

# Organization, diversity, expression and evolutionary dynamics of the NB resistance gene family in grapevine and related species

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## Downy Mildew (*Plasmopara viticola*)



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## Powdery Mildew (*Erysiphe necator*)



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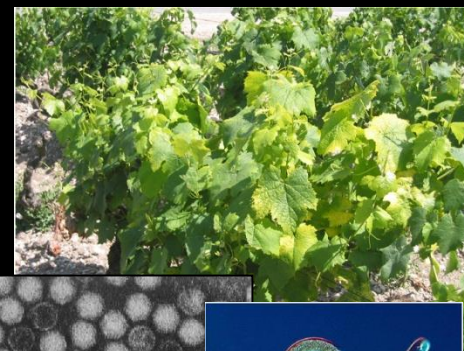
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## Botrytis (*Botrytis cinerea*)



## Phylloxera (*Daktulosphaira vitifoliae*)

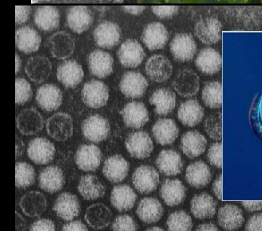
## Grape Fanleaf Disease (*Grape Fanleaf Virus*)



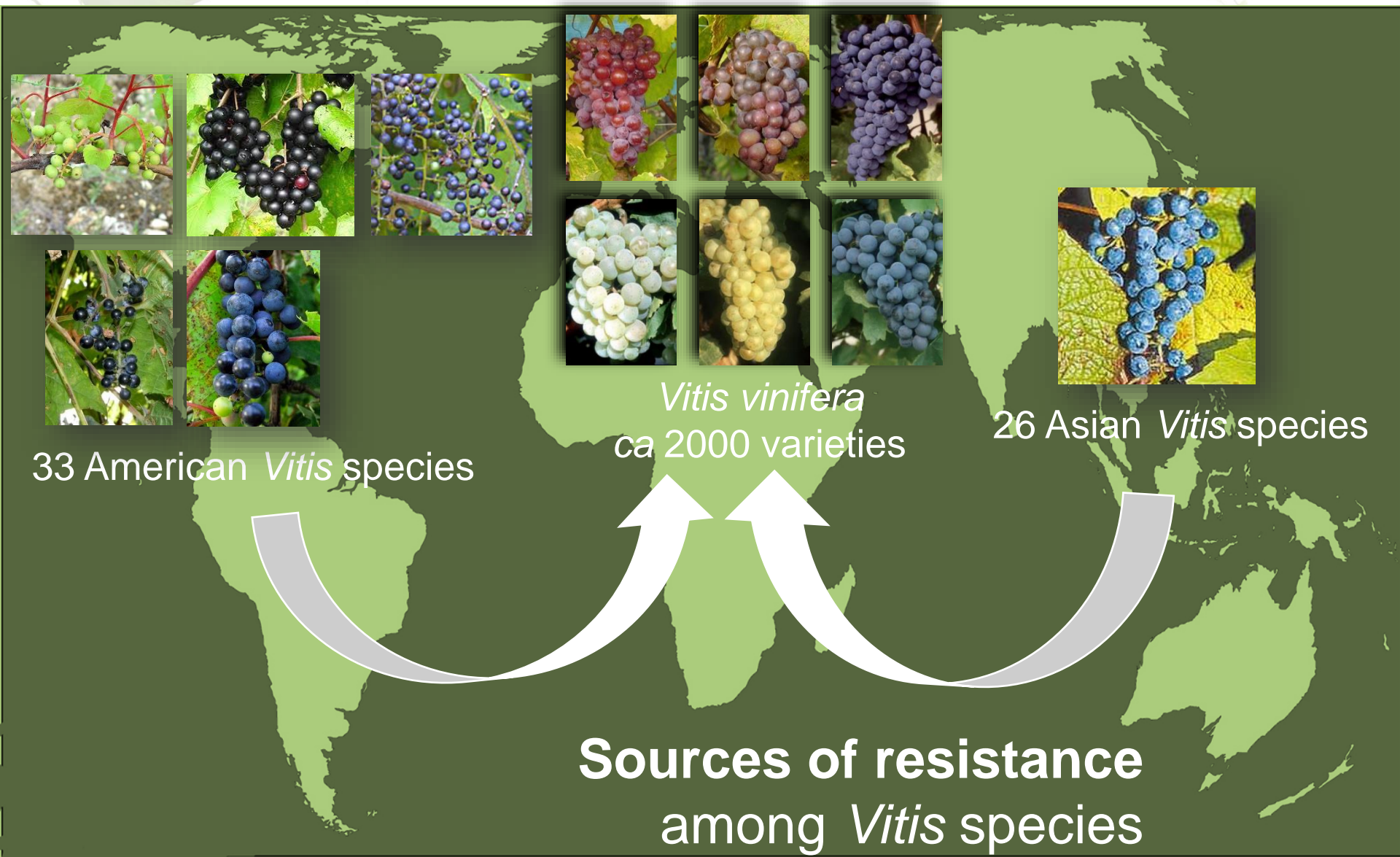
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## Grape Trunk Diseases



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# NB genes, major resistance genes in plants

*Mol Plant Microbe Interact.* 2015 May;28(5):558-68. doi: 10.1094/MPMI-11-14-0367-R.

## **Pi64, Encoding a Novel CC-NBS-LRR Protein. Confers Resistance to Leaf and Neck Blast in Rice.**

*Theor Appl Genet.* 2013 Apr;126(4):985-98. doi: 10.1007/s00122-012-2031-3. Epub 2013 Feb 12.

Ma J<sup>1</sup>, Lei C<sup>1</sup>, Xi

## **Fine-mapping and molecular marker development for Pi56(t), a NBS-LRR gene conferring broad-spectrum resistance to *Magnaporthe oryzae* in rice.**

Liu Y<sup>1</sup>, Liu B, Zhu X, Yang J, Bordeos A, Wang G, Leach JE, Leung H.

*Plant Sci.* 2015 Oct;239:216-29. doi: 10.1016/j.plantsci.2015.07.017. Epub 2015 Jul 30.

## ***Arabidopsis* BNT1, an atypical TIR-NBS-LRR gene, acting as a regulator of the hormonal response to stress.**

Sarazin V<sup>1</sup>, Ducler *Plant J.* 2013 Aug;75(4):539-52. doi: 10.1111/tpj.12219. Epub 2013 May 22.

## **A TIR-NBS protein encoded by *Arabidopsis* Chilling Sensitive 1 (CHS1) limits chloroplast damage and cell death at low temperature.**

Zbierzak AM<sup>1</sup>, Porfirova S, Griebel T, Melzer M, Parker JE, Dörmann P.

*Theor Appl Genet.* 2014 Jun;127(6):1353-64. doi: 10.1007/s00122-014-2303-1. Epub 2014 Apr 23.

## **The Ph-3 gene from *Solanum pimpinellifolium* encodes CC-NBS-LRR protein conferring resistance to *Phytophthora infestans*.**

Zhang C<sup>1</sup>, Liu L, Wang X, Vossen J, Li G, Li T, Zheng Z, Gao J, Guo Y, Visser RG, Li J, Bai Y, Du Y.

*Plant Biol (Stuttg).* 2011 Jan;13(1):145-53. doi: 10.1111/j.1438-8677.2010.00327.x. Epub 2010 Nov 12.

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*Plant Sci.* 2015 Oct;239:216-224. doi: 10.1016/j.plantsci.2015.08.011. Epub 2015 Oct 1.

## **Arabidopsis BN1 Structure and Function of the TIR Domain from the Grape NLR Protein Rpv1.**

*Plant J.* 2011 Feb;67(2):277-86. doi: 10.1111/j.1365-3113.2010.04600.x. Epub 2010 Dec 1.

Sarazin V<sup>1</sup>, Ducler

*Theor Appl Genet.* 2012 Feb;124(2):277-86. doi: 10.1007/s00122-011-1703-8. Epub 2011 Sep 27.

## **Selective sweep at the Rpv3 locus during grapevine breeding for downy mildew resistance.**

Di Gaspero G<sup>1</sup>, Copetti D, Coleman C, Castellarin SD, Eibach R, Kozma P, Lacombe T, Gambetta G, Zvaqin A, Cindrić P, Kovács L, Morgante M, Testolin R.

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# Characterization of the NB gene family

## Structural organization

The grapevine reference genome PN40024



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## Expression analysis

RNA-seq data from 59 experimental conditions



# Characterization of the NB gene family

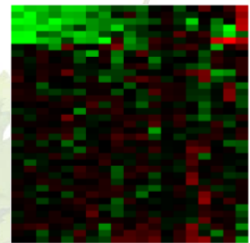
## Structural organization

The grapevine reference genome PN40024



## Expression analysis

RNA-seq data from 59 experimental conditions



## Diversity throughout the *Vitis* genus

54 re-sequenced genomes among cultivated and wild *Vitis*



Listan



Resseguier



Berlandieri



Riesling



Riparia



Savagnin



Humagne



# Annotation of NB genes



Total : 829	Sub-families	Structure
Complete genes 450	CN	CC (light blue oval) - NBS (light blue rectangle)
	CNL	CC (dark blue oval) - NBS (dark blue rectangle) - LRR (dark blue rounded rectangle)
	NBS	NBS (pink rectangle)
	NL	NBS (purple rectangle) - LRR (purple rounded rectangle)
	RNL	RPW8 (green oval) - NBS (green rectangle) - LRR (green rounded rectangle)
	TIR	TIR (red oval)
	TNL	TIR (orange oval) - NBS (orange rectangle) - LRR (orange rounded rectangle)
	TNLi	TIR (yellow oval) - NBS (yellow rectangle) - LIM (yellow rounded rectangle)
Pseudogenes 379	-	NA

# Annotation of NB genes



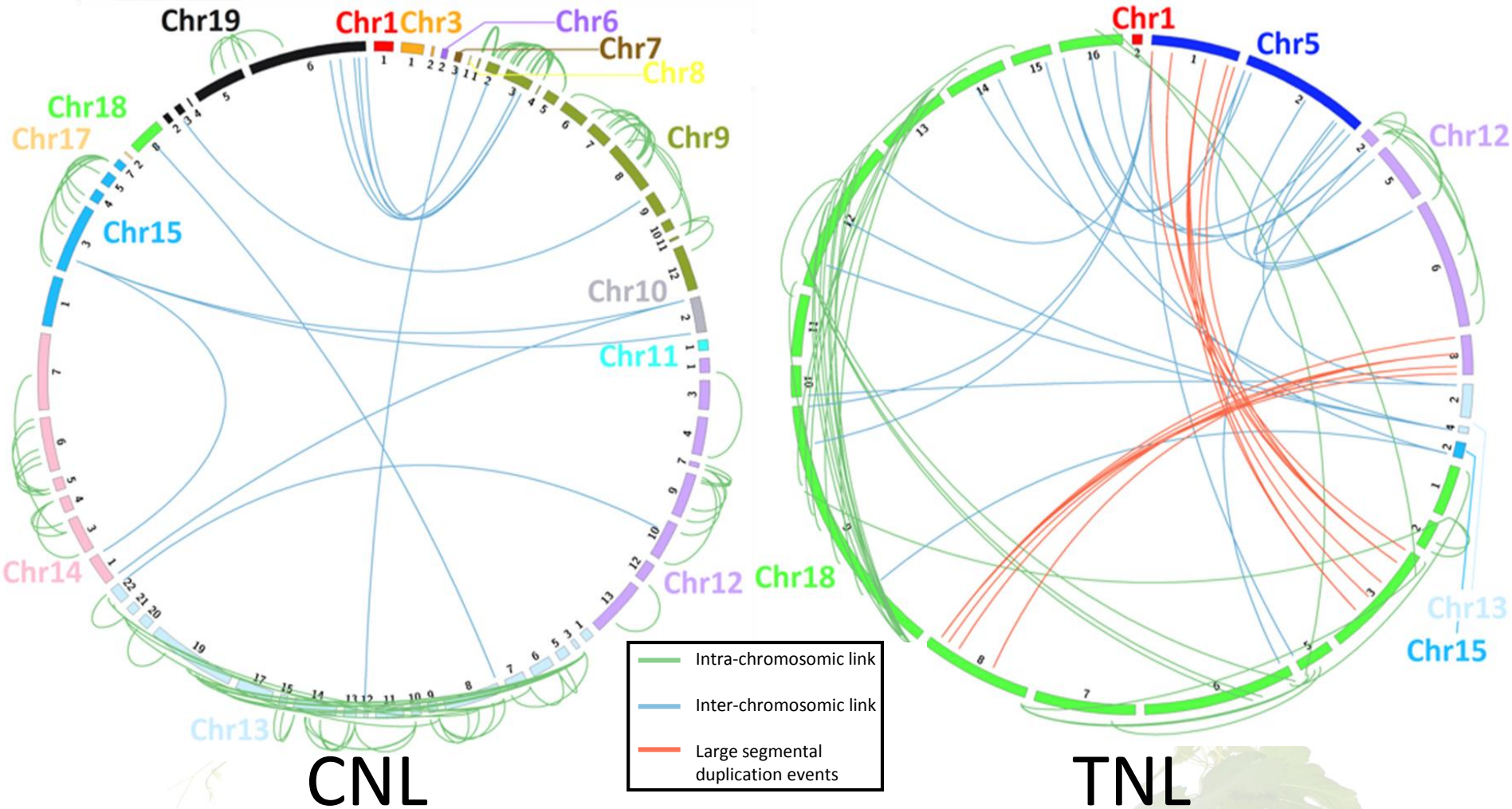
Total : 829	Sub-families	Structure	Number
Complete genes 450	CN		5
	CNL		211
	NBS		14
	NL		102
	RNL		13
	TIR		9
	TNL		94
	TNLi		2
Pseudogenes 379	-	NA	379

216

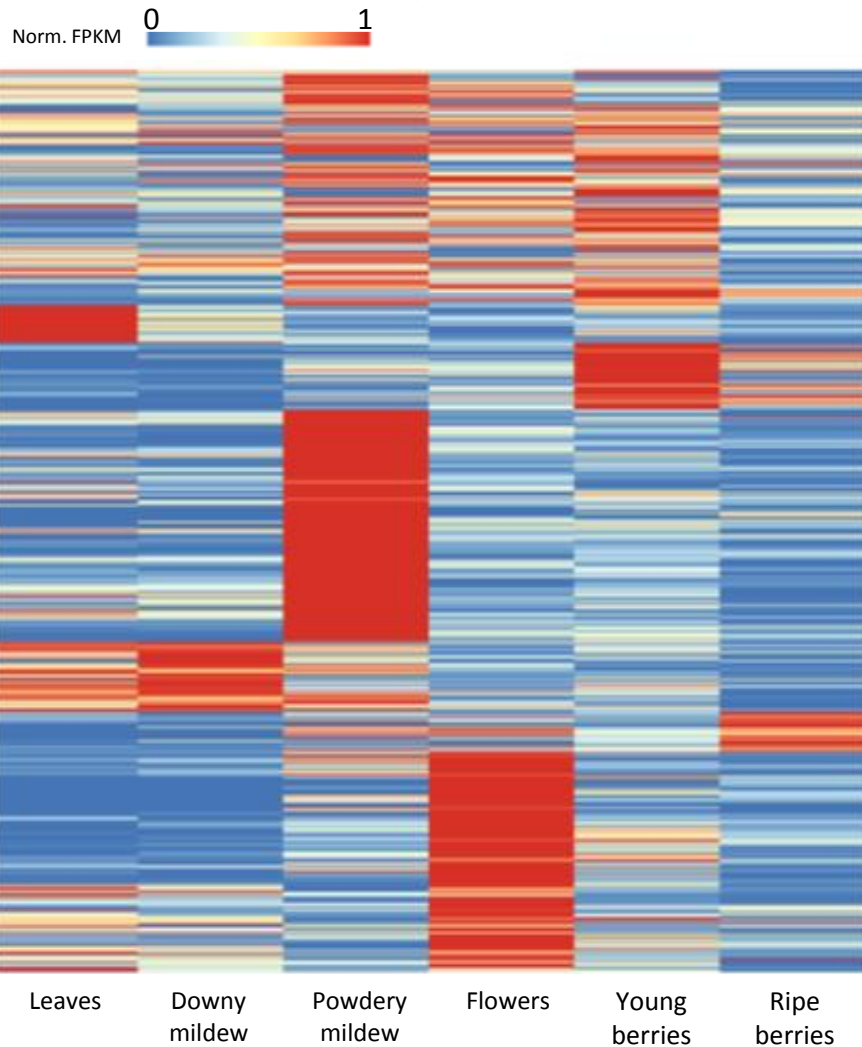
105



# Gene and cluster homology



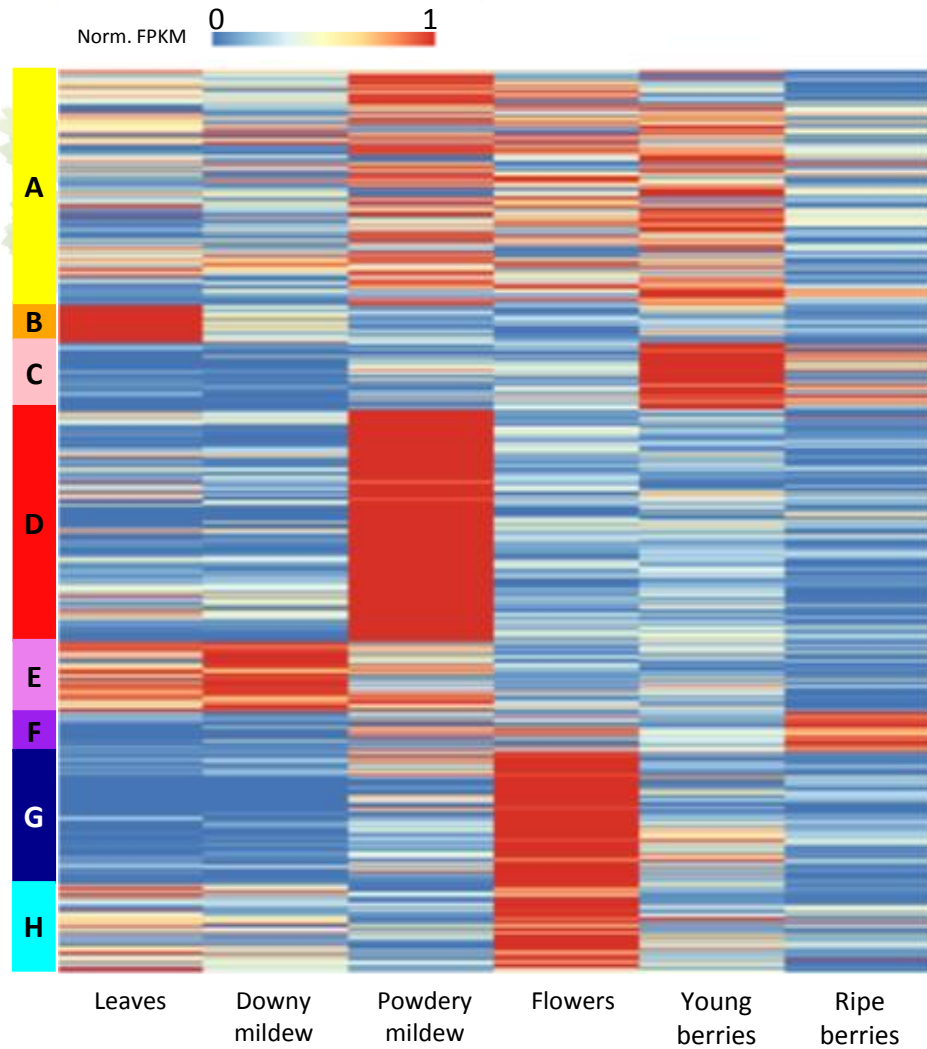
# Expression analysis of NB genes



- Average expression level lower than other gene families



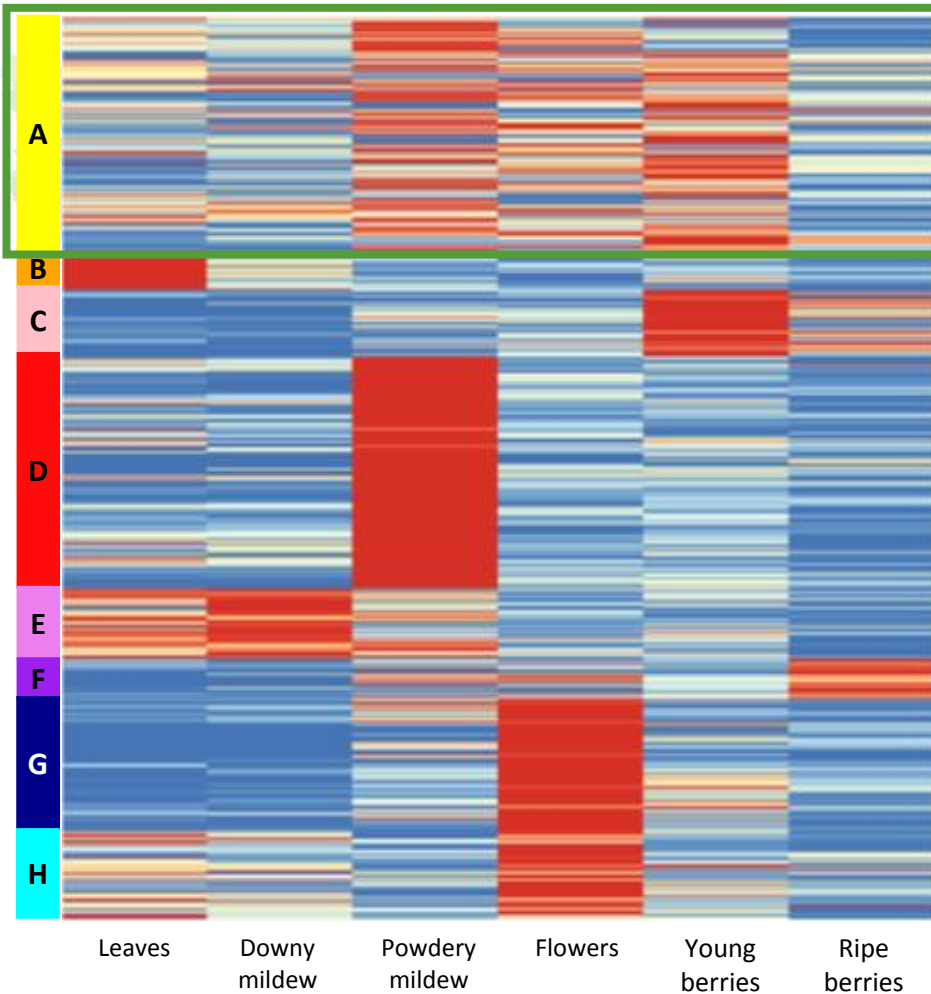
# Expression analysis of NB genes



- Average expression level lower than other gene families
- 8 contrasted expression profiles

# Expression analysis of NB genes

Norm. FPKM 0 1

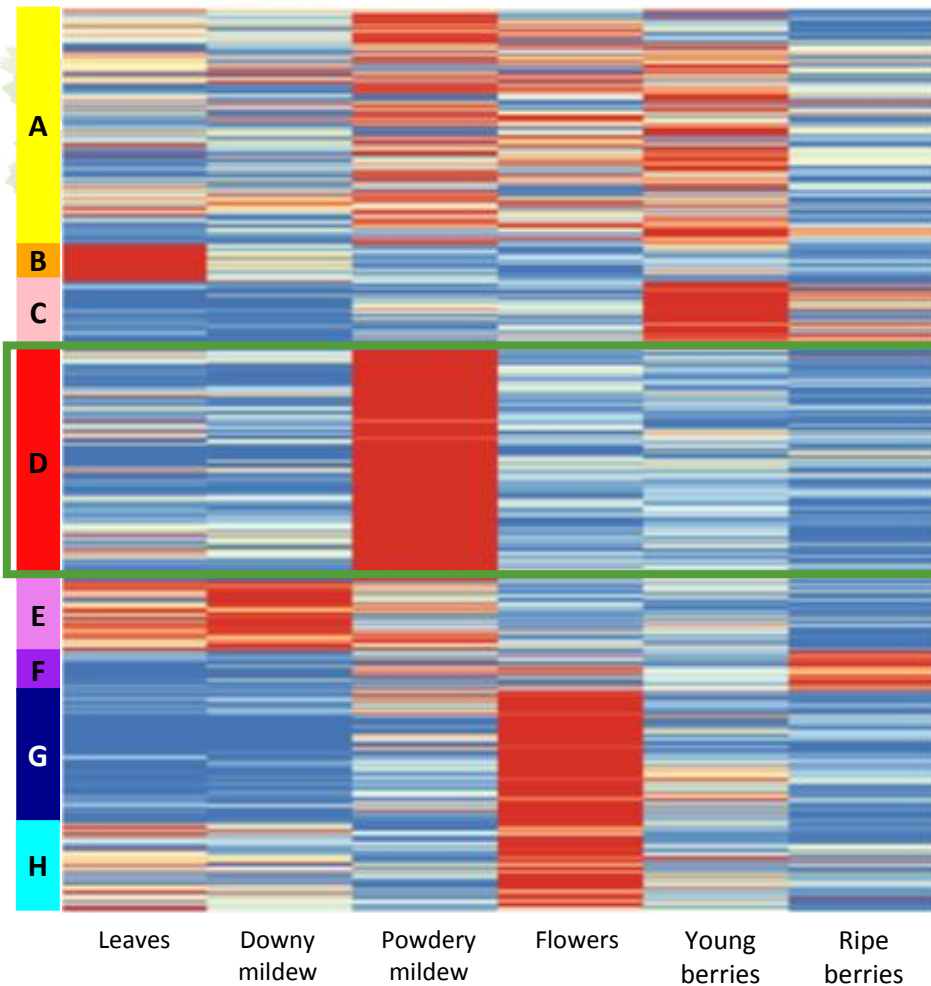



- Average expression level lower than other gene families
- 8 contrasted expression profiles
- 211 NB genes constitutively expressed



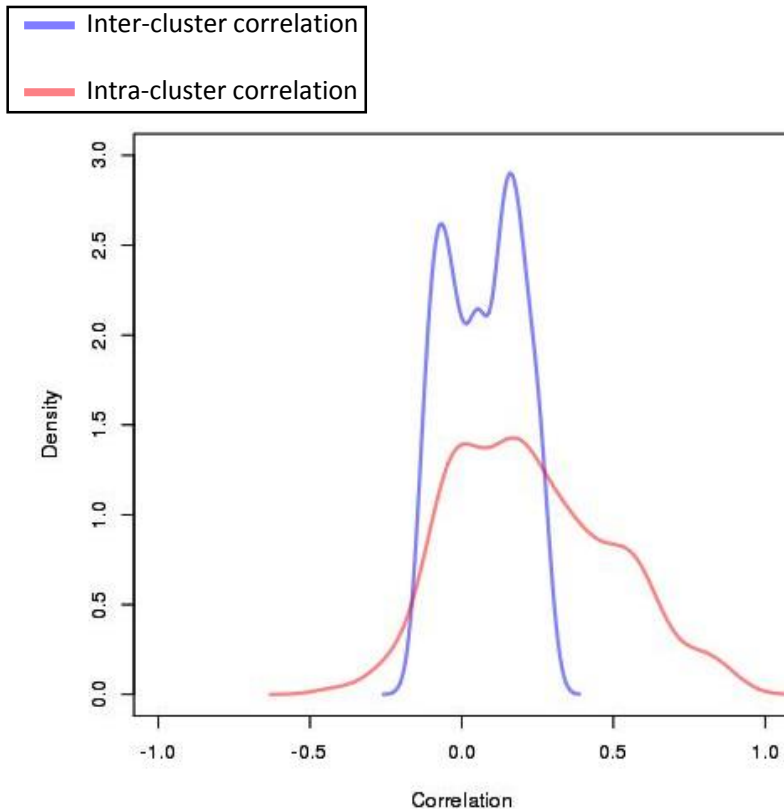
# Expression analysis of NB genes

Norm. FPKM 0 1

- Average expression level lower than other gene families
- 8 contrasted expression profiles
- 211 NB genes constitutively expressed
- 208 NB genes expressed during powdery mildew infection

# Expression analysis of NB genes

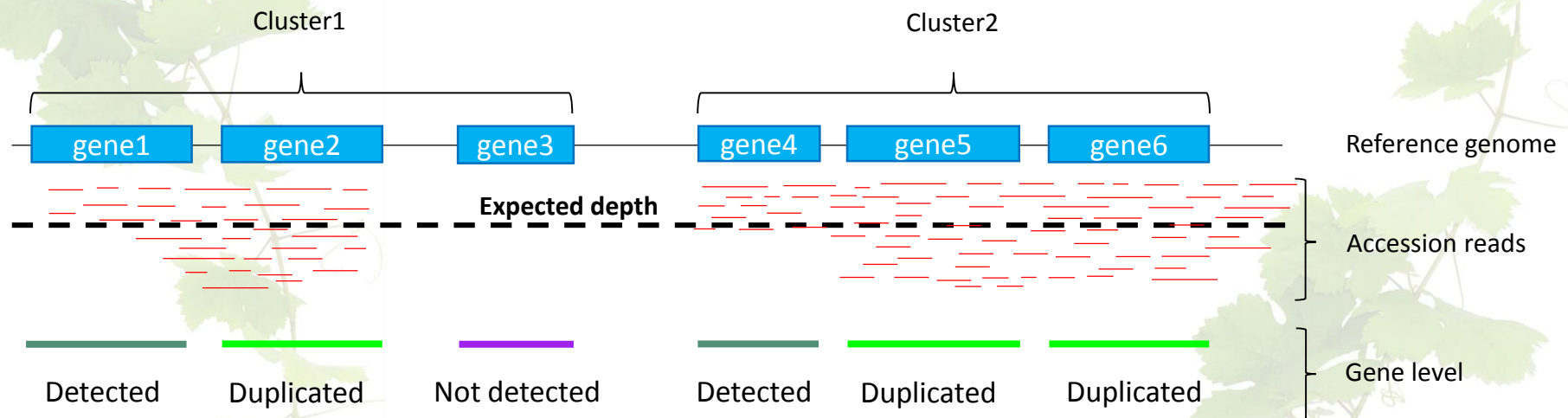


Distribution of the median expression correlation values between NB genes

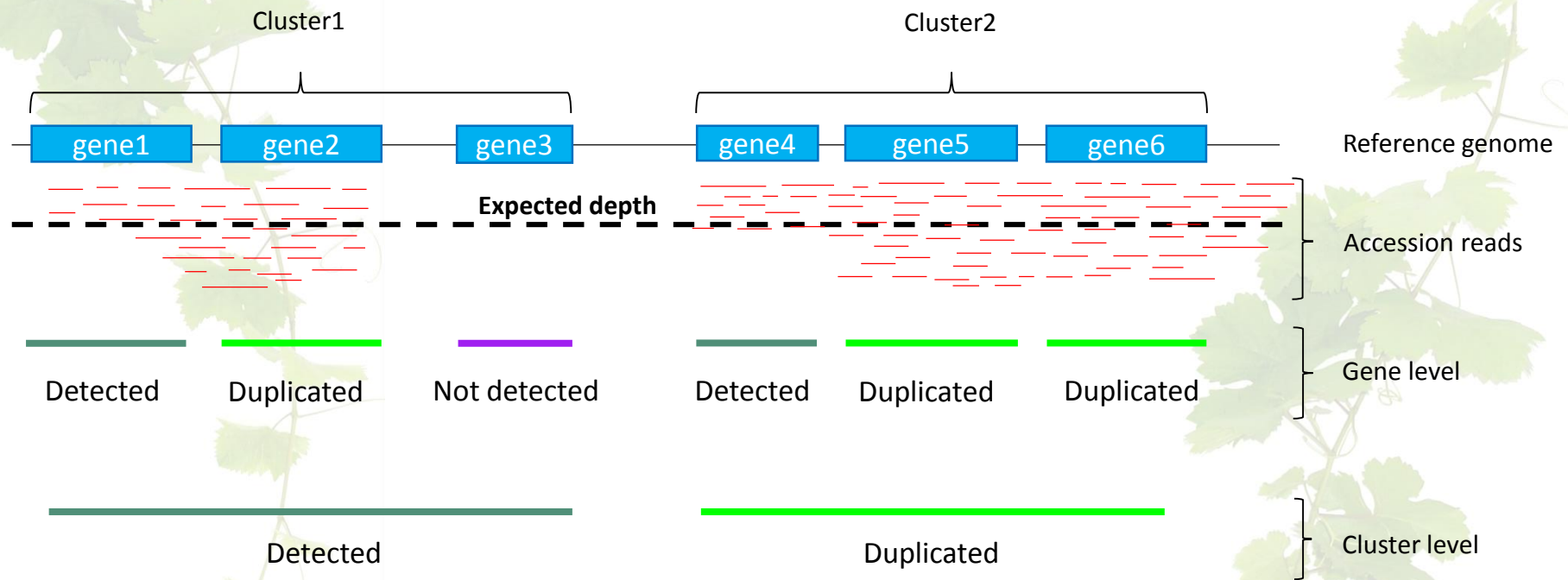
- Average expression level lower than other gene families
- 8 contrasted expression profiles
- 211 NB genes expressed constitutively
- 208 NB genes expressed during a powdery mildew infection
- NB genes in the same cluster preferentially co-expressed



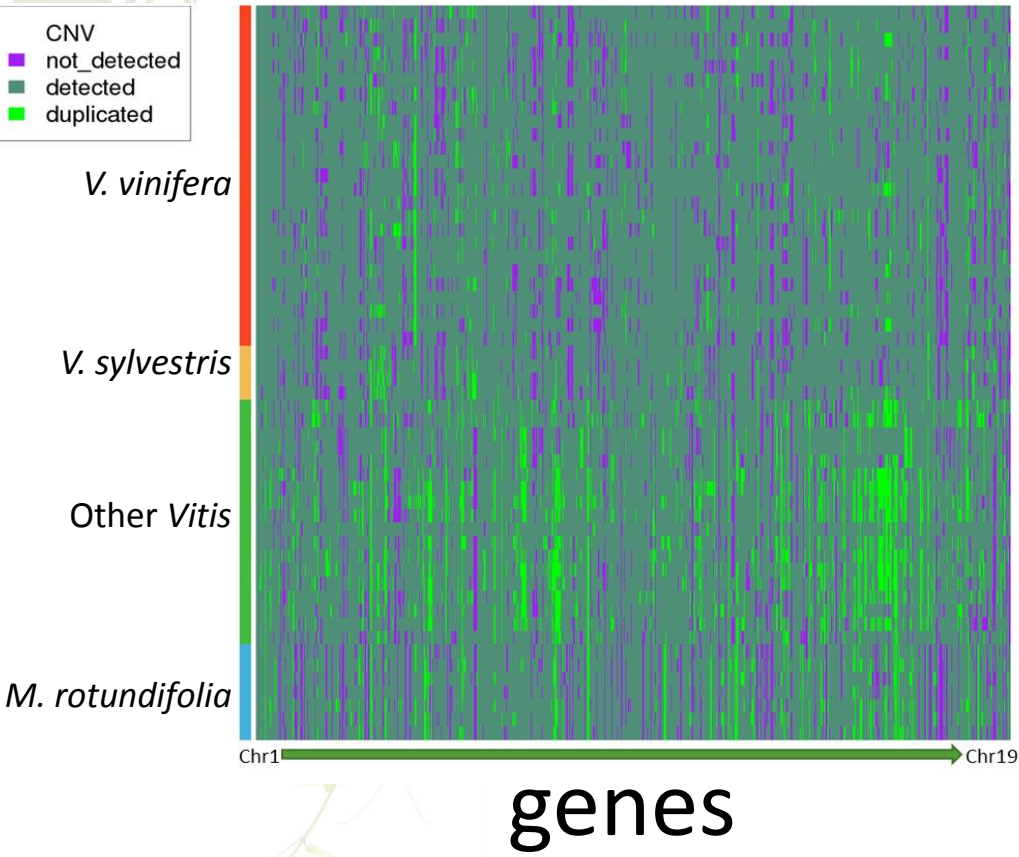
# Copy Number Variation at gene and cluster levels



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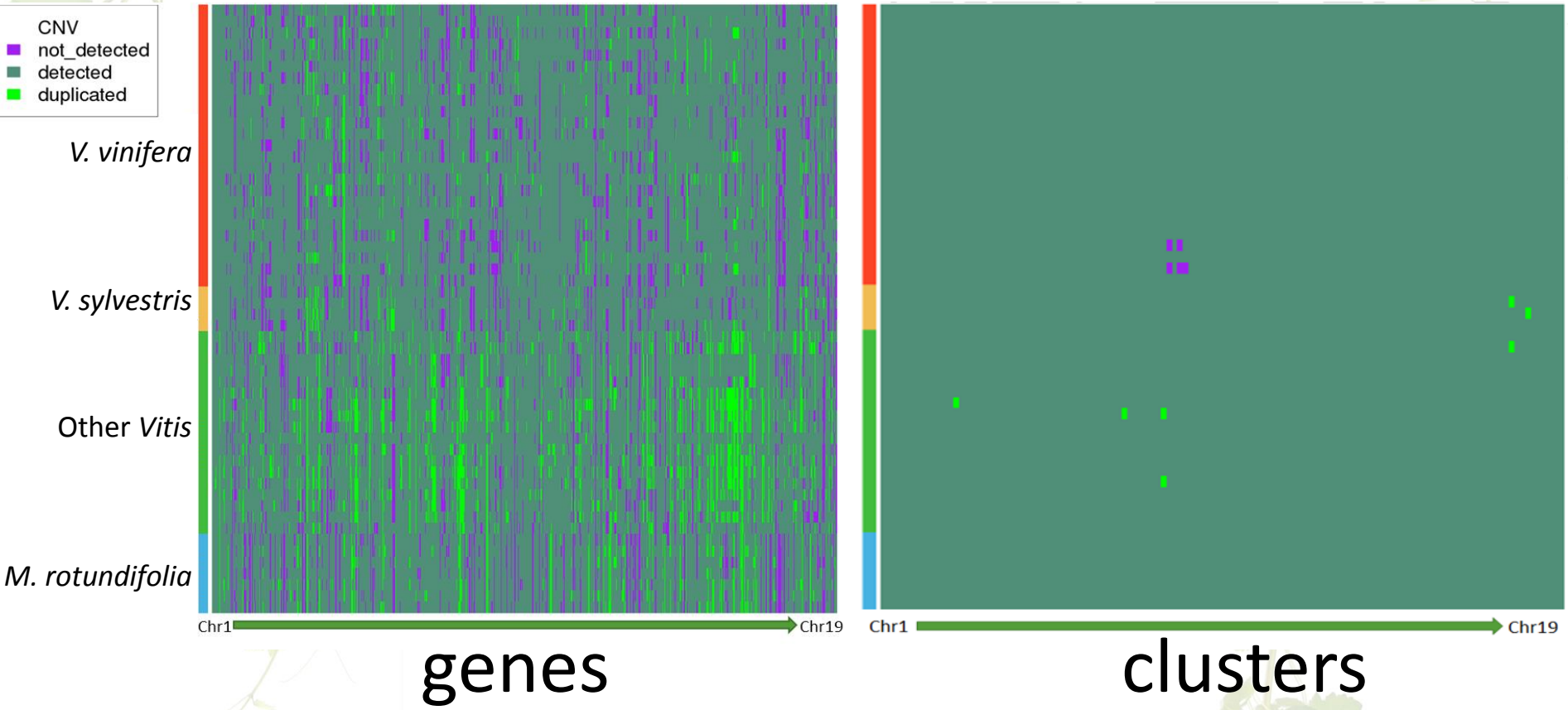


# Copy Number Variation at gene and cluster levels



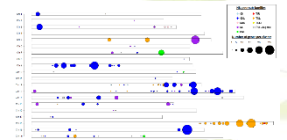


# Copy Number Variation at gene and cluster levels



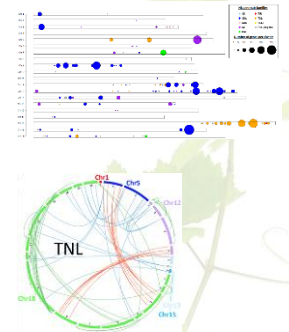
# NB gene family in the grapevine genome

- TNL and CNL display contrasted distribution throughout the genome



# NB gene family in the grapevine genome

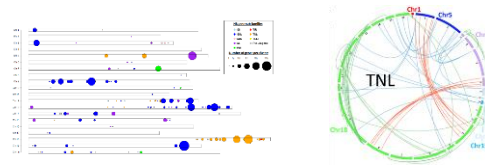
- TNL and CNL display contrasted distribution throughout the genome
- Two large segmental duplication events for the TNL





# NB gene family in the grapevine genome

- **CNL and TNL display different evolution histories**

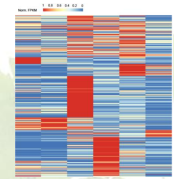


# NB gene family in the grapevine genome

- CNL and TNL display different evolution histories



- Many NB genes are specifically expressed during a powdery mildew infection

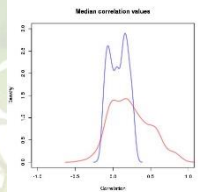
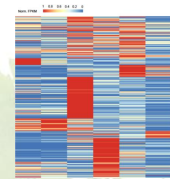


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- CNL and TNL display different evolution histories



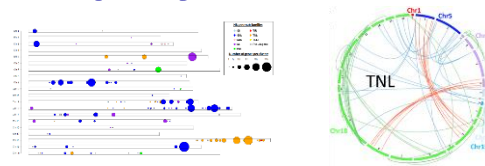
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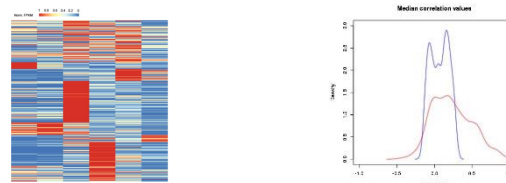


# NB gene family in the grapevine genome

- CNL and TNL display different evolution histories



- NB genes clusters are ideal structures to trigger efficient responses against pathogen attacks



# NB gene family in the grapevine genome

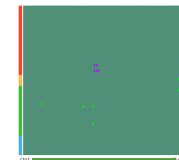
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- NB genes clusters are ideal structures to trigger efficient responses against pathogen attacks



- Clusters are highly conserved among Vitis



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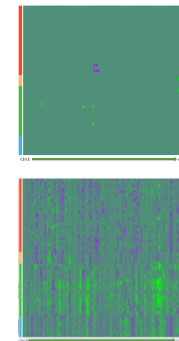
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- NB genes clusters are ideal structures to trigger efficient responses against pathogen attacks



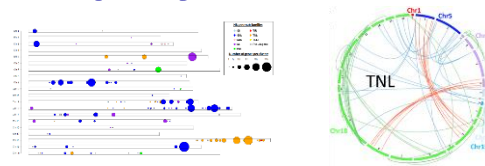
- Clusters are highly conserved among Vitis
- Variations occur mostly at the gene level



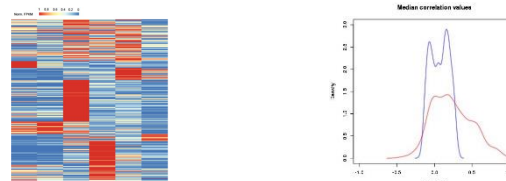


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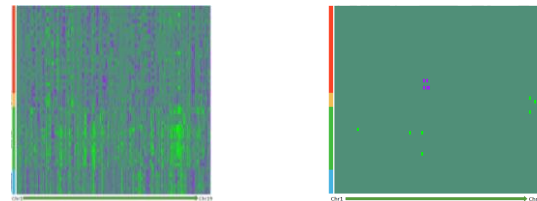
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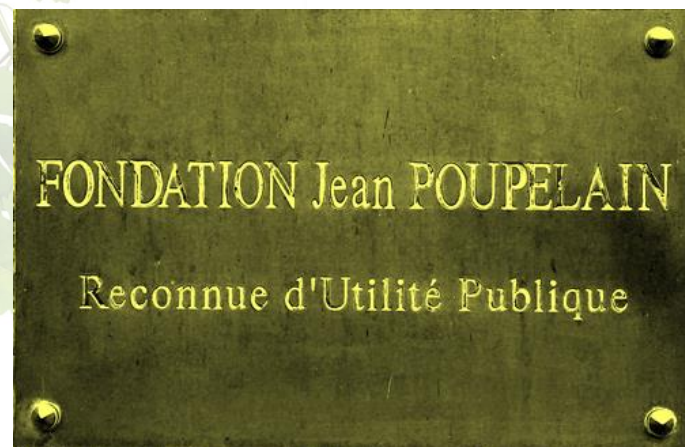
- NB genes clusters are ideal structures to trigger efficient responses against pathogen attacks



- NB genes clusters are conserved “factories” able to catalyze rearrangements leading to adaptive novelties



# Acknowledgements



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# Thanks for your attention.



Vins  
d'Alsace