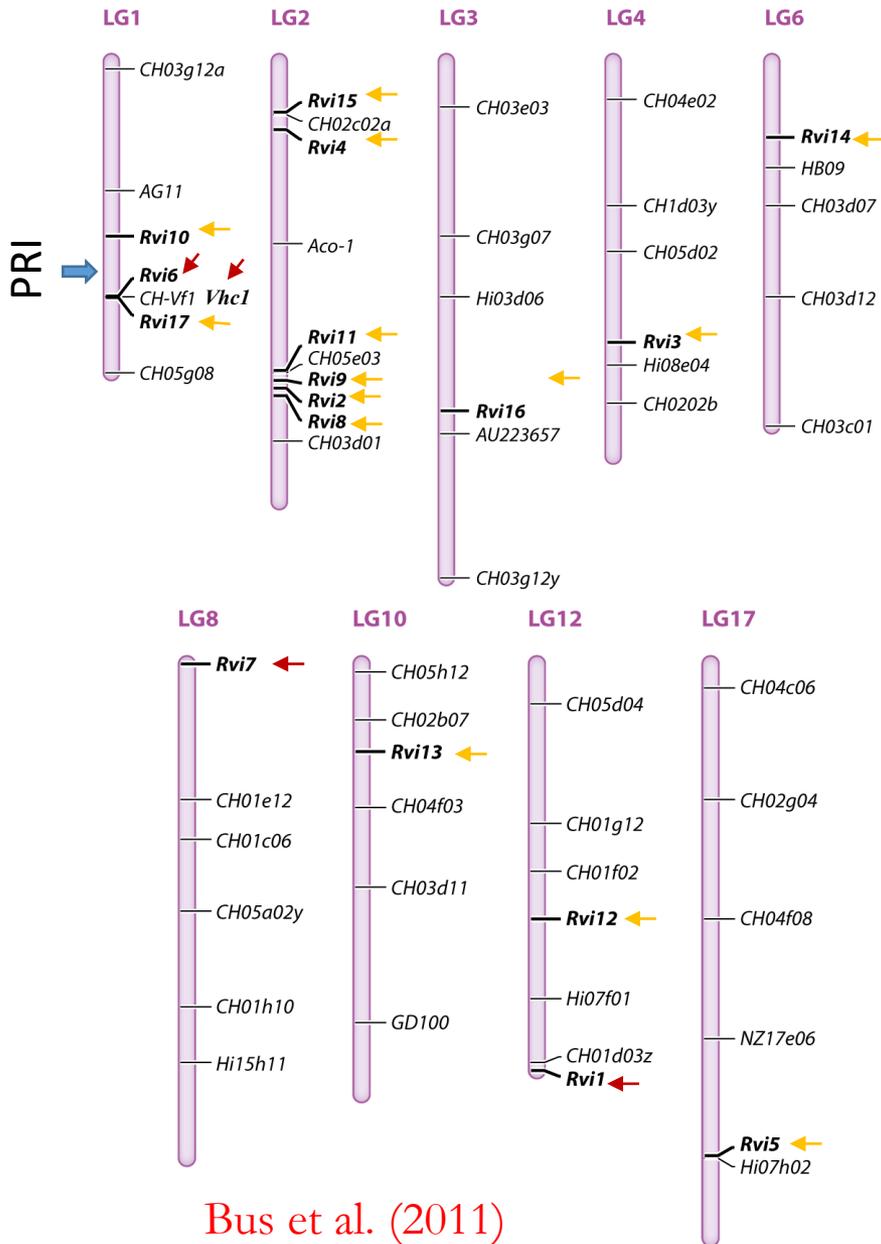
Plant Pathology and Plant-microbe Biology, SIPS,
Cornell University, Geneva, NY

Apple scab caused by *Venturia inaequalis*

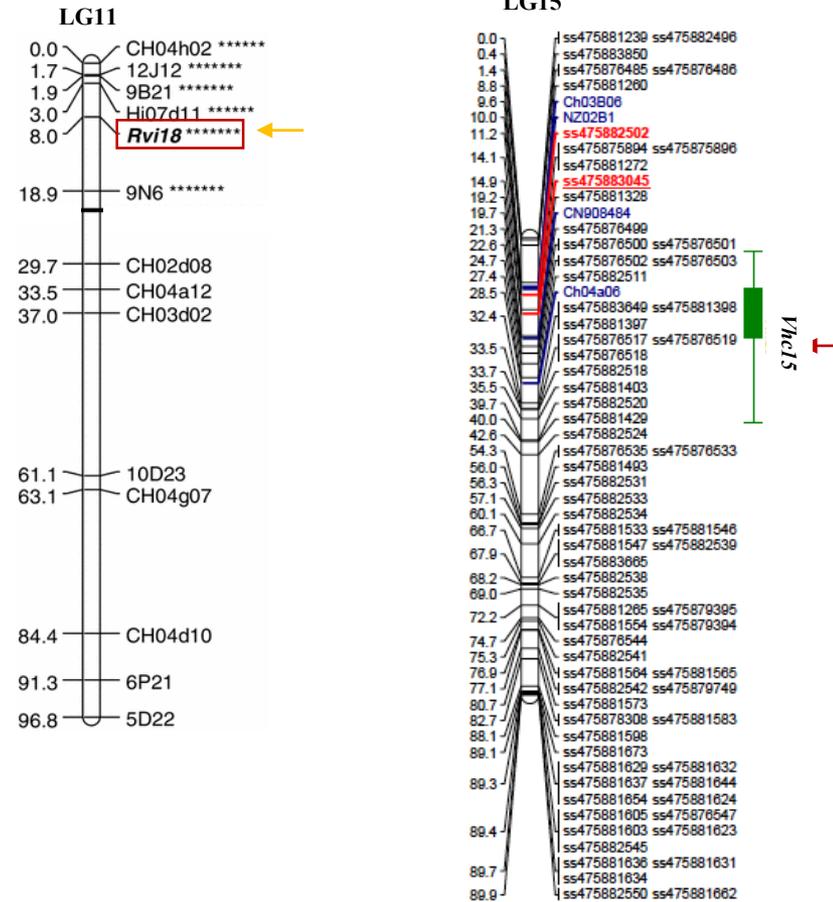
- ❖ Very old disease of apples; fungal evolution is associated with domestication of apples
- ❖ Scab fungus has rapid ecological divergence because it reproduces both asexually and sexually
- ❖ Commercial varieties are susceptible e.g., McIntosh, Red Delicious, Rome Beauty
- ❖ Impact on quality, yield, and plant productivity results in significant cost to apple production



Host genetic resistance against apple scab



Bus et al. (2011)



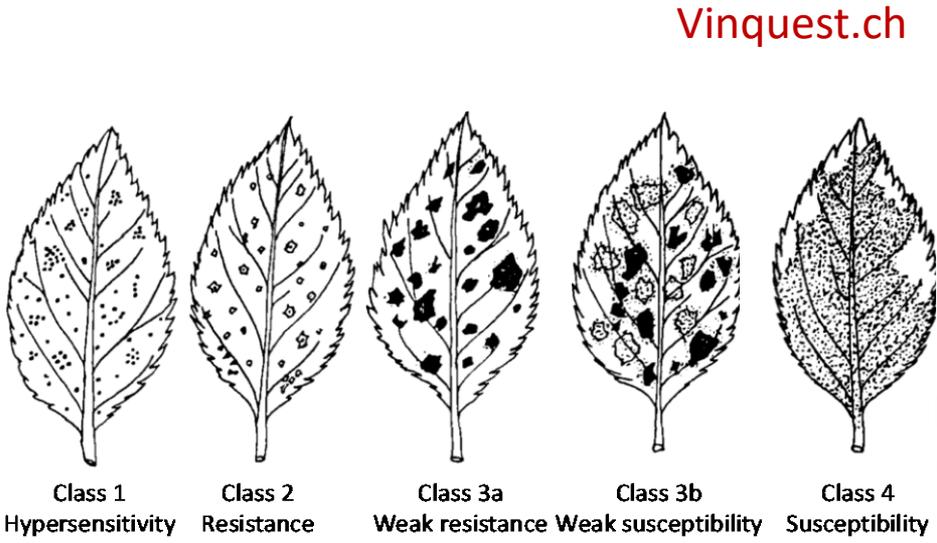
Soriano et al. 2014

Clark et al. (2014)

Characterization of apple scab infection in apple core collection to identify novel sources of resistance

- ❖ 180 accessions from approximately 28 *Malus* species
- ❖ No fungicide spray
- ❖ Partial set of host differentials

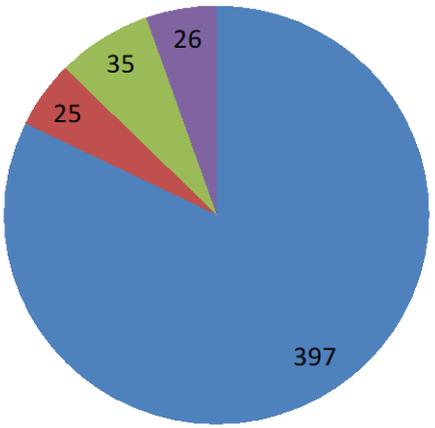
Hosts	Genotypes	R-gene(s) (known)	
		Historical names	New names
h0	'Gala'	none known	
h1	'Golden Delicious'	Vg	Rvi1
h2	TSR34T15	Vh2	Rvi2
h3 ²	Q71 ('Geneva' x 'Braeburn')	Vh3.1	Rvi3
h4	TSR33T239	Vh4	Rvi4
h5	9-AR2T196	Vm	Rvi5
h6	'Priscilla'	Vf	Rvi6
h7	F1 of <i>M. floribunda</i> 821 ¹	Vfh	Rvi7
h8 ²	B45 (Pacific Beauty x <i>M. sieversii</i> GMAL4302-X8)	Vh8	Rvi8
h9 ²	J34 ('Gala' x 'Dolgo')	Vdg	Rvi9
h10	A 723-6 ('Worcester' x PI172623)	Va	Rvi10
h11	<i>M. baccata jackii</i>	Vbj	Rvi11
h12	Hansen's <i>baccata</i> #2	Vb	Rvi12
h13	'Durello di Forlì'	Vd	Rvi13
h14	'Dülmener Rosen'	Vdr1	Rvi14
h15	GMAL 2473	Vr2	Rvi15



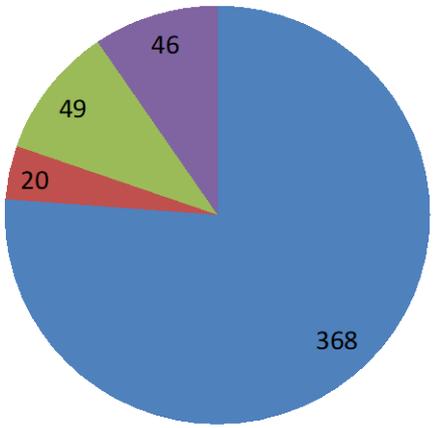
Characterization of apple scab infection in apple core collection to identify novel sources of resistance

2018

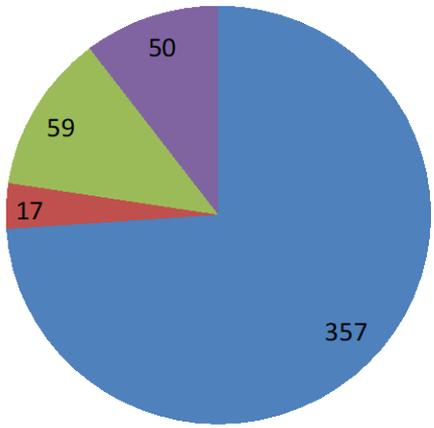
June



July

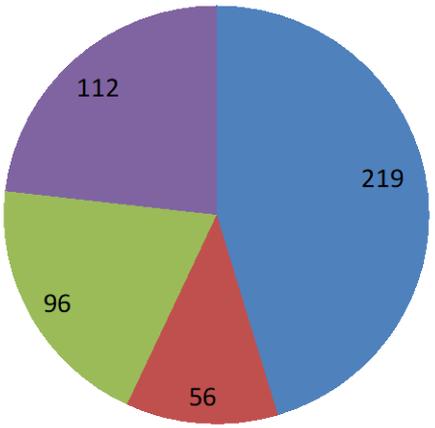


August

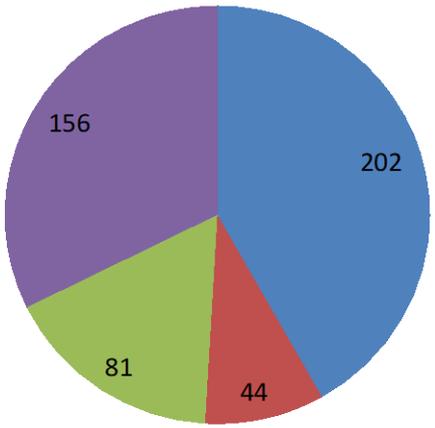


2019

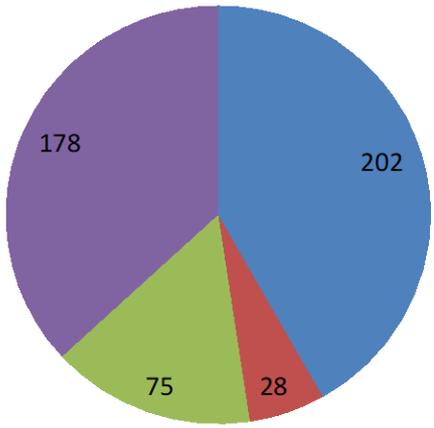
June



July



August



■ Resistant (class 0, 1, 2) ■ Moderately resistant (class 3a) ■ Moderately susceptible (class 3b) ■ Susceptible (class 4)

New North American isolates of *Venturia inaequalis* can overcome apple scab resistance from *M. floribunda* 821
(Papp et al. 2019).



Heavy and sporulating apple scab infection on *M. floribunda* 821 last year.



Chlorotic and pin point type resistance symptoms can also be seen.



Majority of currently available apple scab resistant cultivars carry resistance of *M. floribunda* 821

Papp et al. 2019



Apple scab symptoms and incidence on *Rvi6* cultivars and susceptible controls

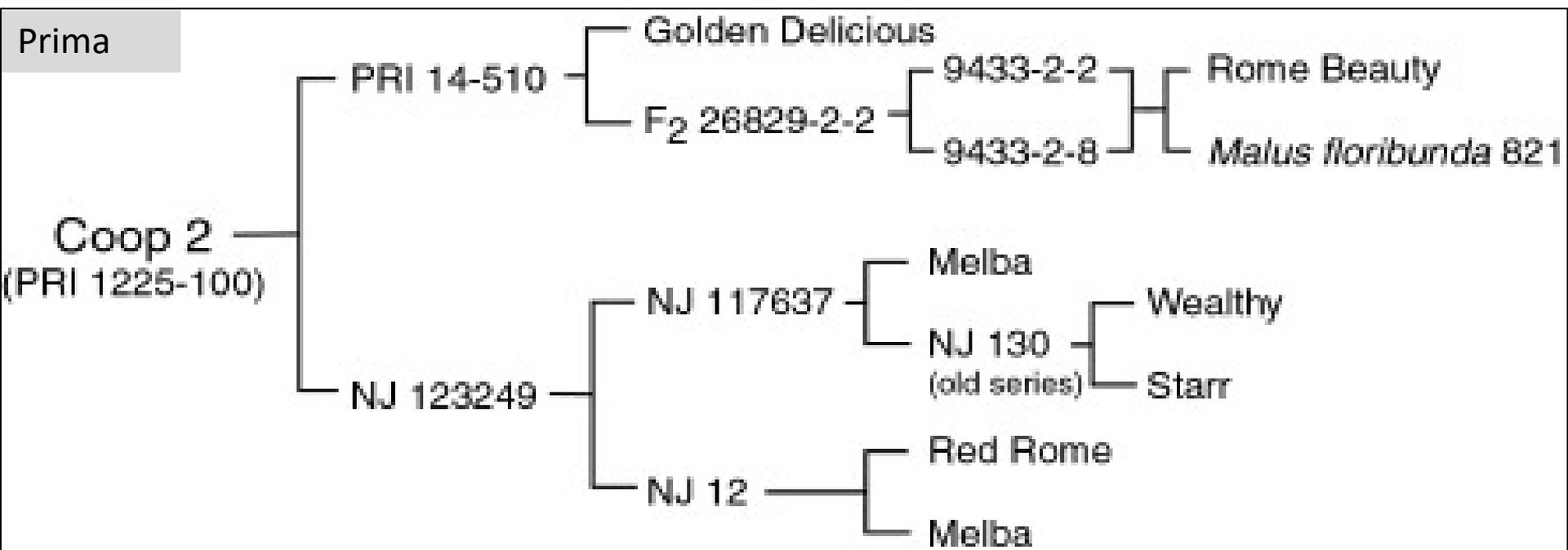
Papp et al. 2019

PI Number	Cultivar Name	<i>Rvi</i> Genes	Symptom class (0-4)	Incidence (0-9)	Source
392303	Gala	none	4	5	-
590186	Wijcik McIntosh	none	4	8	-
588998	Marshall McIntosh	none	4	8	-
590184	Golden Delicious	<i>Rvi1</i>	4	7	-
589827	<i>M. floribunda</i> 821	<i>Rvi6</i> , <i>Rvi7</i>	4	4	-
588747	Florina	<i>Rvi1</i> , <i>Rvi6</i>	0	1	EU (French)
588838	Nova Easygro	<i>Rvi6</i>	M	2	PRI (Canadian)
589181	Prima	<i>Rvi1</i> , <i>Rvi6</i>	3	2	PRI
589962	Jonafree	<i>Rvi6</i>	0	1	PRI
590183	Dayton	<i>Rvi6</i>	0	1	PRI
594111	Redfree	<i>Rvi6</i>	0	1	PRI
589965	Priscilla	<i>Rvi6</i>	0	1	PRI

c) Intact crown of 'Nova Easygro'. D) Weak sporulation surrounded by chlorosis and necrosis on 'Nova Easygro'. E) Strong chlorosis on 'Prima'



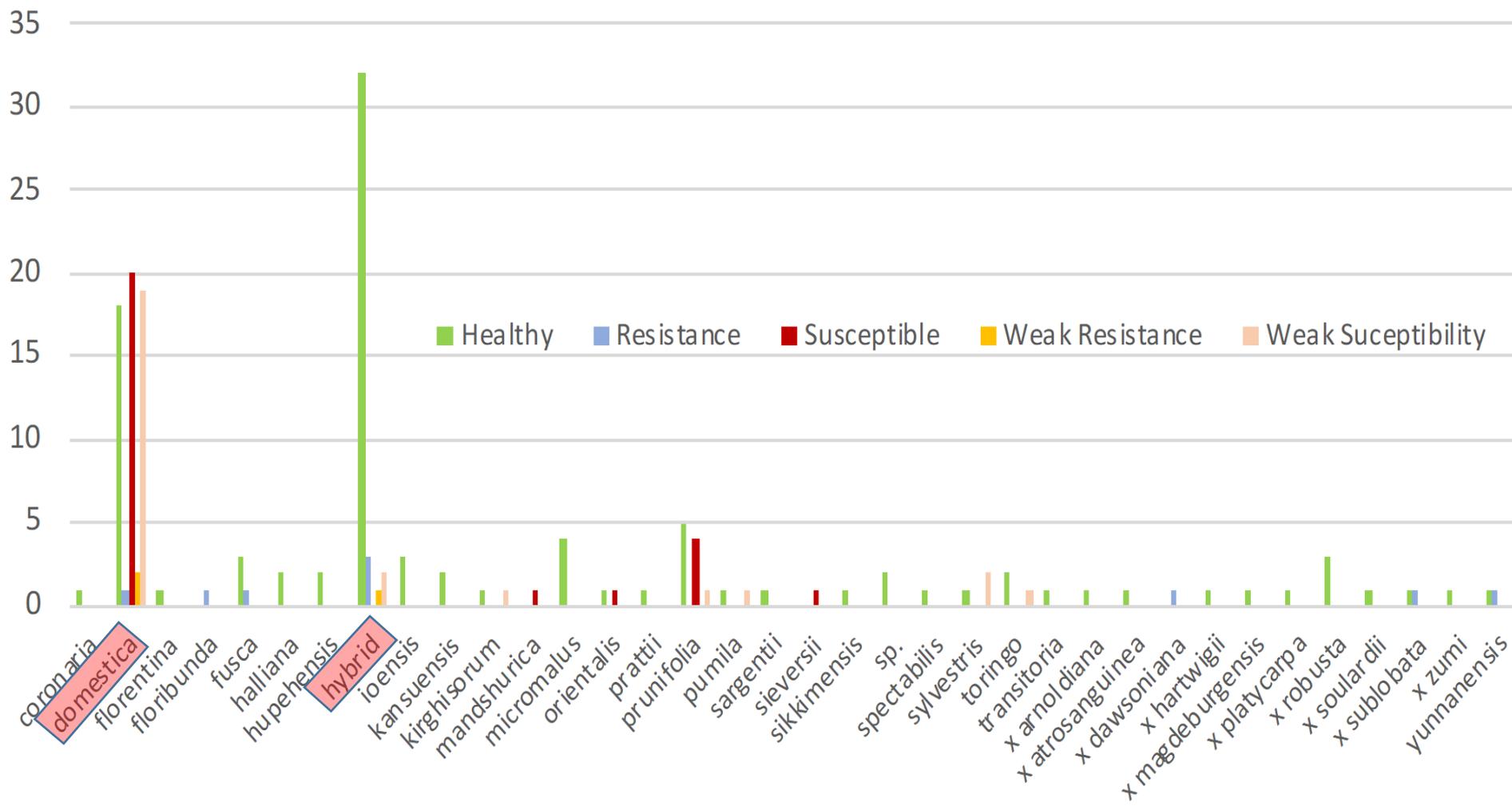
Pedigree of PRI scab resistant cultivars and potential explanation of scab breakdown in *M. floribunda* 821 but not in descendent cultivars



Identification of new sources of resistance to apple scab

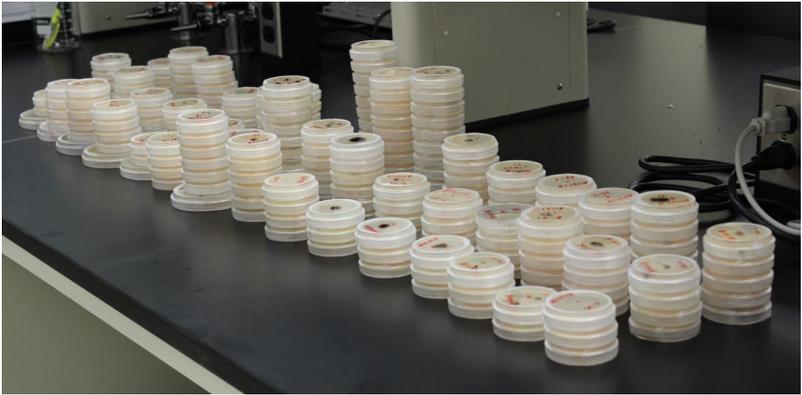
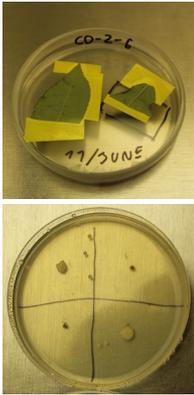


Scab susceptibility of apple core collection



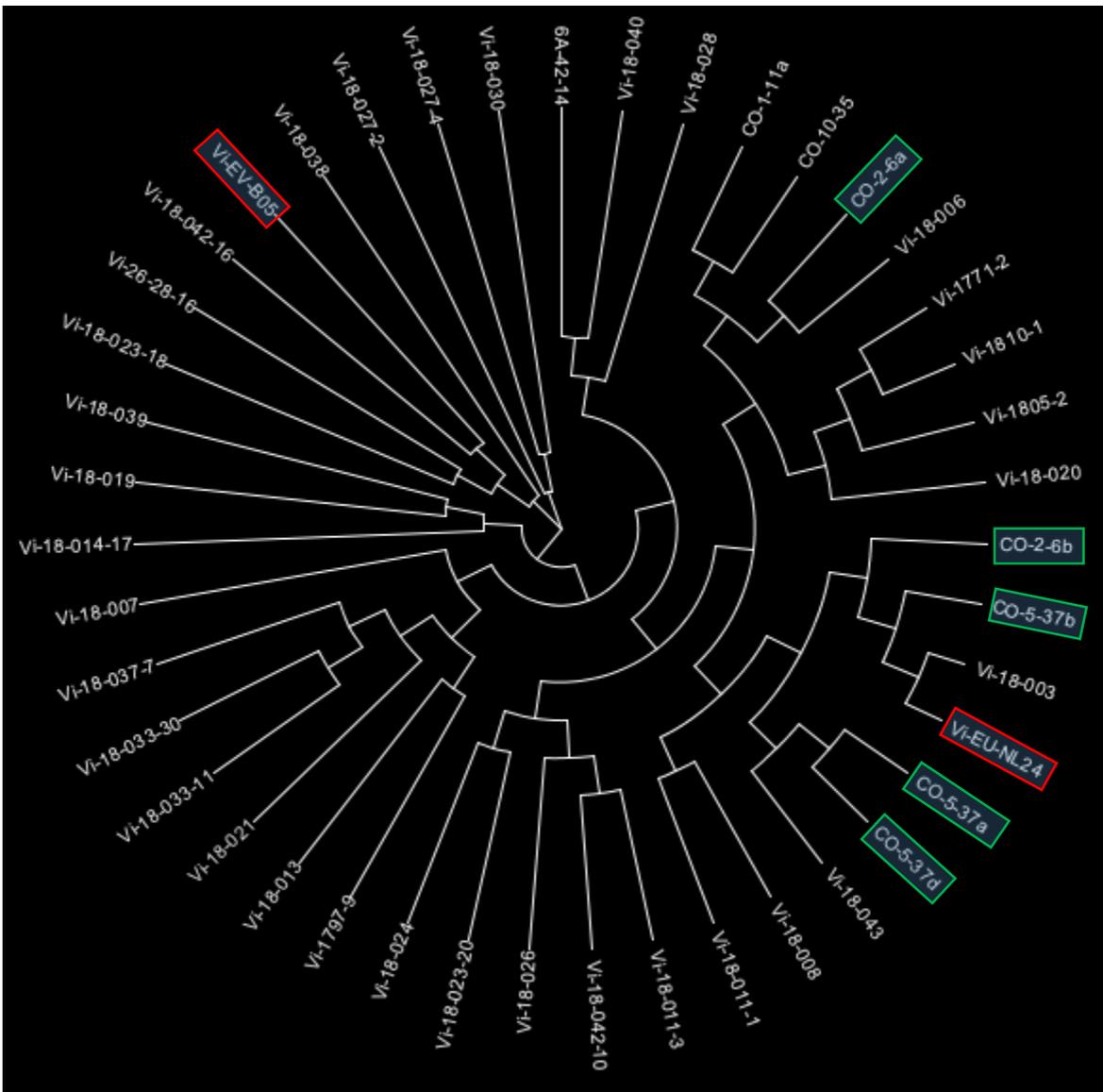
Geographical map of scab isolates collected

- Approx. 150 isolates from NY, Indiana, Michigan, New Hampshire, and Vermont have been collected
- 10 well-characterized isolates have been obtained from Europe

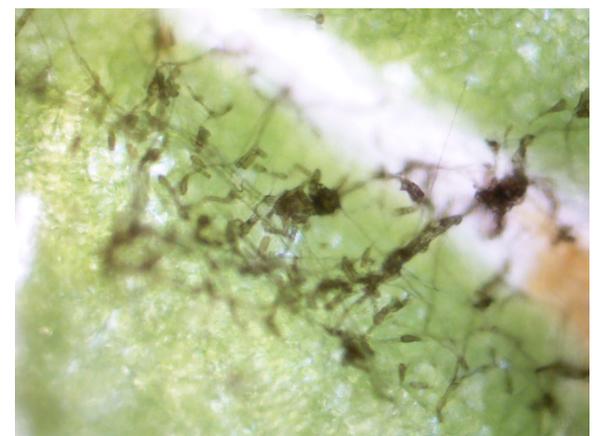
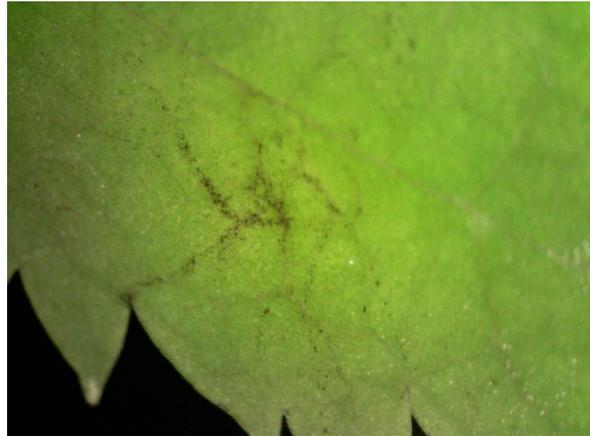
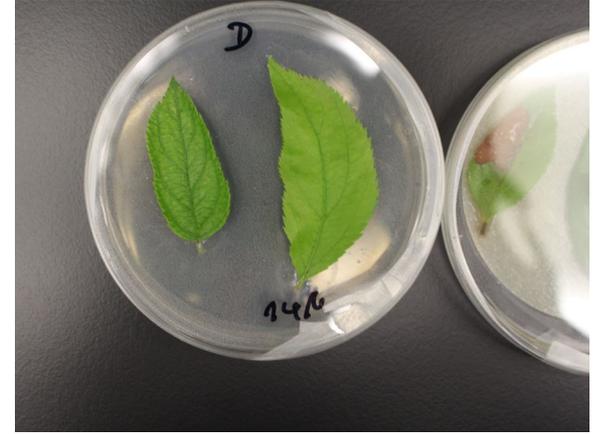


Genetic diversity of *V. inaequalis* isolates across NYS, other regions of the US and Europe

ID	Site	State	Country	Host
CO-1-11a	Geneva	NY	USA	Nova Easygro
CO-10-35	Geneva	NY	USA	MF821
CO-2-6a	Geneva	NY	USA	MF821
CO-2-6b	Geneva	NY	USA	MF821
CO-5-37a	Geneva	NY	USA	MF821
CO-5-37b	Geneva	NY	USA	MF821
CO-5-37d	Geneva	NY	USA	MF821
Vi-1771-2	Purdue	Indiana	USA	
Vi-1797-9	Purdue	Indiana	USA	
Vi-18-003	Canandaigua	NY	USA	
Vi-18-006	Geneva	NY	USA	Microcarpa
Vi-18-007	Geneva	NY	USA	Northern Spy
Vi-18-008	Geneva	NY	USA	Granny Smith
Vi-18-011-1	Geneva	NY	USA	Monroe
Vi-18-011-3	Geneva	NY	USA	Monroe
Vi-18-013	Geneva	NY	USA	Ein Shemer
Vi-18-014-17	Geneva	NY	USA	Sieversii
Vi-18-019	Geneva	NY	USA	Jonsib Crab
Vi-18-020	Geneva	NY	USA	Marshall McIntosh
Vi-18-021	Geneva	NY	USA	Crimson Beauty
Vi-18-023-18	Plattsburgh	NY	USA	
Vi-18-023-20	Plattsburgh	NY	USA	
Vi-18-024	Plattsburgh	NY	USA	McIntosh
Vi-18-026	Plattsburgh	NY	USA	McIntosh
Vi-18-027-2	Plattsburgh	NY	USA	McIntosh
Vi-18-027-4	Plattsburgh	NY	USA	McIntosh
Vi-18-030	Geneva	NY	USA	Cortland
Vi-18-033-11	Geneva	NY	USA	Microcarpa
Vi-18-033-30	Geneva	NY	USA	Microcarpa
Vi-18-037-7	Ithaca	NY	USA	
Vi-18-038	Geneva	NY	USA	Marshall McIntosh
Vi-18-039	Geneva	NY	USA	Cortland
Vi-18-042-10	Geneva	NY	USA	Inuringo
Vi-18-042-16	Geneva	NY	USA	Inuringo
Vi-18-043	Ithaca	NY	USA	Crabapple
Vi-1805-2	Purdue	Indiana	USA	
Vi-1810-1	Purdue	Indiana	USA	
Vi-26-28-16		NY	USA	
Vi-6A-42-14	Geneva	NY	USA	Golden Delicious
Vi-EU-B05			Belgium	Schone von Boskoop
Vi-EU-NL24			The Netherlands	Prima
Vi18-028	Plattsburgh	NY	USA	McIntosh
Vi18-040	Geneva	NY	USA	Marshall McIntosh



Artificial inoculation techniques to evaluate virulence of new scab isolates and fine mapping of scab loci



Artificial scab inoculation of **grafted plants**, **open-pollinated seedlings** and **detached leaves** of Macintosh apples. Single spore scab cultures were used to inoculate in the moist chamber under controlled temperature, light and humidity and in incubation tent.

Acknowledgements

Khan Lab:

- David Papp
- Liqiang Gao
- Jugpreet Singh
- Della Cobb-Smith
- David Strickland

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- Apple Research and Development Program (ARDP)
- NYFVI (New York Farm Viability Institute)
- New York Specialty Specialty Crop Block Grant

Thank you for attention!



KhanLab
351 Tweets

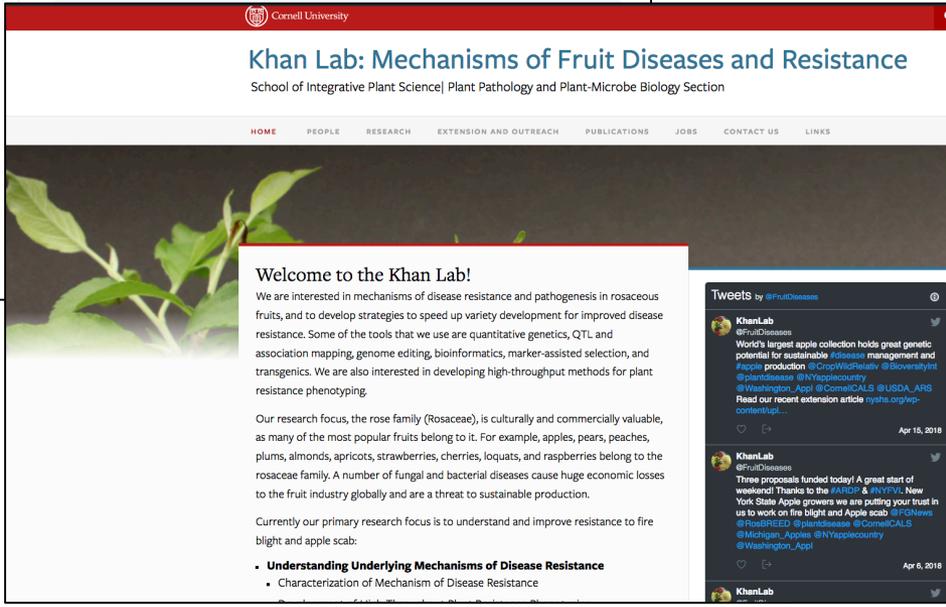


KhanLab
@FruitDiseases

Research and extension to characterize mechanisms of disease resistance and pathogenesis, and development of tools for improvement of rosaceous fruits

Geneva, NY blogs.cornell.edu/khanlab/ Joined December 2016

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Cornell University

Khan Lab: Mechanisms of Fruit Diseases and Resistance

School of Integrative Plant Science | Plant Pathology and Plant-Microbe Biology Section

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Welcome to the Khan Lab!

We are interested in mechanisms of disease resistance and pathogenesis in rosaceous fruits, and to develop strategies to speed up variety development for improved disease resistance. Some of the tools that we use are quantitative genetics, QTL and association mapping, genome editing, bioinformatics, marker-assisted selection, and transgenics. We are also interested in developing high-throughput methods for plant resistance phenotyping.

Our research focus, the rose family (Rosaceae), is culturally and commercially valuable, as many of the most popular fruits belong to it. For example, apples, pears, peaches, plums, almonds, apricots, strawberries, cherries, loquats, and raspberries belong to the rosaceae family. A number of fungal and bacterial diseases cause huge economic losses to the fruit industry globally and are a threat to sustainable production.

Currently our primary research focus is to understand and improve resistance to fire blight and apple scab:

- **Understanding Underlying Mechanisms of Disease Resistance**
 - Characterization of Mechanism of Disease Resistance

Tweets by @FruitDiseases

- KhanLab** @FruitDiseases
World's largest apple collection holds great genetic potential for sustainable disease management and apple production @CropWildRelative @topcrosskey @plantdisease @NYAppleCountry @Washington_Apple @CornellCALS @USDA_ARL Read our recent extension article [nyhs.org/wp-content/Apple...](#)
Apr 15, 2018
- KhanLab** @FruitDiseases
Three proposals funded today! A great start of weekend! Thanks to the #ARDP & #NYAVL New York State Apple growers we are putting your trust in us to work on fire blight and Apple scab @Cornell @RozBREED @plantdisease @CornellCALS @Michigan_Apples @NYAppleCountry @Washington_Apple
Apr 6, 2018

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