



Agriculture and
Agri-Food Canada

Agriculture et
Agroalimentaire Canada



Demystifying the Status of Grapevine Viruses in British Columbia

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OUTLINE

1. British Columbia grape and wine industry

2. Grapevine viruses

- *Importance and economic impact*
- *Status of grapevine viruses in BC and Canada*

3. Current studies on grapevine viruses in BC

- *Field surveys, spread, molecular studies, vectors,...*
- *Grapevine leafrolls and grapevine redblotch*
- *Others (Fanleaf, Arabis mosaic, Pinot Gris viruses,...)*

- Grapes have long been cultivated in BC (1850s)
- British Columbia wine industry pre-pullout (1980s)

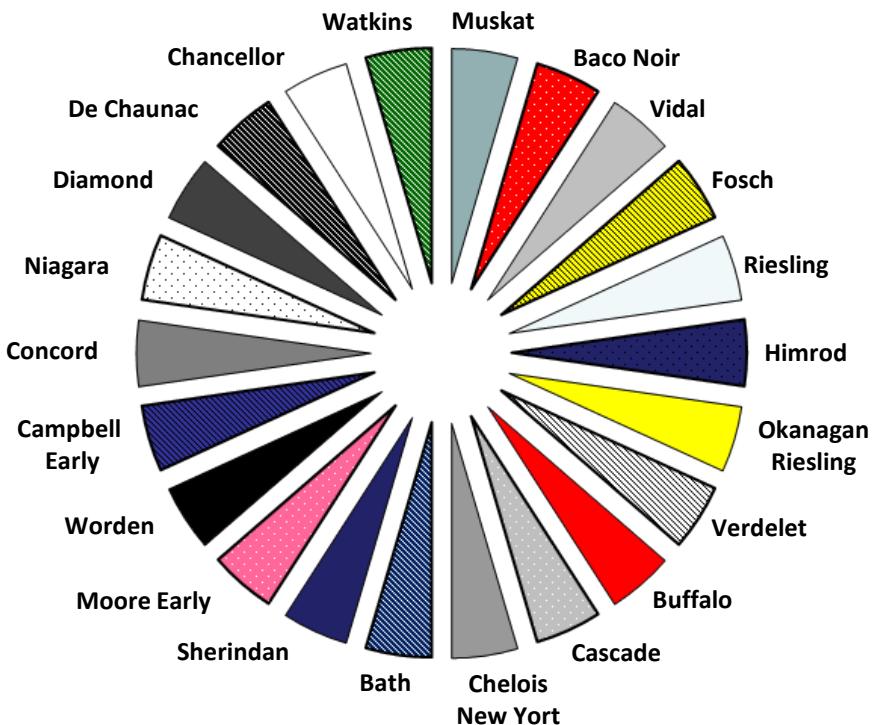
Protected
Generic
Local consumption



- Dramatic change since 1989 (Canada – USA ‘NAFTA’)

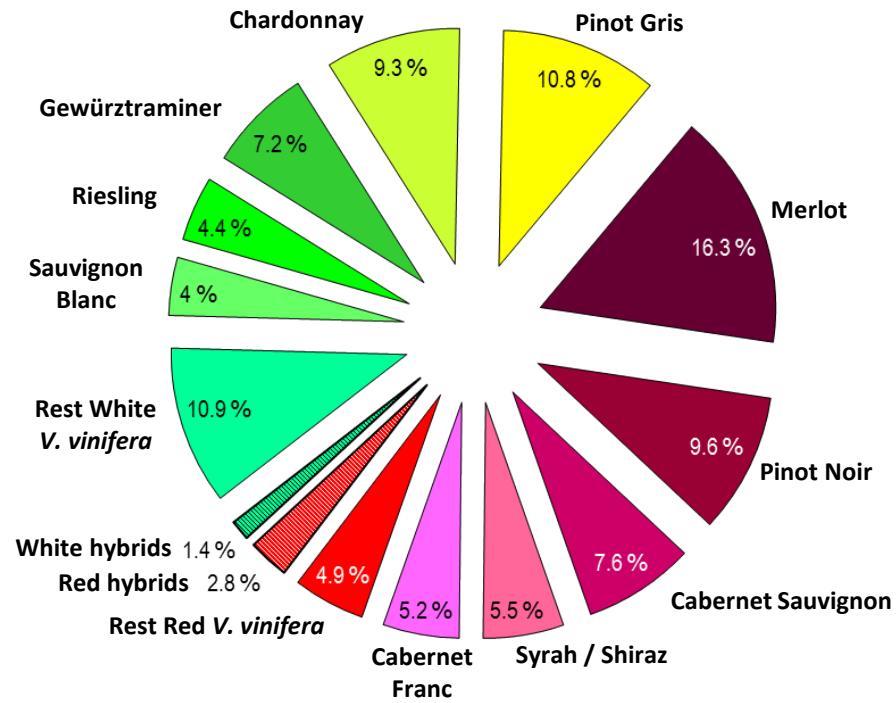
Government replant program led to the removal of 2,500 ac. of hybrids and *V. labrusca* and planting of 1,500 acres of *V. vinifera*

1988



3,025 ac.

2014



10,260 ac.

(2013-2014 BC Wine Institute Annual Report)

- Industry focused on high-quality wines and wine tourism
- Interest in sustainable and organic production systems

The screenshot shows the homepage of the Wines of British Columbia website. At the top left is the logo 'WBC WINES OF BRITISH COLUMBIA'. To the right are navigation links: OUR WINES, DISCOVER BC WINE COUNTRY, TRIP PLANNER, and EVENTS. A search bar with a magnifying glass icon is also present. Below the header is a large, scenic photograph of a vineyard with a wooden barn in the background. The main content area has a green banner with the text 'OUR WINES' and 'SUSTAINABLE WINE GROWING'. Below the banner are two images: one showing a meal on a table overlooking a vineyard and lake, and another showing a modern wine-tasting building at night.

OUR WINES

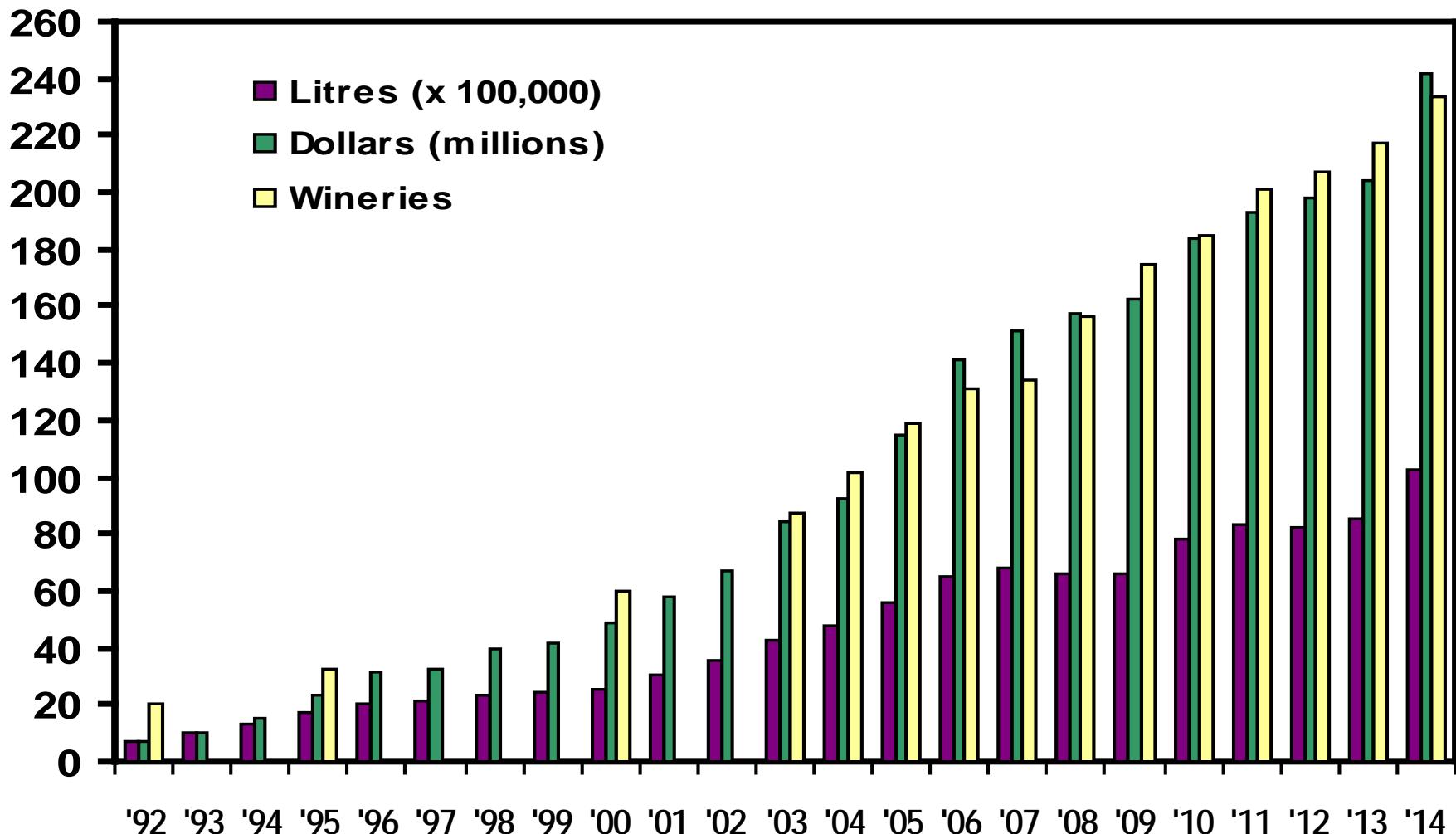
SUSTAINABLE WINE GROWING







BC VQA Wine Sales and Growth History



Data source: BC Wine Institute (Adapted by Dr. P. Bowen)

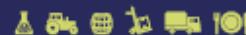
Canada's Wine Economy

RIPE. ROBUST. REMARKABLE.

Today, the Canadian Wine and Grape Industry is a significant driver to the national economy contributing billions of dollars in economic impact, jobs, taxes and tourism.

TOTAL
ECONOMIC
IMPACT

More than
31,000 JOBS
are created in Canada as a result
of the Wine and Grape Industry.



1B

Canadians enjoy
more than 1 billion
glasses of Canadian
produced wine
every year, equal to
220 million bottles.

220,000,000

\$6.8 BILLION

On average, **1 bottle** of Canadian wine generates
\$30.76 of economic impact.

\$21.36 BUSINESS REVENUE

\$5.41 WAGES

\$3.99 TAXES



Each year,
Canadian wineries
welcome over

3,000,000
visitors
generating

\$1.2B

of tourism-related
economic impact.

That's
more than
4X
the number
of visitors to
the 2010
Winter Olympics
in Vancouver.



Source: 2013 Report, Canada's Wine Economy - Ripe Robust Remarkable. Commissioned by the Canadian Vintners Association, the Winery & Grower Alliance of Ontario, the BC Wine Institute and Winery Association of Nova Scotia.
www.canadianvintners.com www.wago.ca www.wincbc.org www.winesofnovascotia.ca

- British Columbia grape industry economic impact

\$2.1 Billion

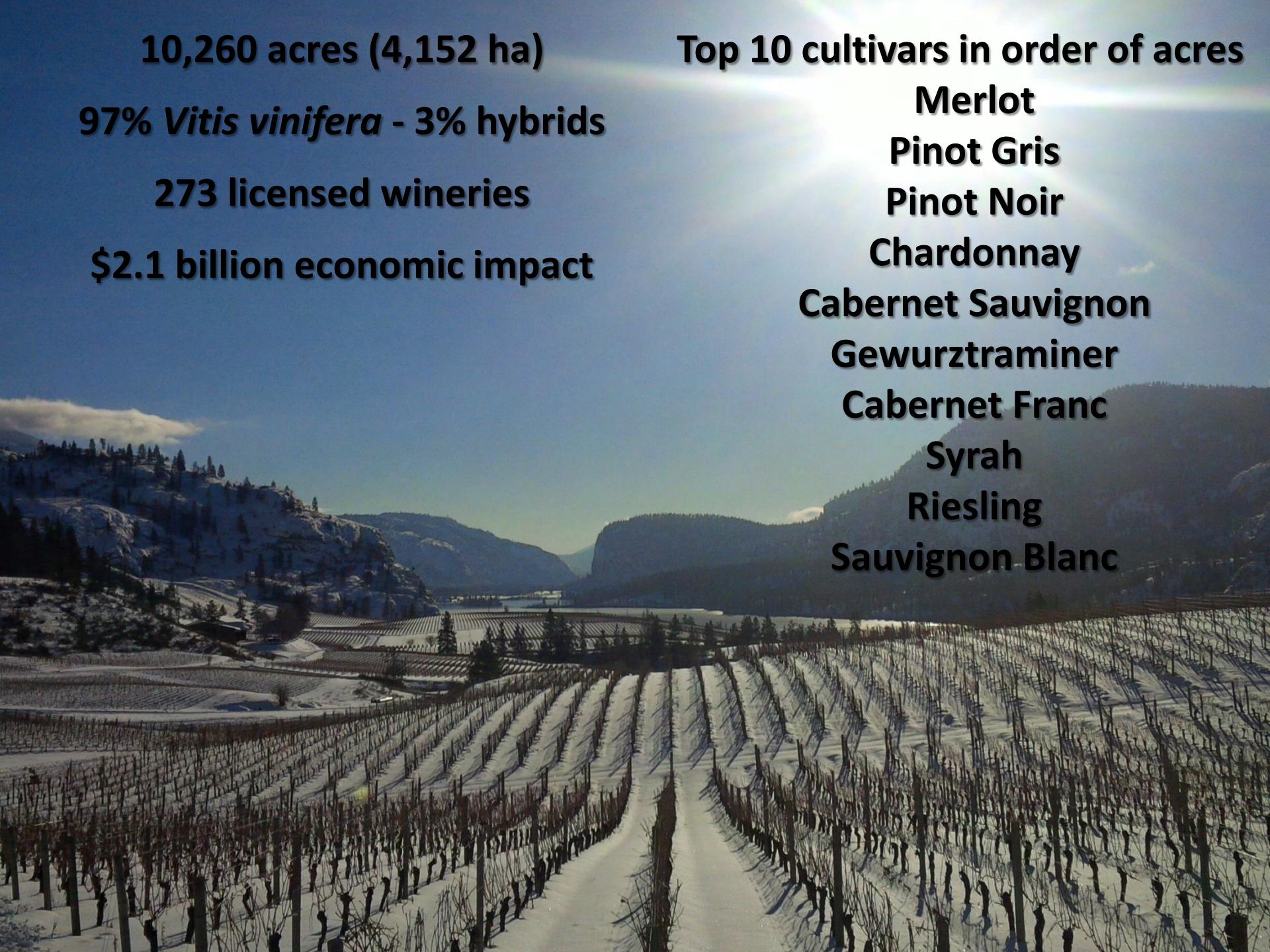
Direct and indirect employment

Wine related tourism expenditures

Provincial and federal revenue taxes

(Rimerman, A. F. 2013. A. Frank, Rimerman + Co. LLP Report)





10,260 acres (4,152 ha)

Top 10 cultivars in order of acres

97% *Vitis vinifera* - 3% hybrids

273 licensed wineries

\$2.1 billion economic impact

Merlot

Pinot Gris

Pinot Noir

Chardonnay

Cabernet Sauvignon

Gewurztraminer

Cabernet Franc

Syrah

Riesling

Sauvignon Blanc

OUTLINE

1. British Columbia grape and wine industry

2. Grapevine viruses

- *Importance and economic impact*
- *Status of grapevine viruses in BC and Canada*

- ***Vitis vinifera* hosts the widest variety of pathogens of any woody agricultural plant** (Martelli, G. P. 1997. Options Mediterranees 29:47-64)

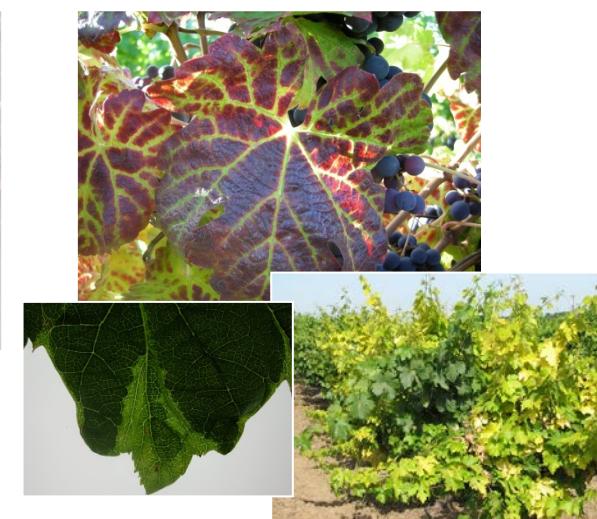
Bacteria



Fungi



Viruses



Over **70** infectious agents among **viruses**, **viroids** and **phytoplasmas** have been recorded from grapevines.

This represents the highest number of intra-cellular pathogens ever found in a single crop (J.P.P. 2014)

Identified viruses in *Vitis* and *Muscadinia* spp.

- Grapevine Cabernet franc-associated virus (GCFaV)
- Grapevine Red Blotch associated virus (GRBaV)
- Grapevine vein clearing virus (GVCV)
- Raphanus sativus cryptic virus 3 (RsCV-3) like
- Beet cryptic virus 3 (BCV-3) like
- Tomato spotted wilt virus (TSWV)
- Grapevine leafroll-associated virus 2 (GLRaV-2)
- Grapevine leafroll-associated virus 1 (GLRaV-1)
- Grapevine leafroll-associated virus 3 (GLRaV-3)
- Grapevine leafroll-associated virus 4 (GLRaV-4)
 - GLRaV-4 strain 5
 - GLRaV-4 strain 6
 - GLRaV-4 strain 9
 - GLRaV-4 Pr
 - GLRaV-4 strain Car
- Grapevine leafroll-associated virus 7 (GLRaV-7)
- Potato virus X (PVX)
- Grapevine rupestris stem pitting-associated virus (GRSPaV)
- Grapevine berry inner necrosis virus (GINV)
- Grapevine Pinot gris virus (GPGV)
- Grapevine virus A (GVA)
- Grapevine virus B (GVB)
- Grapevine virus D (GVD)
- Grapevine virus E (GVE)
- Grapevine virus F (GVF)
- Bean common mosaic virus (BCMV),
- Tobacco mosaic virus (TMV)
- Tomato mosaic virus (ToMV)
- Broadbean wilt virus (BBWV)
- Artichoke Italian latent virus (AILV)
- Raspberry bushy dwarf virus (RBDV)
- Sowbane mosaic virus (SoMV)
- Southern tomato virus (STV)
- Artichoke Italian latent virus (AILV)
- *Arabis* mosaic virus (ArMV)
- Blueberry leaf mottle virus (BBLMV)
- Cherry leafroll virus (CLRV)
- Grapevine Bulgarian latent virus (GBLV)
- Grapevine Anatolian ringspot virus (GARSV)
- Grapevine deformation virus (GDefV)
- Grapevine chrome mosaic virus (GCMV)
- Grapevine fanleaf virus (GFLV)
- Grapevine Tunisian ringspot virus (GTRV)
- Peach rosette mosaic virus (PRMV)
- Raspberry ringspot virus (RpRSV)
- Tobacco ringspot virus (TRSV)
- Tomato ringspot virus (ToRSV)
- Tomato blackring virus (TBRV)
- Strawberry latent ringspot virus (SLRSV)
- Alfalfa mosaic virus (AMV)
- Cucumber mosaic virus (CMV)
- Grapevine line pattern virus (GLPV)
- Grapevine angular mosaic virus (GAMoV)
- Carnation mottle virus (CarMV)
- Tobacco necrosis virus D (TNV-D)
- Grapevine Algerian latent virus (GALV)
- Petunia asteroid mosaic virus (PAMV)
- Grapevine asteroid mosaic-associated virus (GAMaV)
- Grapevine redglobe virus (GRGV)
- Grapevine Syrah virus 1 (GSV-1)
- Blackberry virus S (BIVS)
- Grapevine fleck virus (GFkV)
- Grapevine rupestris vein feathering virus (GRVFV)
- Grapevine Ajinashika virus (GAgV)
- Grapevine stunt virus (GSV)
- Grapevine labile rod-shaped virus (GLRSV)

- **Viruses cause production issues in nurseries and vineyards**

Rooting ability

Graft take and rootstock-scion compatibility

Overall vine vigor

Yield and fruit quality

REDUCE

- **Major viral diseases**

Grapevine leafroll disease (GLRD)

Grapevine leafroll associated viruses (GLRaV-1 to -9)



Rugose wood complex (RW)

Grapevine rupestris stem pitting associated virus (GRSPaV)

Grapevine virus A (GVA), B (GVB), and D (GVD)



Grapevine fanleaf degeneration complex

Grapevine fanleaf virus (GFLV)



- **Grapevine leafroll disease (GLRD)**

Virus colonizes and reproduces in the phloem tissue disrupting the flow of nutrients to shoots, leaves and fruit.

Negative impact on fruit quality characteristics

- berry weight
- fruit maturity
- soluble solids ($^{\circ}$ Brix)
- pH
- titrable acidity

Can delay fruit maturity up to 4 weeks with uneven fruit size

Fewer and smaller clusters (reduced yields up to 50%)

GLRD infected vines can not be cured

Spread by insect vectors both within and between vineyards

Can be introduced into a vineyard with the planting propagated material



- Viruses cause significant economic losses worldwide

GLRD in California

\$29,902 - 226,405 USD / ha

(Ricketts et al. 2015. AJEV 66:138-147)

GLRD in New York (Finger Lakes)

\$25,000 - \$40,000 USD / ha

(Atallah et al. 2012. AJEV 63:73-79)

GLRD in Washington

Up to 77% revenue decline / ac

30% yield reduction

1.00 Brix reduction

(T. Ball. 2014 YVCC)

Economic Impact of Grapevine Leafroll Disease on *Vitis vinifera* cv. Cabernet franc in Finger Lakes Vineyards of New York

Shady S. Atallah,^{1,*} Miguel I. Gómez,¹ Marc F. Fuchs,² and Timothy E. Martinson³

Abstract: Leafroll disease is one of the most important virus diseases of grapevines worldwide. It reduces yields, delays fruit ripening, reduces soluble solids, and increases titratable acidity in fruit juice. This study uses a net present value (NPV) approach over a 25-year lifespan of a vineyard to examine the economic impact of grapevine leafroll disease (GLRD) on *Vitis vinifera* cv. Cabernet franc in Finger Lakes vineyards of New York. It identifies optimal disease control options under several scenarios of disease prevalence, yield reduction, and fruit quality effects. The estimated economic impact of GLRD ranges from approximately \$25,000 (for a 30% yield reduction and no grape quality penalty) to \$40,000 (for a 50% yield reduction and a 10% penalty for poor fruit quality) per hectare in the absence of any control measure. The per hectare impact of GLRD can be substantially reduced to \$3,000–\$23,000 through roguing if levels of disease prevalence are moderate (1–25%). With disease prevalence levels greater than 25%, replacing the entire vineyard is the optimal response, yielding economic losses of ~\$25,000/ha. Furthermore, the use of vines derived from certified, virus-tested stocks in replant sites is predicted to keep the costs associated with GLRD infection to ~\$1,800/ha. No intervention appears to be economically optimal when (1) infection levels are high (>25%), yield reduction is moderate (<30%), and no price penalty is enforced or (2) when GLRD is transmitted through vectors after year 19. These findings are valuable to construct integrated decision matrices for vineyard managers to devise profit-maximizing disease control strategies and to create incentives for extended uses of clean, virus-tested planting material.

Key words: grapevine leafroll disease (GLRD), Finger Lakes region New York, net present value, roguing, vine replacement



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of
ENOLOGY AND VITICULTURE

Research Article

Reducing the Economic Impact of Grapevine Leafroll Disease in California: Identifying Optimal Disease Management Strategies

Katie D. Ricketts^{1,*}, Miguel I. Gomez¹, Shady S. Atallah¹, Marc F. Fuchs², Timothy E. Martinson³, Mark C. Battany⁴, Larry J. Bettiga⁵, Monica L. Cooper⁶, Paul S. Verdegaaal⁷ and Rhonda J. Smith⁸

• Grapevine viruses in Canada

Special Report



Table 2. Aggregate summary of infected samples by region

	BC ^a (1,485) ^b	ON (9,779)	PQ (39)	NS (114)	Totals (11,417)
ArMV ^c	0.34% (5)	0.55% (54)	2.56% (1)	0	0.53% (60)
GFLV	0.06% (1)	0.32% (31)	0	0	0.25% (32)
GLRaV-I	1.28% (19)	1.75% (171)	0	0.87% (1)	1.67% (191)
GLRaV-III	2.15% (32)	12.2% (1,191)	5.12% (2)	1.75% (2)	10.8% (1,227)

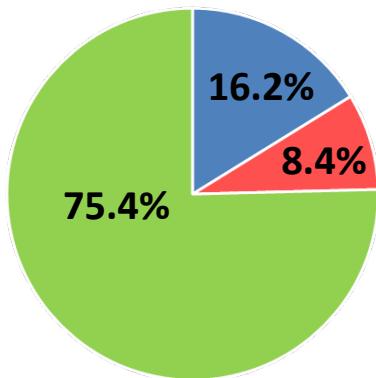
^a Province abbreviations: British Columbia (BC), Ontario (ON), Quebec (PQ), Nova Scotia (NS).

^b Numbers in parentheses represent absolute numbers of samples tested per region or the number of samples found positive or suspect for each virus in each region.

^c ArMV = arabis mosaic virus, GFLV = grapevine fanleaf virus, and GLRaV-I and -III = grapevine leafroll associated virus types I and III.

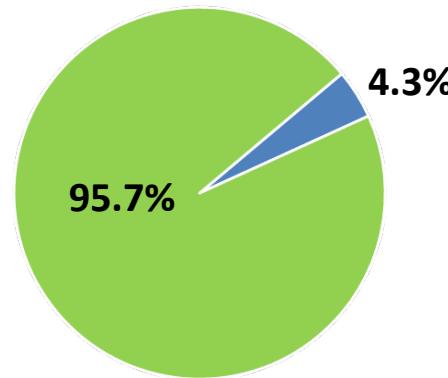
ArMV, GFLV, and GLRaVs are not regulated pests by CFIA

BRITISH COLUMBIA



1996 (1,375 ac.)

- *Vitis vinifera*
- Hybrid
- Other



2014 (10,260 ac.)

The increasing number of young and old vines showing GLRD symptoms has recently raised BC industry's concern.

Delayed ripening and rapid symptoms spread within and between vineyards have been observed during the past years.

1) Lack of a domestic grapevine clean program

Most planting material comes from international sources

2) Current lack of information on:

- Incidence of GLRD in BC, it has increased since 1996?
- GLRaVs currently present in BC (GLRaV-1, -3, ???)
- Spreading within and between vineyards?
- Are there potential GLRaVs vectors in BC?
- Economic impact of GLRaVs in BC wine-industry

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- *Field surveys, spread, molecular studies, vectors,...*
- *Grapevine leafrolls and grapevine redblotch*
- *Others (Fanleaf, Arabis, fleck, and Pinot gris viruses)*

GROWING FORWARD 2 – AGRI-INNOVATION PROGRAM (AIP) INDUSTRY-LED RESEARCH AND DEVELOPMENT STREAM

'ENHANCING THE SUSTAINABILITY OF THE BC GRAPE AND WINE SECTORS'

- **TITLE:** Investigation of grapevine leafroll associated virus (Activity 3)

- **PRINCIPAL INVESTIGATOR**

José R. Úrbez-Torres (SuRDC)

- **COLLABORATORS**

Tom Lowery (SuRDC)

Sudarsana Poojari (NSERC-VF)

Pat Bowen (SuRDC)

Anna-Mary Schmidt (CFIA)

Carl Bogdanoff (SuRDC)

Michael Rott (CFIA)

Kevin Usher (SuRDC)

Dan O'Gorman (SuRDC)



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- **ACTIVITY OBJECTIVES**

3.1. Identification, molecular characterization, and distribution of GLRaVs in BC

3.2. Identification, abundance and control of potential GLRaVs insect vectors in BC

3.3. Determine insect vector's efficiency in spreading GLRaVs in BC vineyards

3.4. Quantification of GLRaVs effects on vine growth, winter hardiness, fruit, and wine

A-BASE PROGRAM (GOVERNMENT OF CANADA)

'GRAPEVINE PESTS/DISEASE MANAGEMENT AND ENHANCE SUSTAINABILITY'

- **TITLE:** Investigation of lesser known grapevine viruses in BC (Activity 2)

- **PRINCIPAL INVESTIGATOR**

Tom Lowery (SuRDC)

- **COLLABORATORS**

José R. Úrbez-Torres (SuRDC)

Sudarsana Poojari (SuRDC)

Pat Bowen (SuRDC)

Carl Bogdanoff (SuRDC)

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Dan O'Gorman (SuRDC)

Anna-Mary Schmidt (SuRDC)



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- **ACTIVITY OBJECTIVES**

3.1. Characterization, and distribution of GFLV, ArMV, GFkV, GRBaV

3.2. Identification, abundance and control of potential insect vectors in BC

3.3. Quantification of virus effects on vine growth, winter hardiness, fruit, and wine

- **3.1. Characterization and distribution of grapevine viruses in BC**

Preliminary field survey started in 2011 and continued in 2013 (GLRaVs)

Field surveys started in 2014 for GRBaV

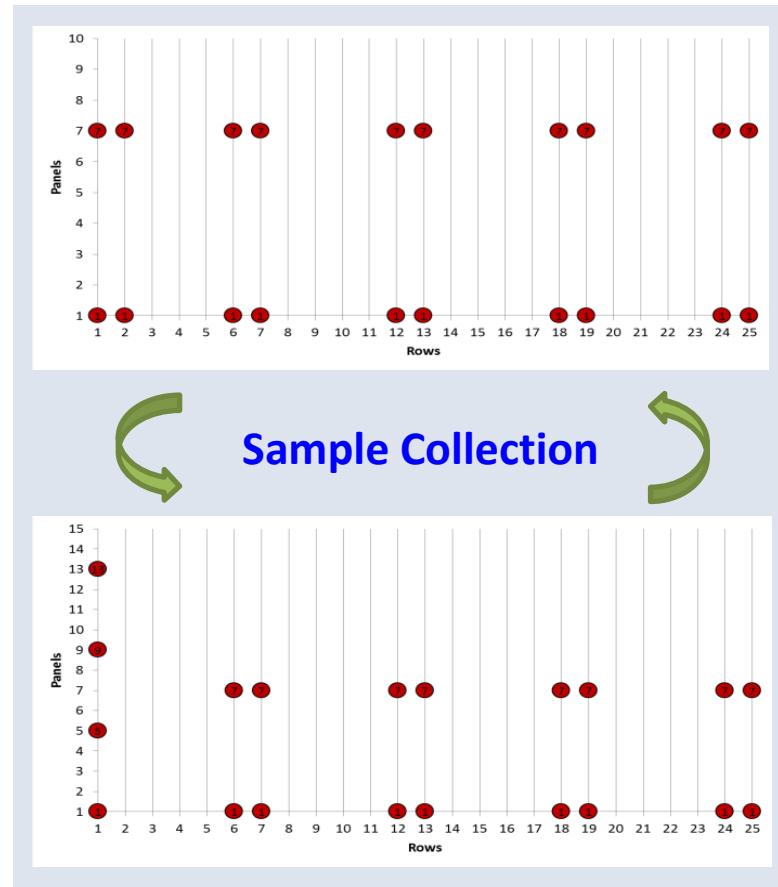
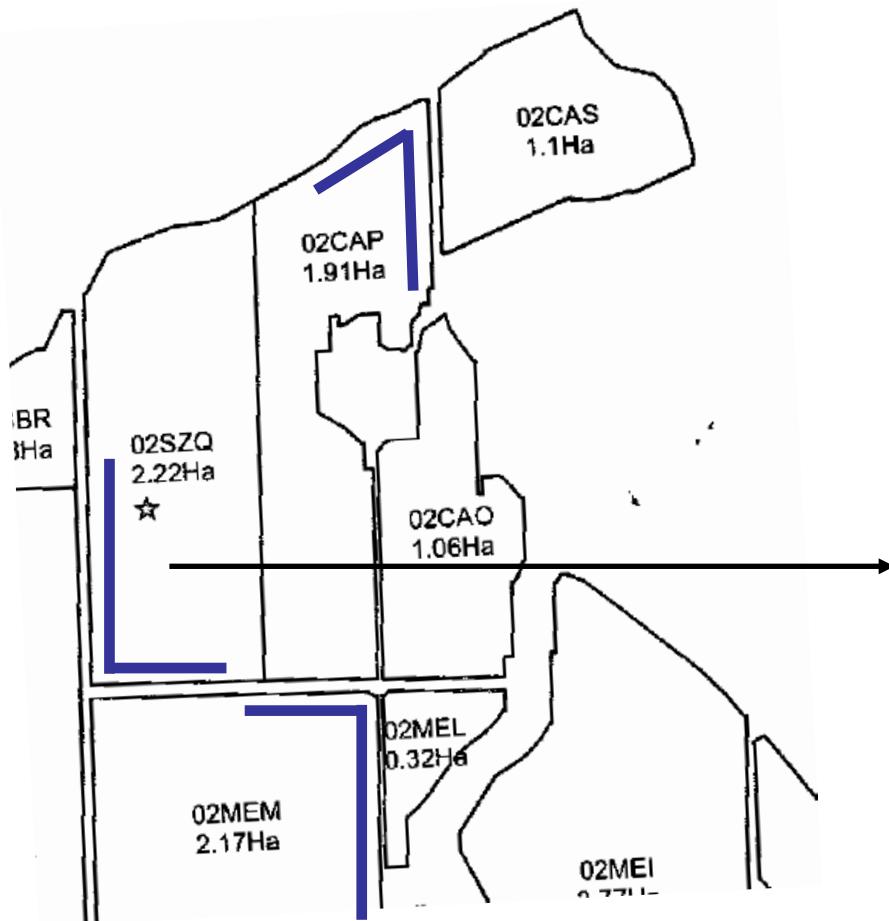


• 3.1. Characterization and distribution of grapevine viruses in BC

Random Sampling 20 composite samples (5 vines/sample) / block

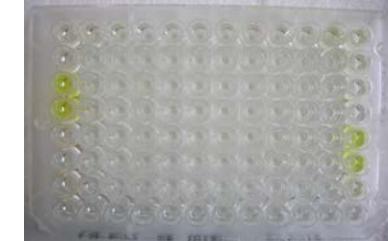
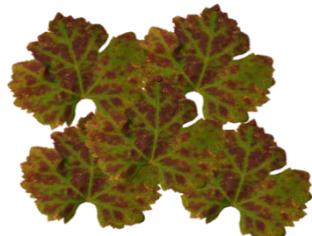
Single vine target-samples (symptomatic or suspicious)

Rootstock/scion (clone) combination, age of vineyard, source of material



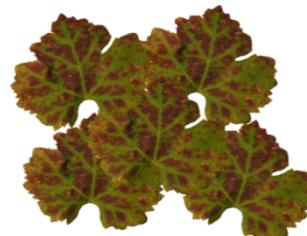
• 3.1. Characterization and distribution of grapevine viruses in BC

Random Sampling 20 composite samples / block (= 100 vines)



Sample was grinded and first tested by
ELISA (BIOREVA Kits)

GLRaV-1	GFLV
GLRaV-2	ArMV
GLRaV-3	GfKV
GLRaV-4	



Sample tested (+)

leaf samples or dormant canes
from each of the 5 vines
were collected during winter and
tested by RT-PCR

- 3.1. Characterization and distribution of grapevine viruses in BC

PCR-BASED DIAGNOSTICS FOR GRAPEVINE VIRUSES THREE-STEP EXTRACTION METHOD

1

Grind 0.25g of petiole/leaf/green bark tissue in 5ml of Buffer-A

2

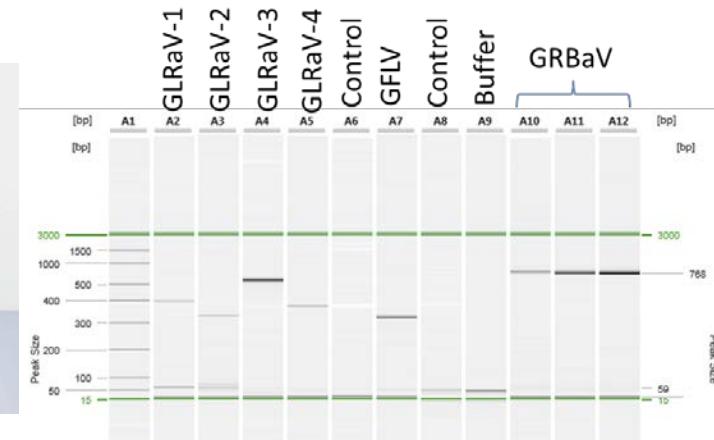
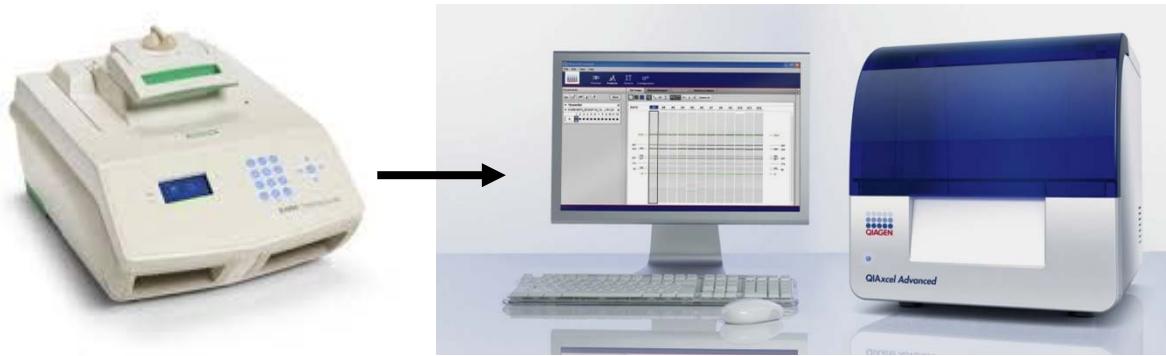
Mix 2 μ l of Buffer-A with 25 μ l of Buffer-B, denature at 95°C for 10 min and snap cool on ice.

3

Take 3 μ l of Buffer B eluate as template for PCR or RT-PCR for virus detection.

Modified from: Rowhani et al. 2000

QIAxcel® digital gel electrophoresis



Rapid, sensitive and cost-effective method
ideal for large scale diagnostics

• 3.1. Characterization and distribution of grapevine viruses in BC

Sample Code	ELISA				PCR / RT-PCR										
	GLRaV-1	GLRaV-2	GLRaV-3	GLRaV-4-9	GLRaV-1	GLRaV-2	GLRaV-2-RG	GLRaV-3	GLRaV-4	GLRaV-4-S5	GLRaV-4-S6	GLRaV-7	GLRaV-9	GLRaV-10	GRBaV
M10-CAK-22-1	1				NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
M10-CAK-22-1-1	NT	NT	NT	NT						NT	NT	NT			
M10-CAK-22-1-2	NT	NT	NT	NT						NT	NT	NT			
M10-CAK-22-1-3	NT	NT	NT	NT						NT	NT	NT			
M10-CAK-22-1-4	NT	NT	NT	NT						NT	NT	NT			
M10-CAK-22-1-5	NT	NT	NT	NT						NT	NT	NT			

Sample Code	ELISA				PCR / RT-PCR										
	GLRaV-1	GLRaV-2	GLRaV-3	GLRaV-4-9	GLRaV-1	GLRaV-2	GLRaV-2-RG	GLRaV-3	GLRaV-4	GLRaV-4-S5	GLRaV-4-S6	GLRaV-7	GLRaV-9	GLRaV-10	GRBaV
KL-B-94-1	1	1	1		NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
KL-B-94-1-1	NT	NT	NT	NT						NT	NT	NT			
KL-B-94-1-2	NT	NT	NT	NT						NT	NT	NT			
KL-B-94-1-3	NT	NT	NT	NT						NT	NT	NT			
KL-B-94-1-4	NT	NT	NT	NT						NT	NT	NT			
KL-B-94-1-5	NT	NT	NT	NT						NT	NT	NT			

Sample Code	ELISA				PCR / RT-PCR										
	GLRaV-1	GLRaV-2	GLRaV-3	GLRaV-4-9	GLRaV-1	GLRaV-2	GLRaV-2-RG	GLRaV-3	GLRaV-4	GLRaV-4-S5	GLRaV-4-S6	GLRaV-7	GLRaV-9	GLRaV-10	GRBaV
P3-CHA-17-2	1	1	1		NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
P3-CHA-17-2-1	NT	NT	NT	NT						NT	NT	NT			
P3-CHA-17-2-2	NT	NT	NT	NT						NT	NT	NT			
P3-CHA-17-2-3	NT	NT	NT	NT						NT	NT	NT			
P3-CHA-17-2-4	NT	NT	NT	NT						NT	NT	NT			
P3-CHA-17-2-5	NT	NT	NT	NT						NT	NT	NT			

Current studies on grapevine viruses in British Columbia

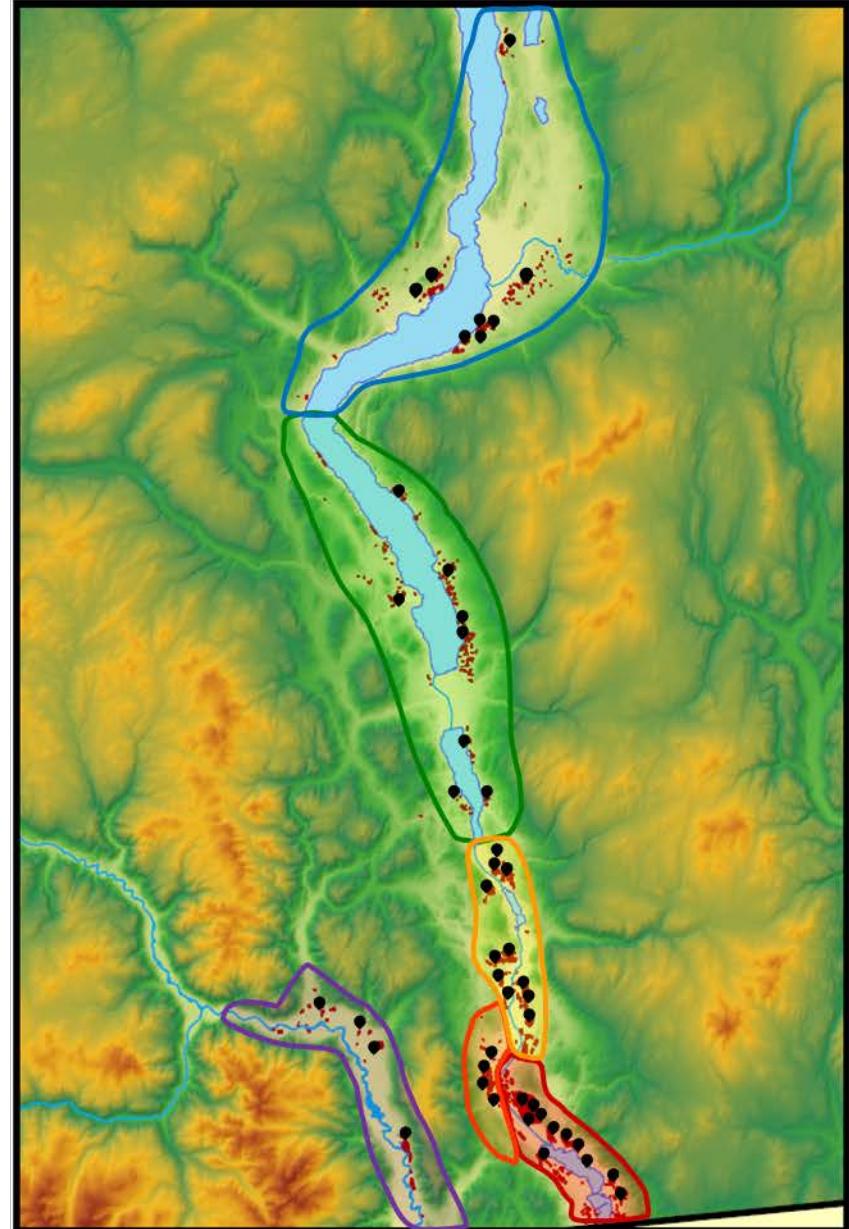
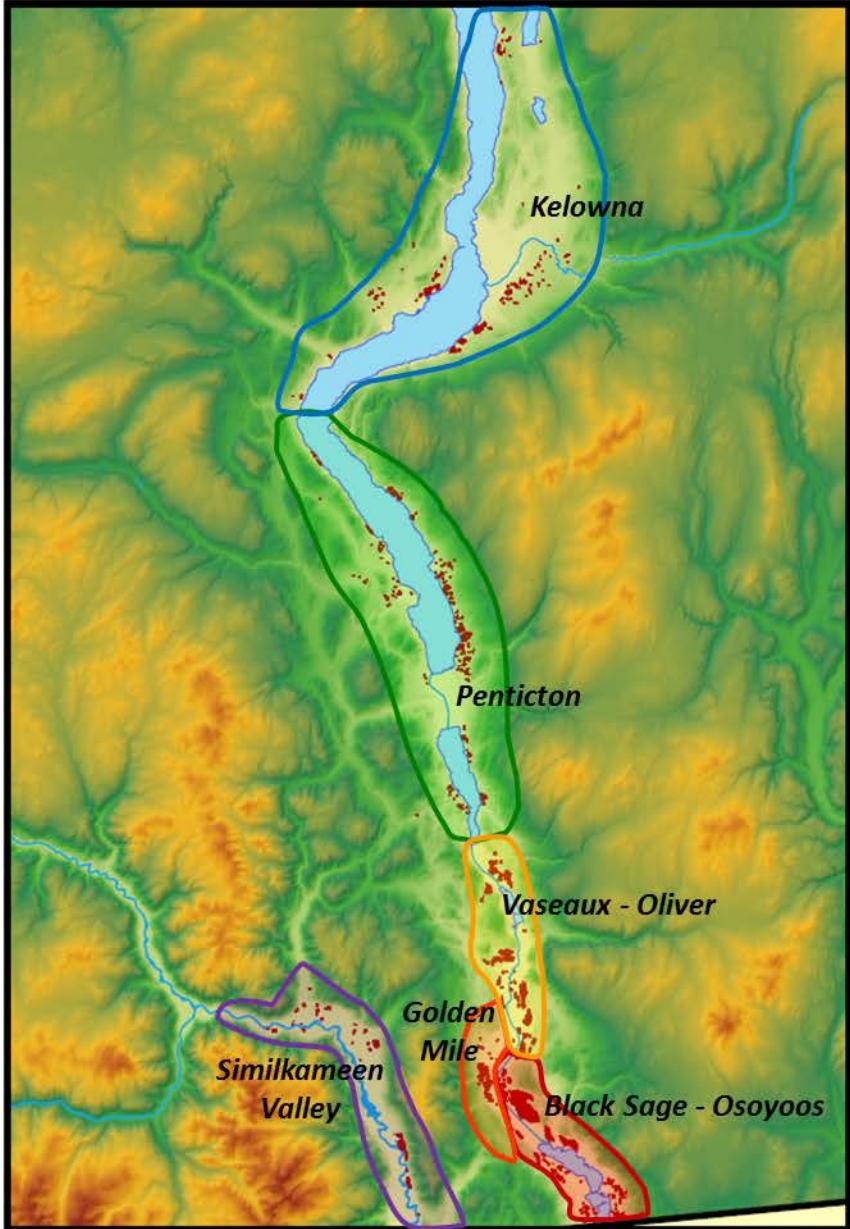
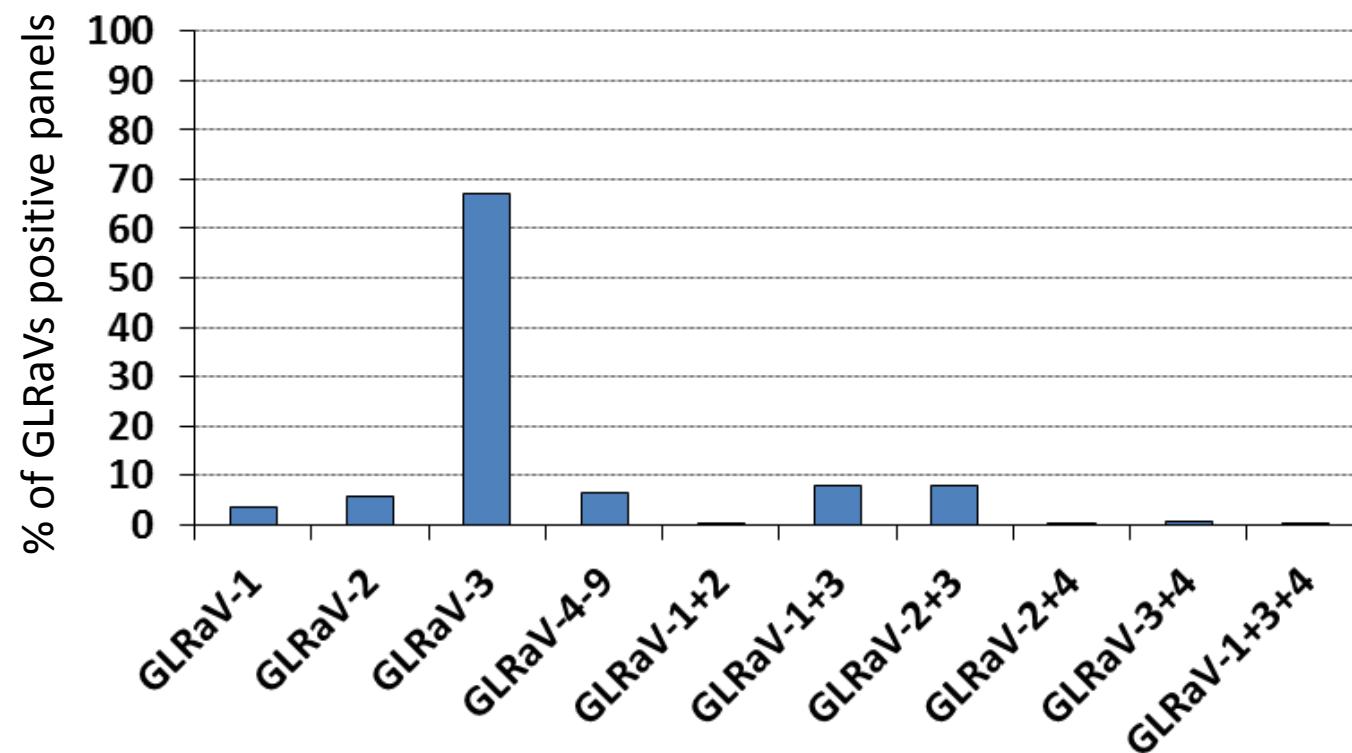


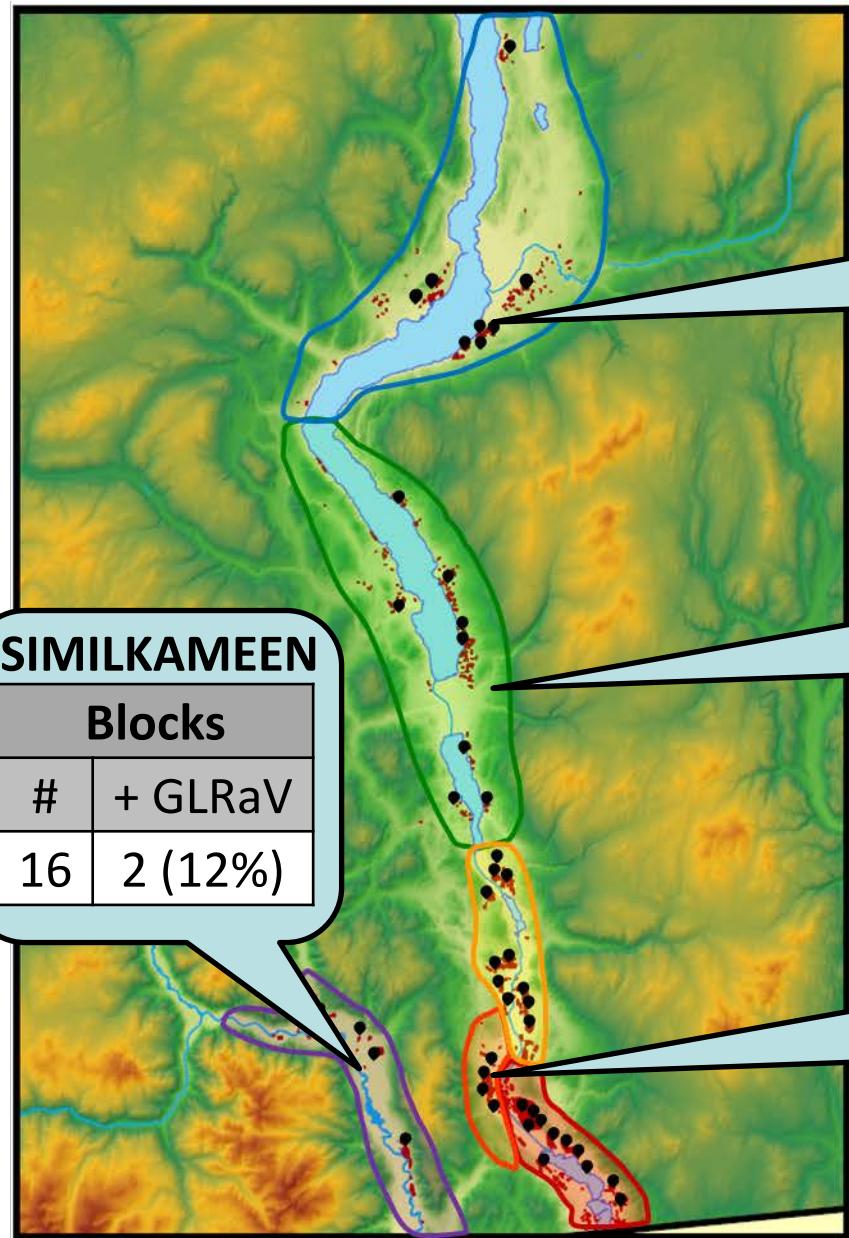
Image Courtesy: Dr. P. Bowen AAFC-SuRDC

• 3.1. Characterization and distribution of GLRaVs in BC

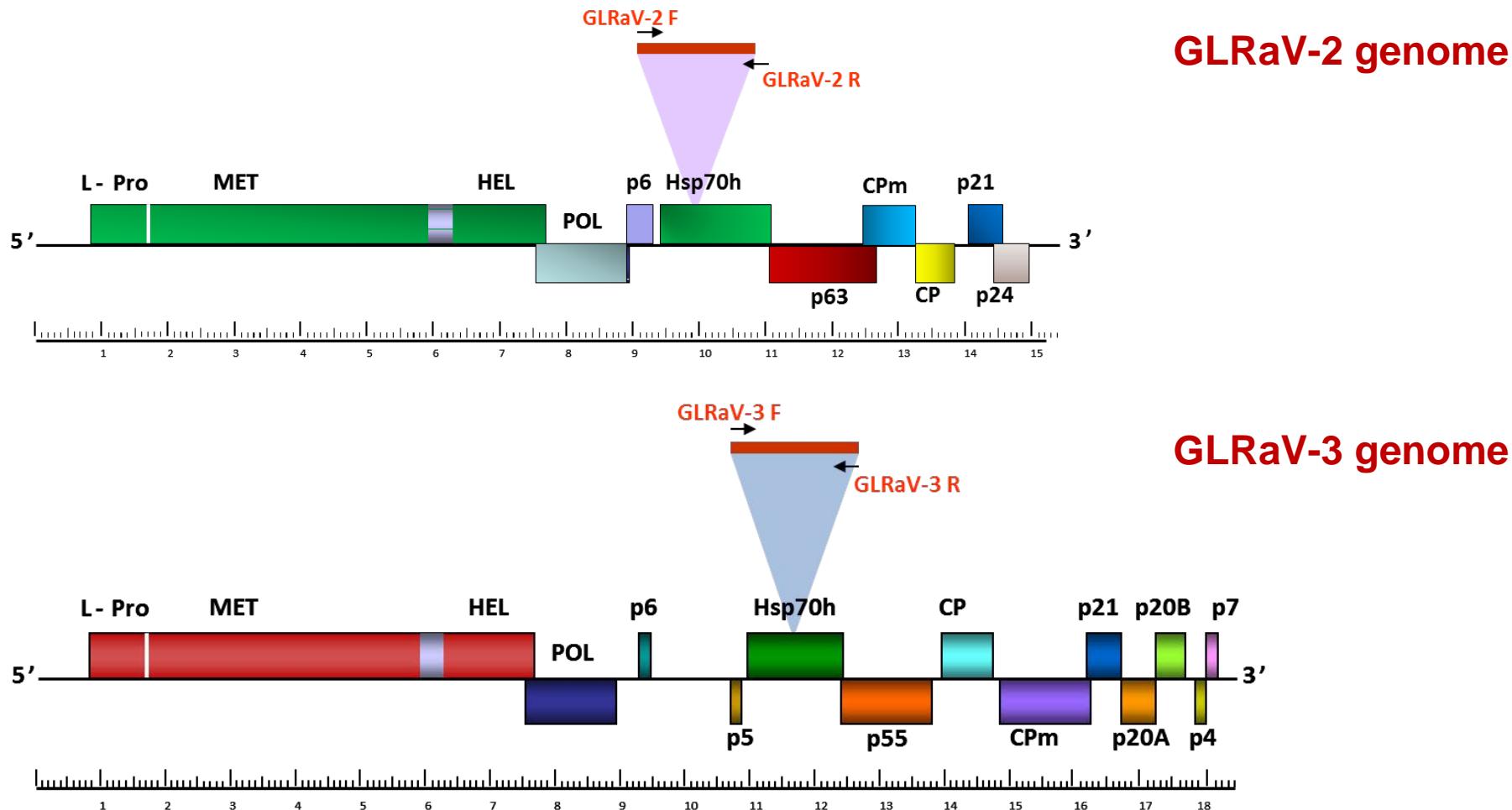
Field survey results summary 2014 and 2015 growing seasons

	Blocks		Panel		Targeted Vines		Total Vines Tested
	#	+ (%)	#	+ (%)	#	+ (%)	
GLRaV	241	131 (54.3)	3,261	858 (26.3)	261	100 (38.3)	16,566





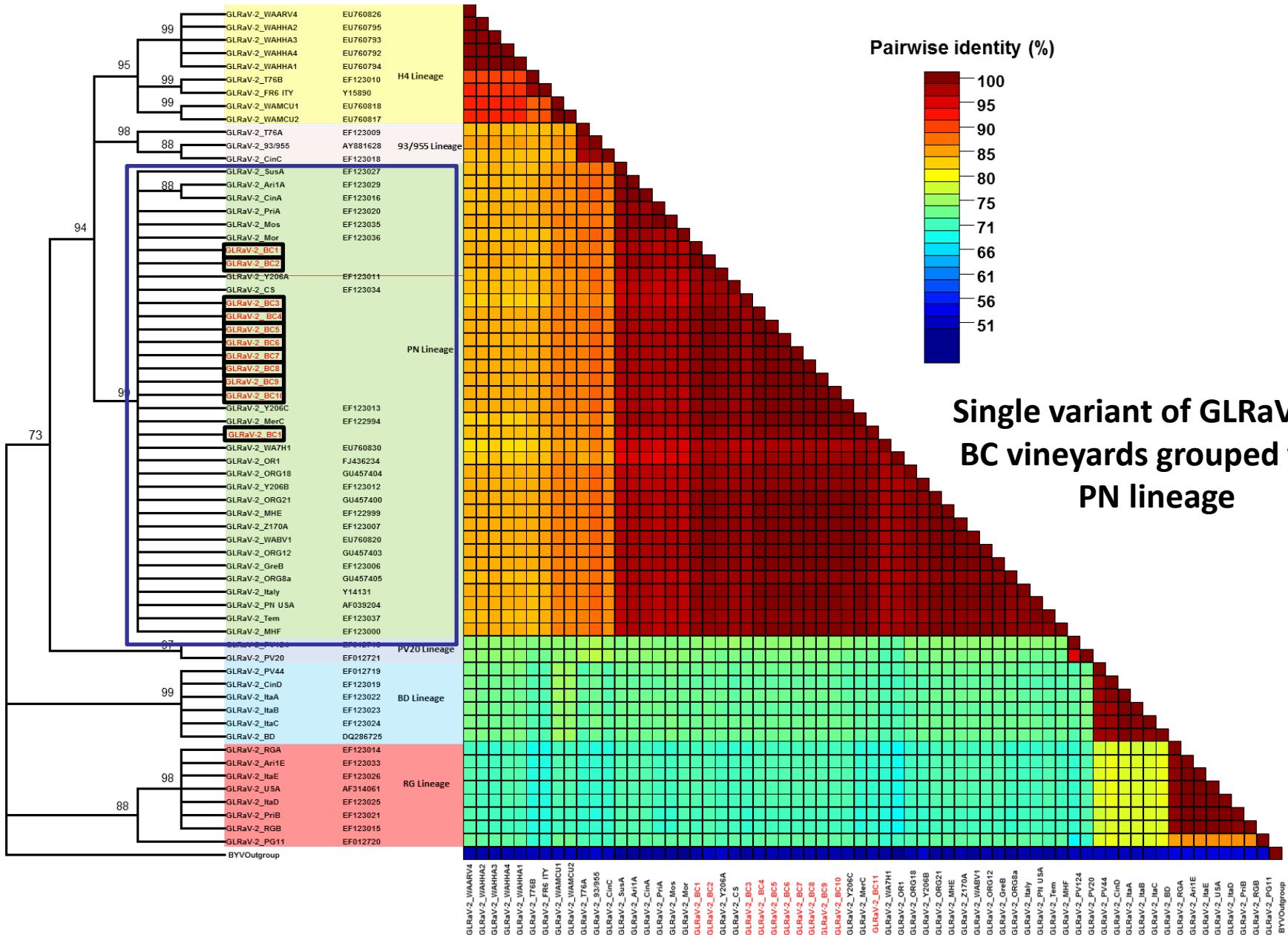
- 3.1. Genetic diversity of Grapevine leafroll viruses in BC



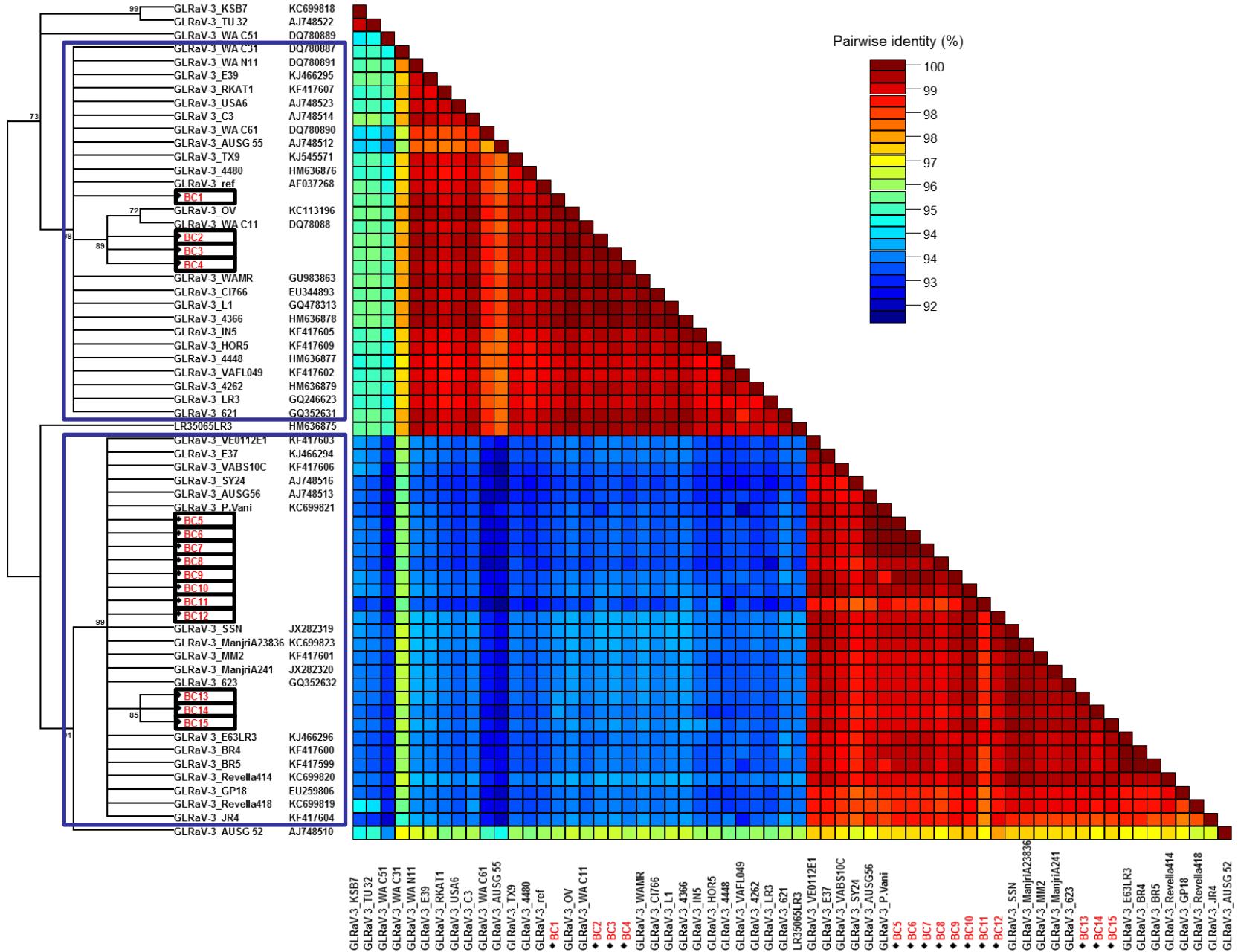
(Rayapati *et al.* 2014. Plant Disease 98:1172-1185)

GLRaV-2 and -3 Primers: (Osman and Rowhani 2006 and Abou Ghanem)

Genetic diversity of GLRaV-2 in BC vineyards



Genetic diversity of GLRaV-3 in BC vineyards



• 3.2. Study of potential GLRaVs vectors in BC

Table 1. Mealybug (Pseudococcidae) and scale insect (Coccoidea) species currently reported as vectors for grapevine-infecting ampeloviruses

Virus	Mealybugs	Scale insects	References
GLRaV-1	Bohemian mealybug (<i>Helicoccoides boemicus</i>) Apple mealybug (<i>Phenacoccus aceris</i>) Obscure mealybug (<i>Pseudococcus viburni</i> [formerly <i>Ps. affinis</i>]) Citrophilous mealybug (<i>Pseudococcus calceolariae</i>) Grape mealybug (<i>Pseudococcus maritimus</i>) Comstock mealybug (<i>Pseudococcus comstocki</i>)	<i>Pulvinaria vitis</i> <i>Parthenolecanium corni</i> <i>Neopulvinaria innumerabilis</i>	14, 17, 22, 48, 49, 65, 66, 67, 73, 83, 93, 98, 102, 108, 112, 122, 145, 147, 156, 158, 171
GLRaV-3	Bohemian mealybug (<i>Helicoccoides boemicus</i>) Vine mealybug (<i>Planococcus ficus</i>) Citrus mealybug (<i>Planococcus citri</i>) Longtailed mealybug (<i>Pseudococcus longispinus</i>) Citrophilous mealybug (<i>Pseudococcus calceolariae</i>) Grape mealybug (<i>Pseudococcus maritimus</i>) Obscure mealybug (<i>Pseudococcus viburni</i>) Comstock mealybug (<i>Pseudococcus comstocki</i>) Apple mealybug (<i>Phenacoccus aceris</i>)	<i>Pulvinaria vitis</i> <i>Neopulvinaria innumerabilis</i> <i>Parthenolecanium corni</i> <i>Coccus hesperidium</i> <i>Coccus longulus</i> , <i>Saissetia</i> sp. <i>Parasaissetia nigra</i> <i>Ceroplastes rusci</i>	
GLRaV-4 and its strains -5, -6, and -9	Vine mealybug (<i>Planococcus ficus</i>)	<i>Ceroplastes rusci</i>	

(Rayapati *et al.* 2014. Plant Disease 98:1172-1185)

Over 80 blocks throughout the Okanagan Valley surveyed

Morphological and molecular characterization

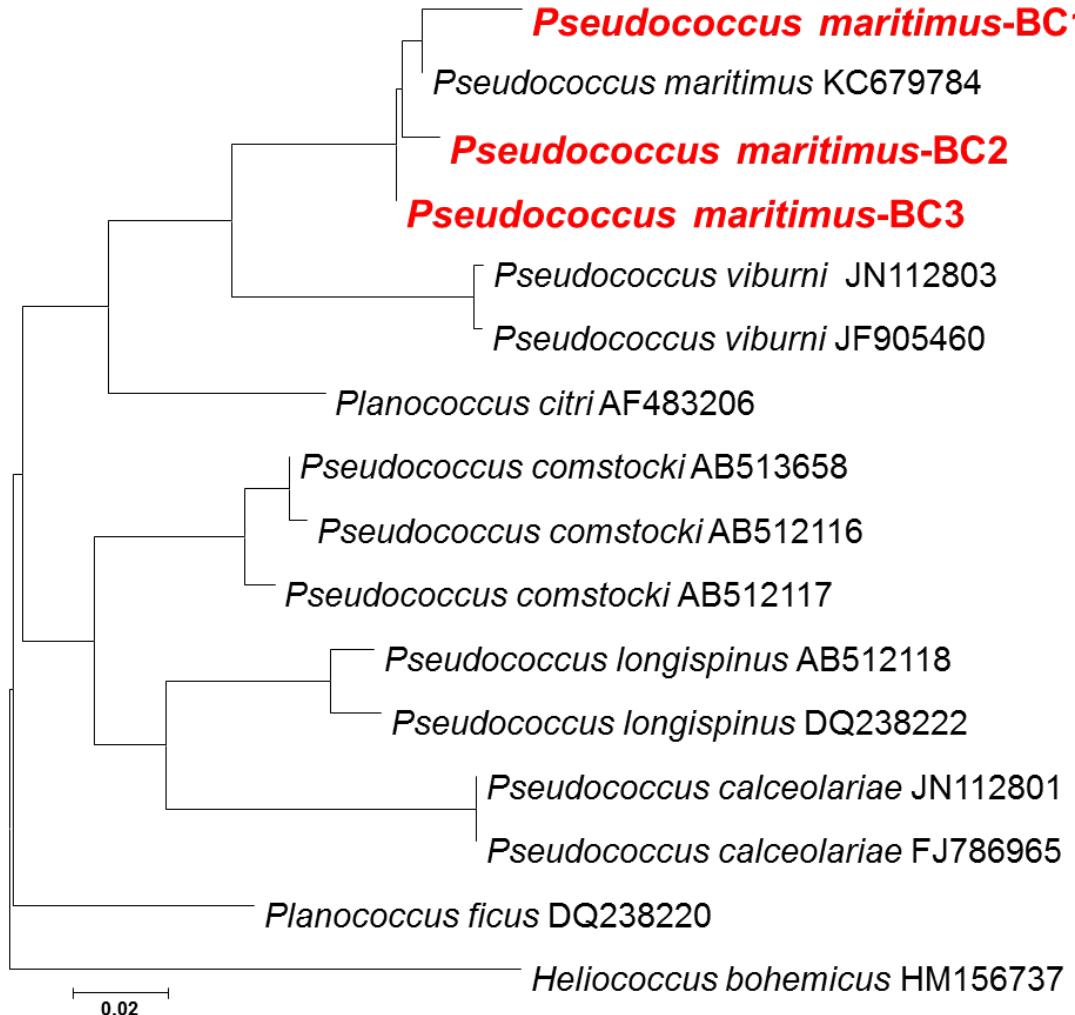
6 blocks monitored weekly April-May to August-September

Scale/mealybug stages, environmental conditions, grape phenology

DNA barcoding
Guelph (ON)
5 species

• 3.2. Study of potential GLRaVs vectors in BC

Molecular studies at SuRDC confirmed the presence of **Grape mealybug** in BC



Photos: S. Poojari (SuRDC)

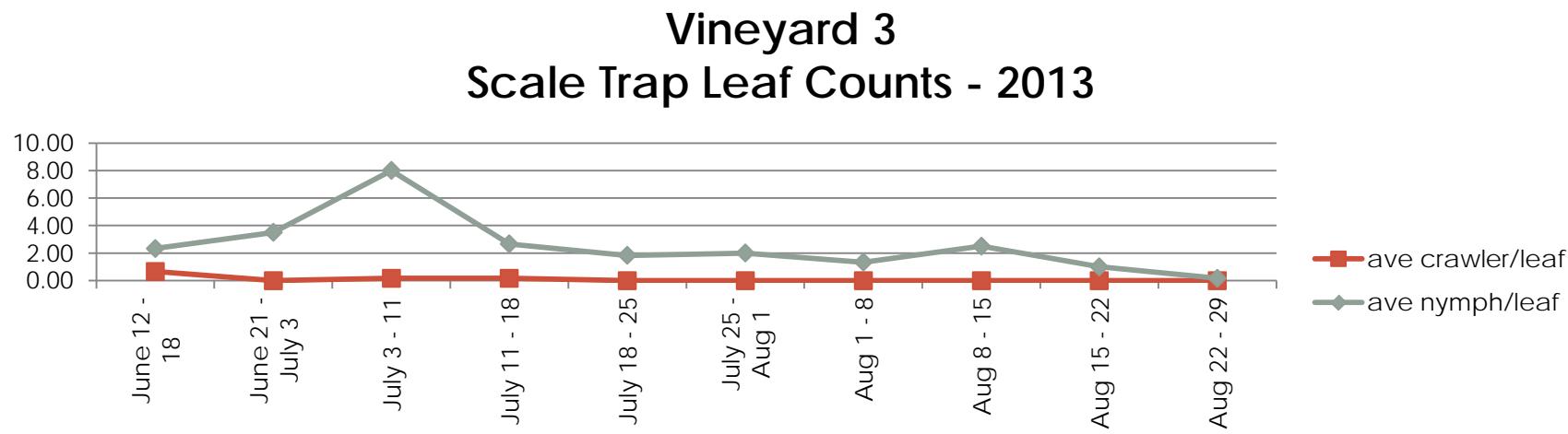
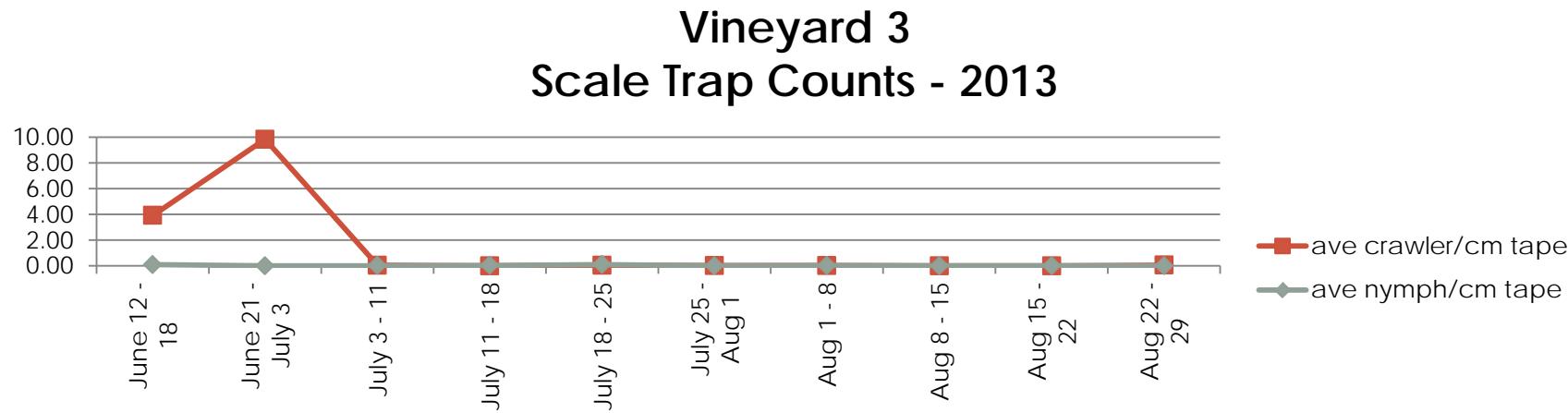
- **3.2. Study of potential GLRaVs vectors in BC**



Photos: H. Buchler

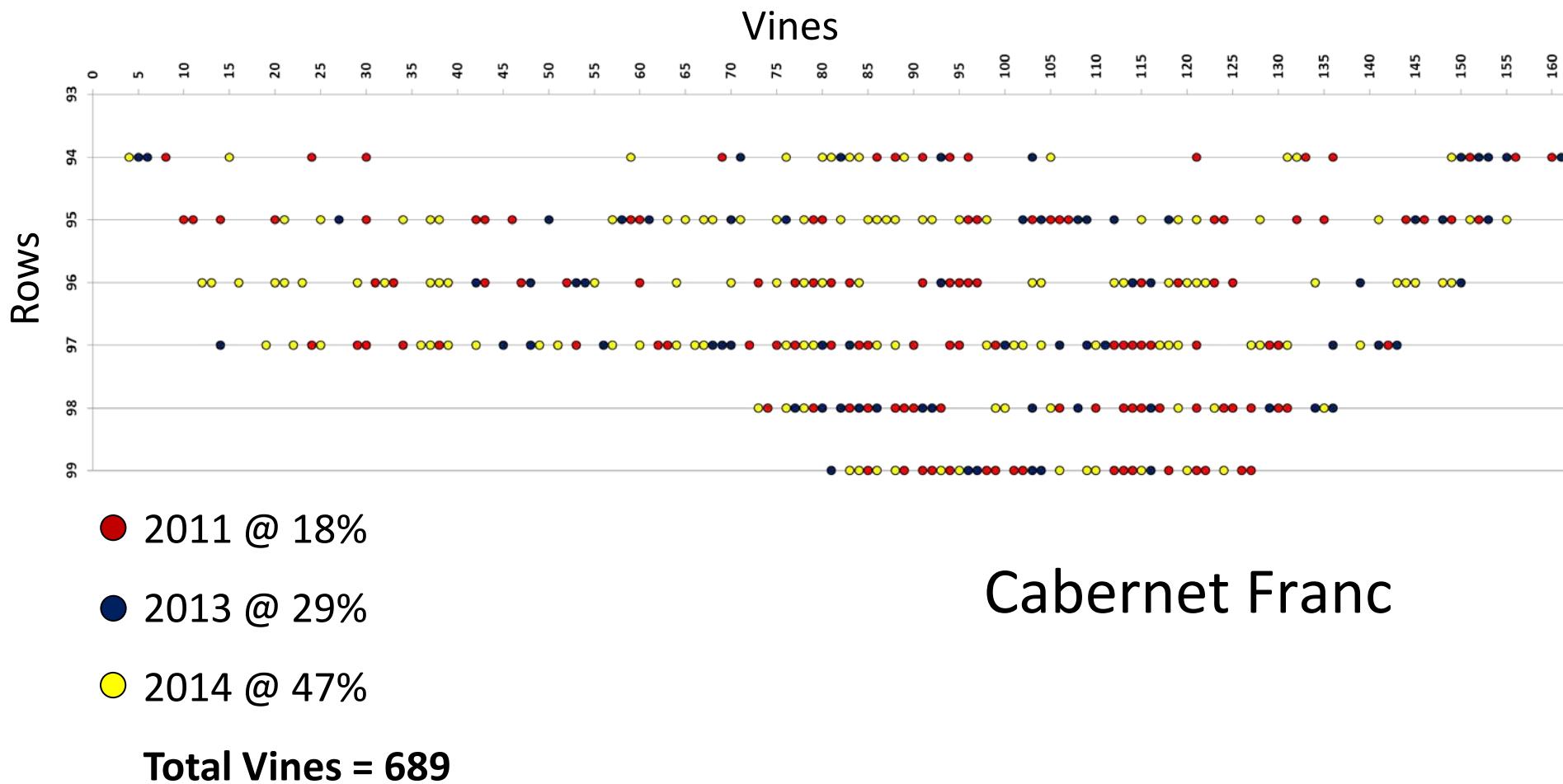


- 3.2. Study of potential GLRaVs vectors in BC

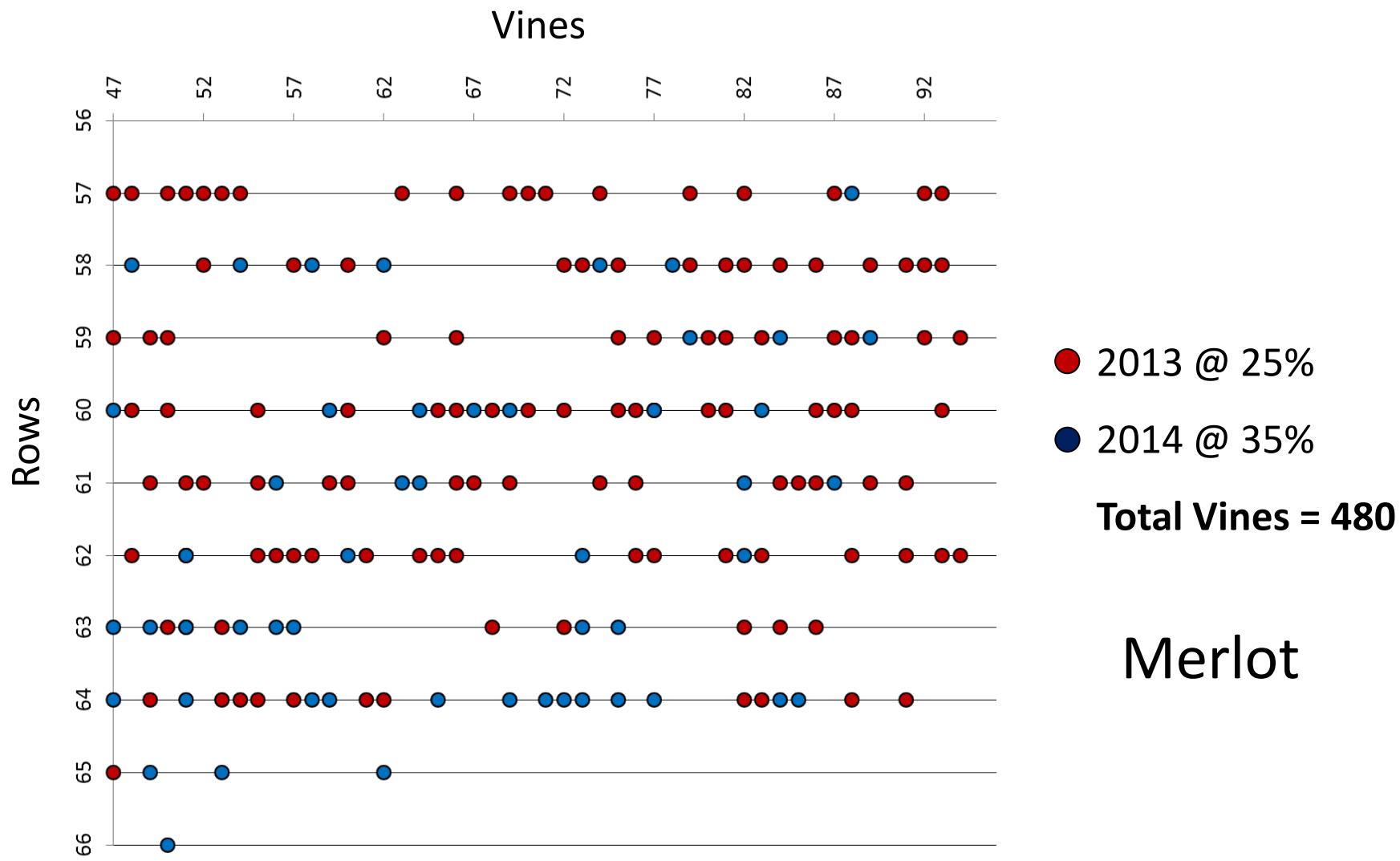


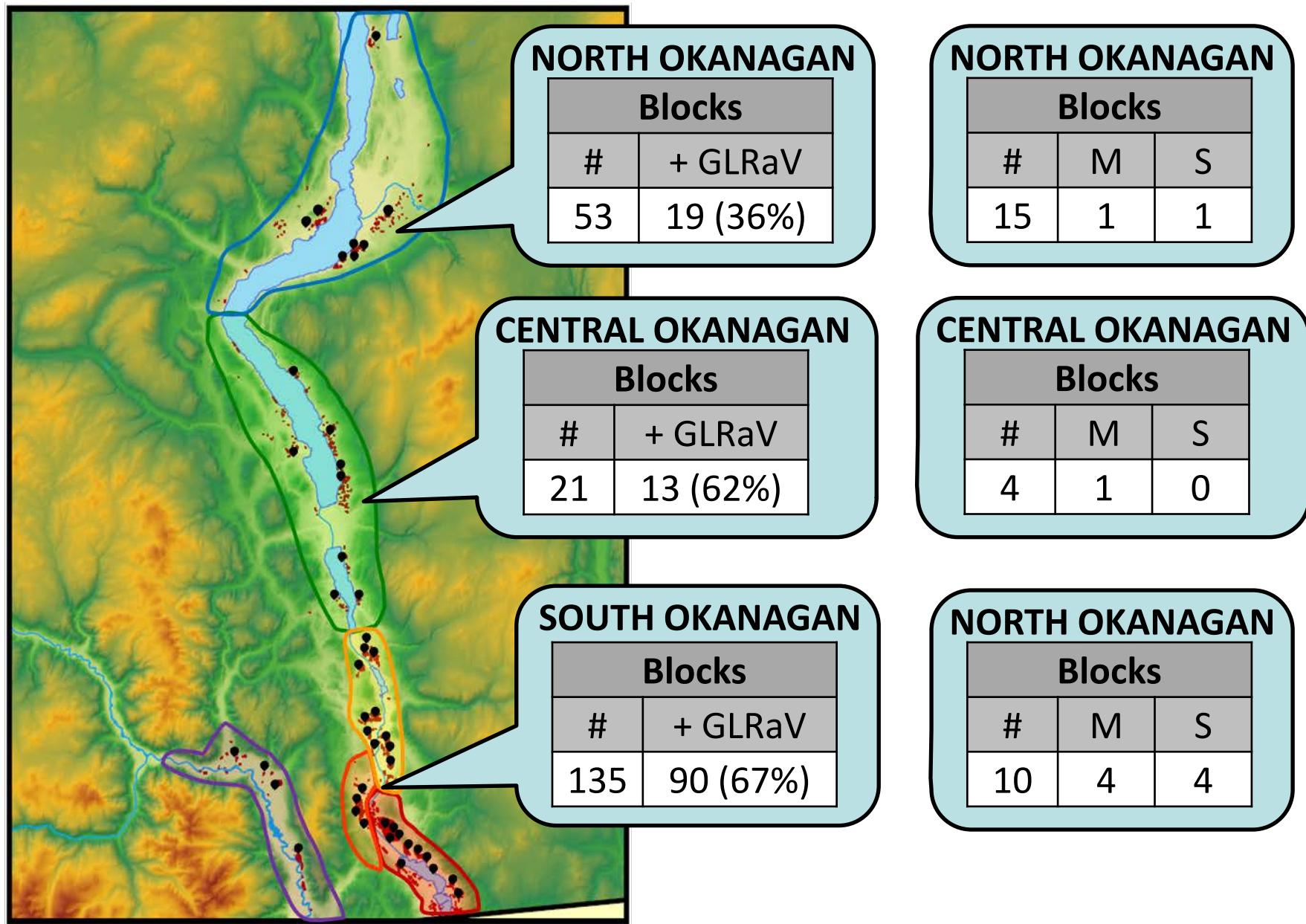
• 3.3. Spread of GLRaV in BC vineyards

Merlot (3 vineyards) and Cabernet Franc (1 vineyard) monitored for GLRD spread
2011, 2013, 2014, and 2015



- 3.3. Spread of GLRaV in BC vineyards

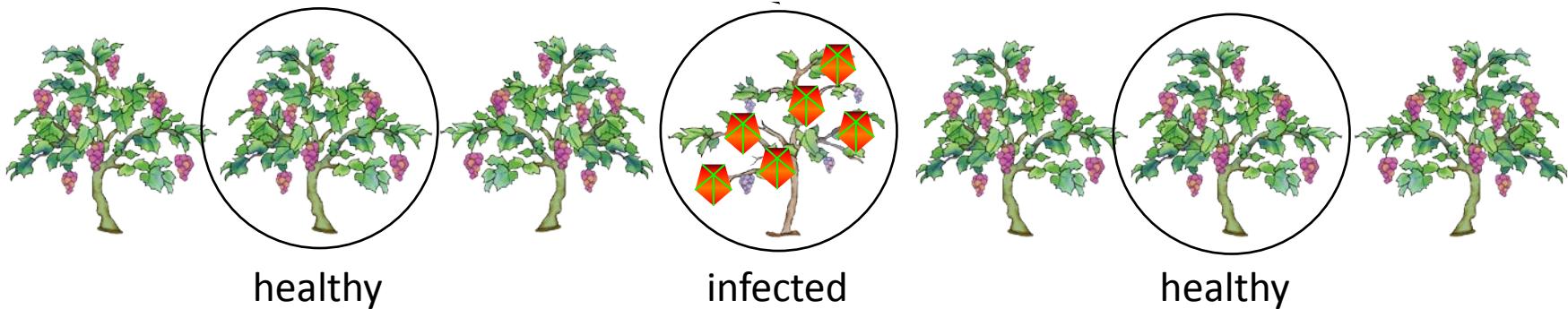




- **3.4. Effect of GLRaV on vine growth, fruitfulness, and winter hardiness and in fruit and wine quality**

Merlot (3 vineyards) and Cabernet Franc (1 vineyard) monitored for GLRD spread

Yield (kg)	pH
No. clusters	TA (g/L)
Cluster weight (g)	Pruning weight (g)
No. berries/cluster	Crop load (yld/pwt)
Berry weight (g)	Lethal temperature exotherm (°C)
Brix	



MERLOT VINEYARD 1 (2013)

	Treatment	n	Mean	LSD = 0.05 *
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No. clusters	Healthy	40	45.7	a
	GLRaV	20	39.0	b



No. berries/cluster	Healthy	40	75	a
	GLRaV	20	65	b

Brix	Healthy	40	24.5	a
	GLRaV	20	22.7	b

TA (g/L)	Healthy	40	5.5	a
	GLRaV	20	5.9	b

* Means followed by the same letter(s) in each column can

Courtesy C. Bogdanoff (SuRDC)

- Significance increase of GLRaVs in BC since last survey (1996)
- GLRaV are widespread in BC (highest incidence in South Okanagan)
- Standardize virus extraction and PCR-based protocols for GLRaVs
- GLRaV-1, -2, -3, -4 occur in BC (GLRaV-3 most prevalent)
- GLRaVs isolates characterized to the molecular level (genomes)
- Grape mealybug, Fruit lecanium scale and Cottony maple scales
- Rapid spread in vineyards with presence of mealybug
- Reduction in total soluble solids in all sites
- *GLRaV transmision studies*
- *Effects of GLRaV on white cultivar*
- *Management studies for mealybug and scale (oils, insecticides,...)*

- **Grapevine red-blotch associated virus (GRBaV)**



GLRaV

GRBaV

Photo: J.R. Úrbez-Torres (SuRDC)

- **Grapevine red-blotch field surveys in BC**

Blocks		Panel		Targeted Vines		Total Vines Tested
#	+ (%)	#	+ (%)	#	+ (%)	
GRBaV	205	19 (9.3)	2,196	34 (1.5)	229	26 (11.3) 11,209

2014 = 3 GRBaV (+) samples

2015 = 29 GRBaV (+) samples

PCR-based diagnostics

Most of the blocks < 10 year-old

Most of the blocks > 10 year-old

Cabernet Franc

Chardonnay (1)

Muscat (13)

Cabernet Franc (8)

Syrah (5)

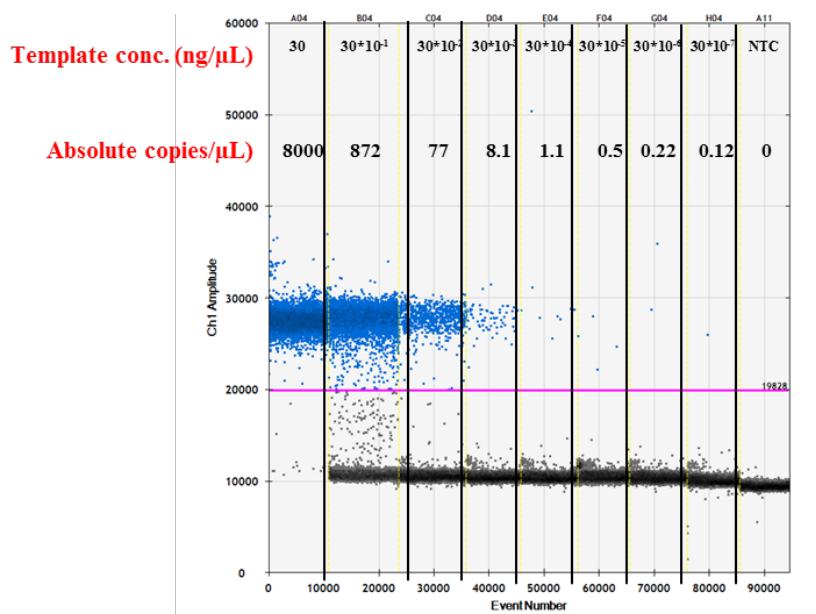
Zinfandel (1)

Petit Verdot (1)

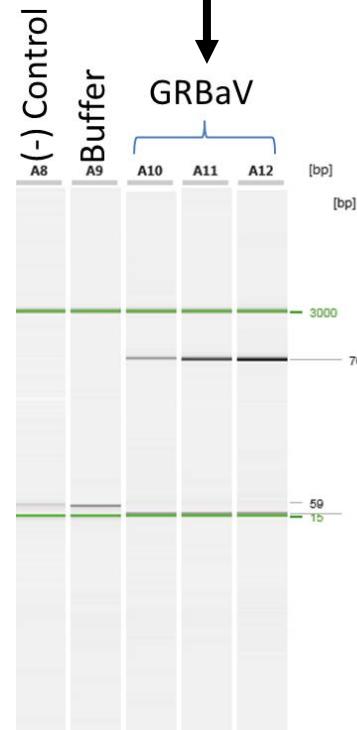
• Grapevine red-blotch molecular characterization



DNA Extraction

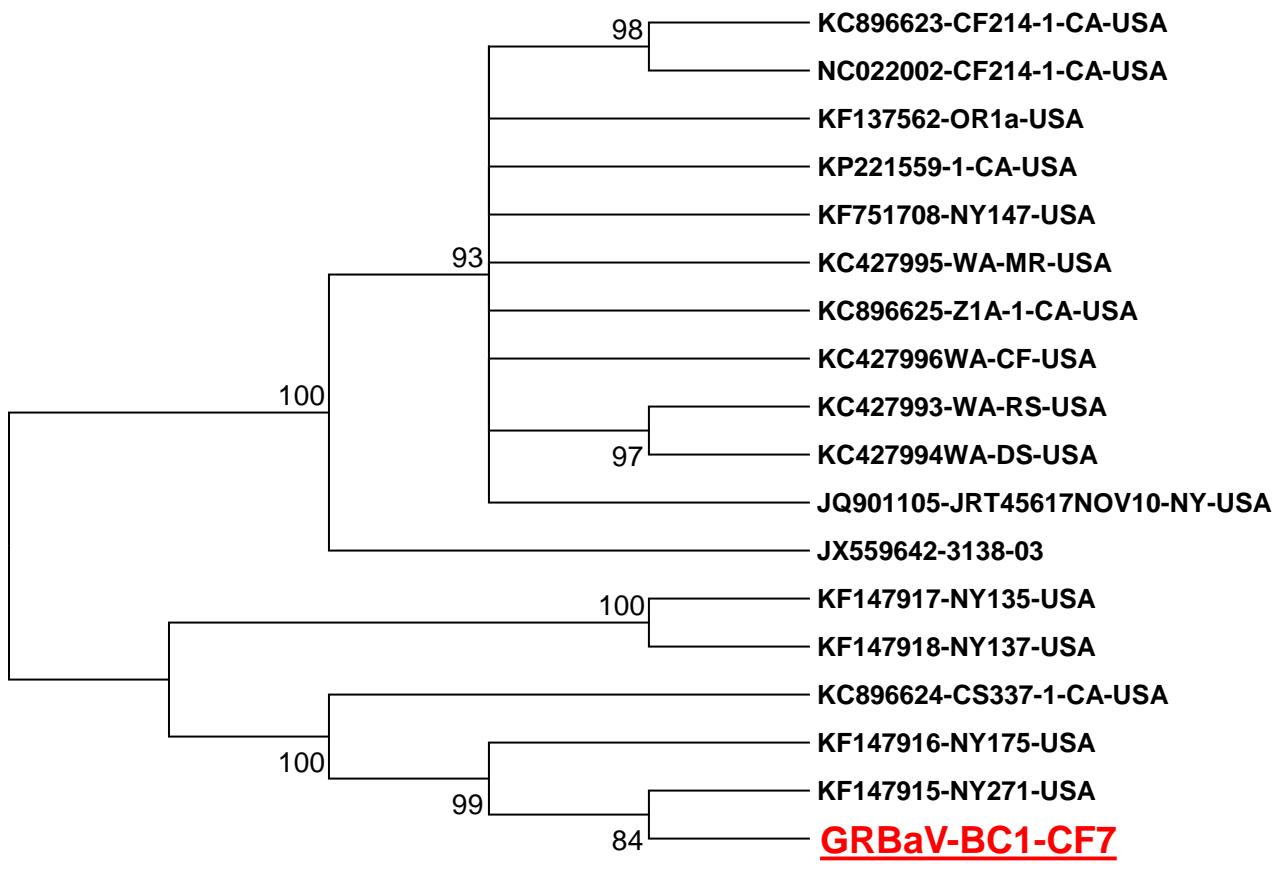


Droplet Digital PCR



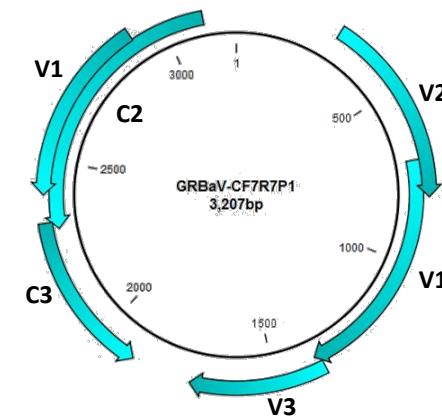
- **Grapevine red-blotch molecular characterization**

Phylogenetic analysis of GRBaV-BC isolate



II

I



- GRBaV is present in British Columbia
- Very low incidence compared to grape-growing regions in USA
- Does not appear to spread as fast as reported in the USA
- Standardize virus extraction and PCR-based protocols for GRBaV
- Developed and standardize ddPCR for absolute quantification
- GRBaV-BC genome clusters with type I isolates
- *Studies on potential GRBaV in BC*
- *Monitor spread of GRBaV*
- *Effects of GRBaV on red and white cultivars in BC*

- **Nepoviruses: Grapevine fanleaf degeneration complex (GFLV)**

Arabis mosaic virus (ArMV)

	Blocks		Panel		Targeted Vines		Total Vines Tested
	#	+ (%)	#	+ (%)	#	+ (%)	
GFLV	188	17 (9.0)	1,220	25 (2.0)	549	15 (2.7)	6,649
ArMV	129	0 (0.0)	918	0 (0.0)	519	0 (0.0)	5,109

Table 2. Aggregate summary of infected samples by region

	BC^a (1,485) ^b	ON (9,779)	PQ (39)	NS (114)	Totals (11,417)
ArMV ^c	0.34% (5)	0.55% (54)	2.56% (1)	0	0.53% (60)
GFLV	0.06% (1)	0.32% (31)	0	0	0.25% (32)
GLRaV-I	1.28% (19)	1.75% (171)	0	0.87% (1)	1.67% (191)
GLRaV-III	2.15% (32)	12.2% (1,191)	5.12% (2)	1.75% (2)	10.8% (1,227)

^a Province abbreviations: British Columbia (BC), Ontario (ON), Quebec (PQ), Nova Scotia (NS).

^b Number of samples tested for each virus.

^c Number of infected samples.

- **Nepoviruses: Grapevine fanleaf degeneration complex (GFLV)**

Determine GFLV spread within vineyards



No spread was detected in any of the vineyards tested (+) for GFLV in the Okanagan

- **Grapevine Pinot Gris Virus (GPGV)**

Discovered by NGS in Italy in 2012 (Giampetrucci et al. 2012. *Virus. Res.* 163:262-268)

Proposed in the genus *Trichovirus* in the family *Flexiviridae*.

Reported: **Bosnia, Croatia, Greece, Portugal, Romania, Serbia, Spain, Ukraine, the Czech Republic, Slovakia, France, and Slovenia**

Outside Europe: **China, Korea, Turkey, USA**

Reported in **Ontario** in 2015 (Xiao et al. PDIS-12-15-1405-PDN)

- **Symptomatic (leaf mottling and deformation) and asymptomatic strains**

- Unusual symptoms in a Pinot Gris plant in the Okanagan



Foliar symptoms of GPGV on cv. Pinot gris: Chlorotic mottling and severe leaf deformation

- Unusual symptoms in a Pinot Gris plant in the Okanagan

GLRaV-1 (-)

GLRaV-2 (-)

GLRaV-3 (-)

GLRaV-4 (-)

GLRaV-7 (-)

GFLV (-)

ArMV (-)

GRBaV (-)

GPGV (+)

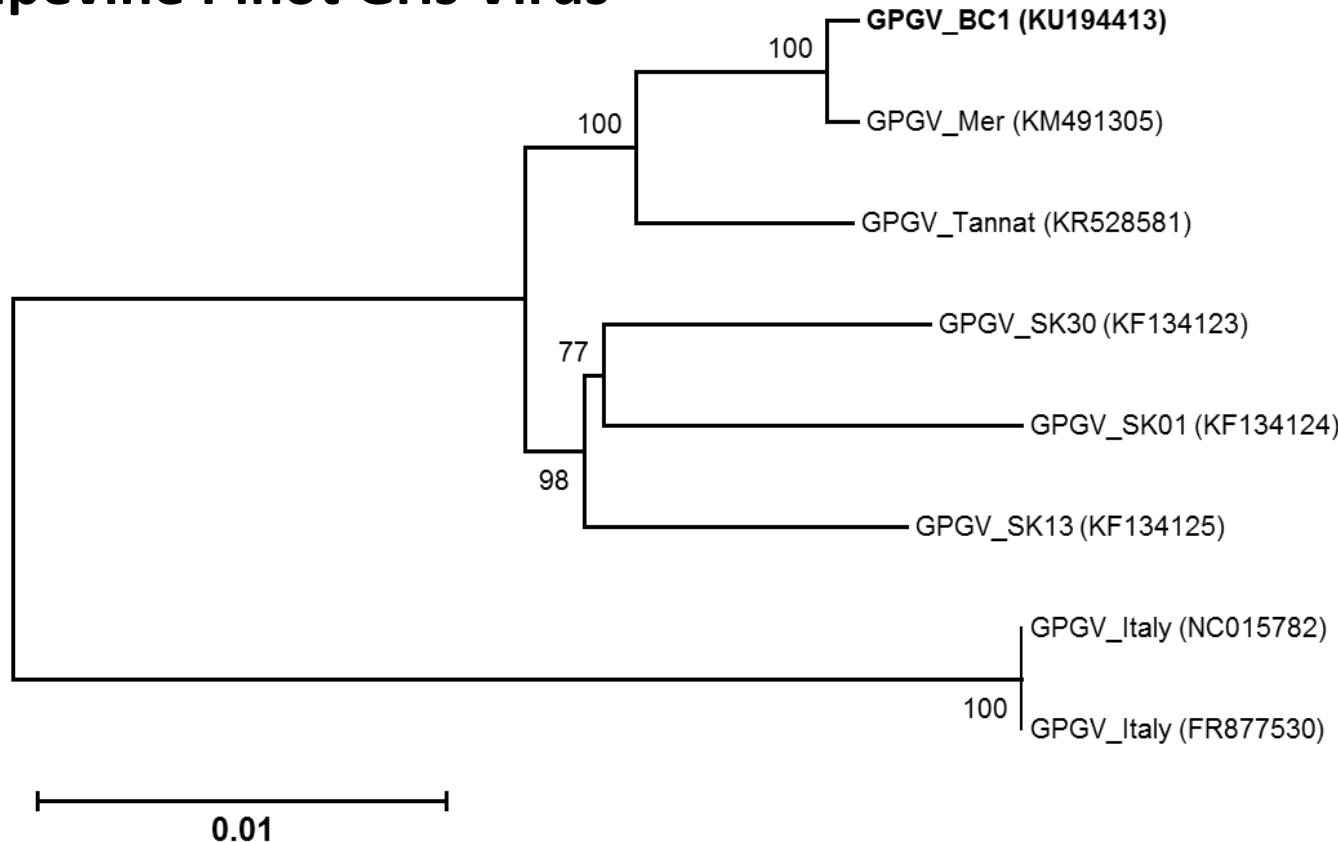
5'-ATGTCGATTGTCAGGAGCTG-3'

5'-CTACATACTAAATGCACTC-3'

(CP) gene of GPGV (Cho et al. 2013)

Name	Sequence (5' 3')	Position
GP1F	GATCAATTGATCCCGTGTAGTGC	6-28
GP1R	GATCCCTAATAACCCACATCTC	1107-1128
GP2F	GATCCTCCAGTCACATAGGGC	899-919
GP2R	CAGCGATCACCTTATCAAGGGT	1845-1866
GP3F	GCAAGCTCAAGGGGAACC	1782-1799
GP3R	CCATACACCTCATTAGATTCTG	2946-2968
GP4F	GGTGTGAAGGTCCGGAGG	2784-2800
GP4R	CCTGGACTCCTCAGACAAGG	3853-3872
GP5F	GAGATGTAATCAAAAGATCGATGTGG	3725-3750
GP5R	GTCTGTCCAGCCTTGCCTCG	4724-4744
GP6F	CCATAGCAGGCAACTCAGGTCG	4621-4642
GP6R	GGAATGCCTGAAGGAGTGCC	5928-5947
GP7F	CCAATGGAGCAATTGAAGC	5776-5793
GP7R	CTGTATTCCCTCACGACCGGC	6791-6811
GP8F	GATCTGGCCTTGACCACATC	6680-6699
GP8R	CACTCTCCCCGAAGCCG	7134-7151
GP5'R	CAAGCAGGATGACTATGTGC	300-319
GP3'F	CGGCTCGGGGGAGAGTG	7134-7151

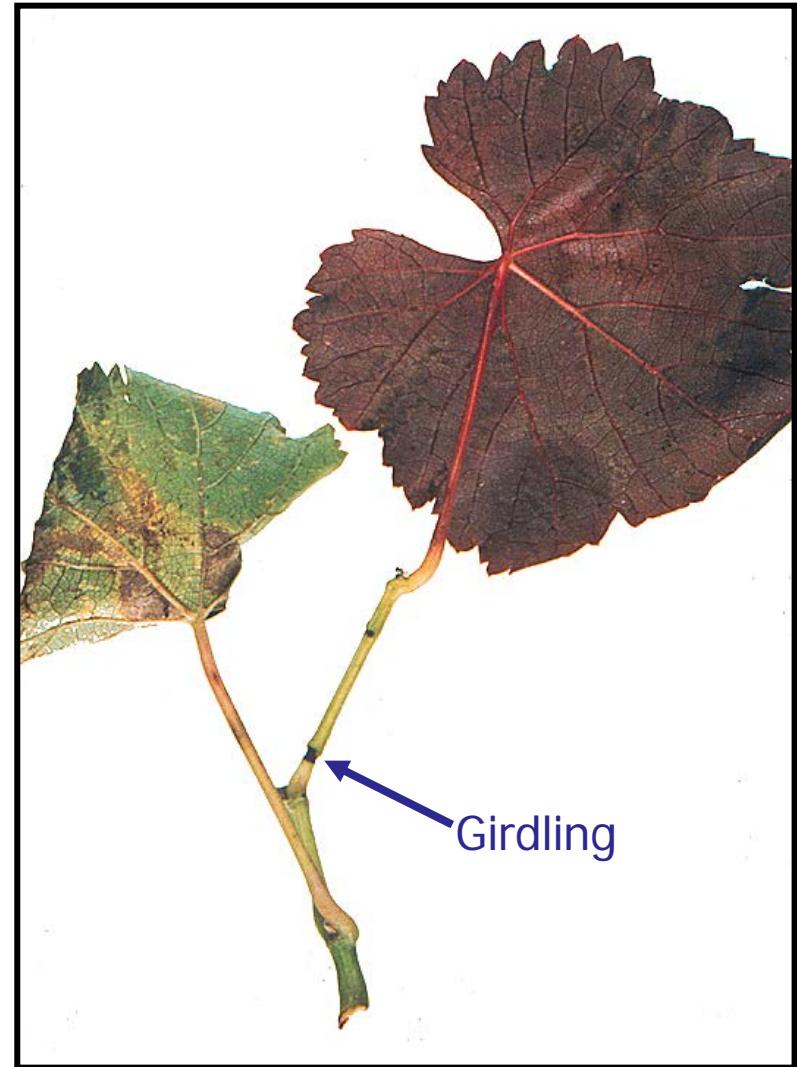
• Grapevine Pinot Gris Virus



Virus isolate	Accession #	Genome	5'LTR	Replicase	MP	CP	3'UTR
	Blocks	Panel		Targeted Vines		Total Vines	
GPGV_Mer							89.2
GPGV, Grapevine	#	+ (%)	#	+ (%)	#	+ (%)	polymerase;
MP, movement protein	51	2 (3.9)	294	0 (0.0)	98	2 (2.0)	
GPGV						1,568	

Ontario isolate (KU052861) is 99% identical to GPGV-Mer from France (KM491305),

TREEHOPPERS



- ⌘ Girdling damage caused by feeding.
- ⌘ Not leafroll!

Courtesy Dr. Golino (FPS - UC Davis) VEN-118

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AAFC A-base initiative

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Mark Calingo (University of British Columbia)

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Canada



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THANK YOU!!!







