Epidemiological interactions between strains of the plum pox virus

Combining a mathematical model with field data

Olivier Cotto, Sylvie Dallot, Darko Jevremović, Svetlana Paunović, François Bonnot, Gaël Thébaud

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Multiple viral infections in plants

- Diversity of plant pathogens
- Several viruses or strains infecting a single host

							Multiple infections[3]															
		Single infections					AMV+										BMV+				CMV+	
Host species[1]	N[2]	AMV	BWYV	CMV	TSWV	WMV	B	C	T	W	B+C	B+T	C+T	T+W	B+C+T	B+T+W	C	T	C+T	C+T+W	B+T	B+W
Amaranthus spp.	87	1	5	31	3	4		1														
C. bursa-pastoris (L.) Medicus	5	0	0	0	1	0																
Chenopodium album L.	69	4	0	3	1	1																1
Cirsium arvense (L.) Scop.	42	8	8	20	1	3					4				1							
Convolvulus arvensis L.	113	10	6	7	0	0	5															
Conyza sp.	121	5	10	7	5	1		1	1	1		1										
Datura stramonium L.	26	4	2	2	0	3	2			1												2
Diplotaxis erucoides (L.) DC.	164	15	11	44	11	2	1	2					1		3	1	2					
Lactuca serriola L.	66	1	1	13	1	1											1					1
Lamium amplexicaule L.	35	2	2	5	2	0							1		1							
Malva sylvestris L.	4	0	0	1	0	0																
Medicago sativa L.	90	38	4	9	5	5	2	3			1		1									
Papaver rhoeas L.	61	1	0	0	3	0																
Plantago sp	61	7	6	7	4	0			1						3		1					
Portulaca oleracea L.	7	0	0	5	0	0																
Silybum marianum (L.)Gaertner	29	1	2	1	1	0																
Solanum nigrum L.	24	0	0	4	0	0																
Sonchus oleraceus L.	51	3	1	4	3	2						1		1								
Taraxacum sp.	15	0	0	10	0	0																
Trifolium pratense L.	37	1	0	2	1	1																1
Xanthium strumarium Moretti.	8	1	0	1	1	1																1

No multiple infection

Malpica et al. 2006 Plos One

5 viruses tested in 21 weed species

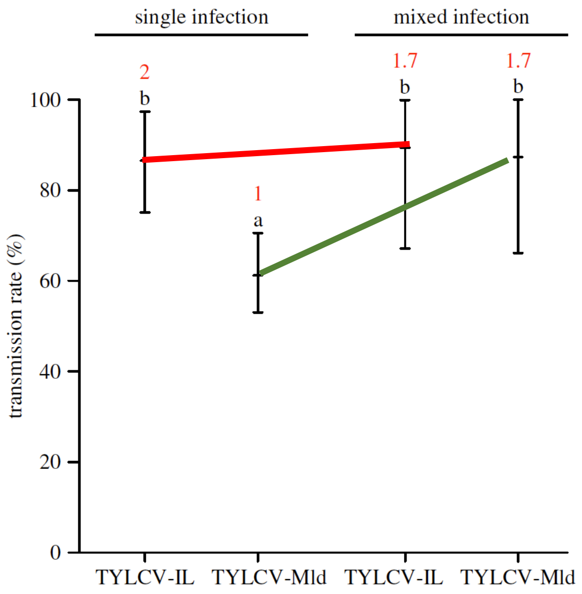
16/21 species with multiple infections

Multiple viral infections in plants

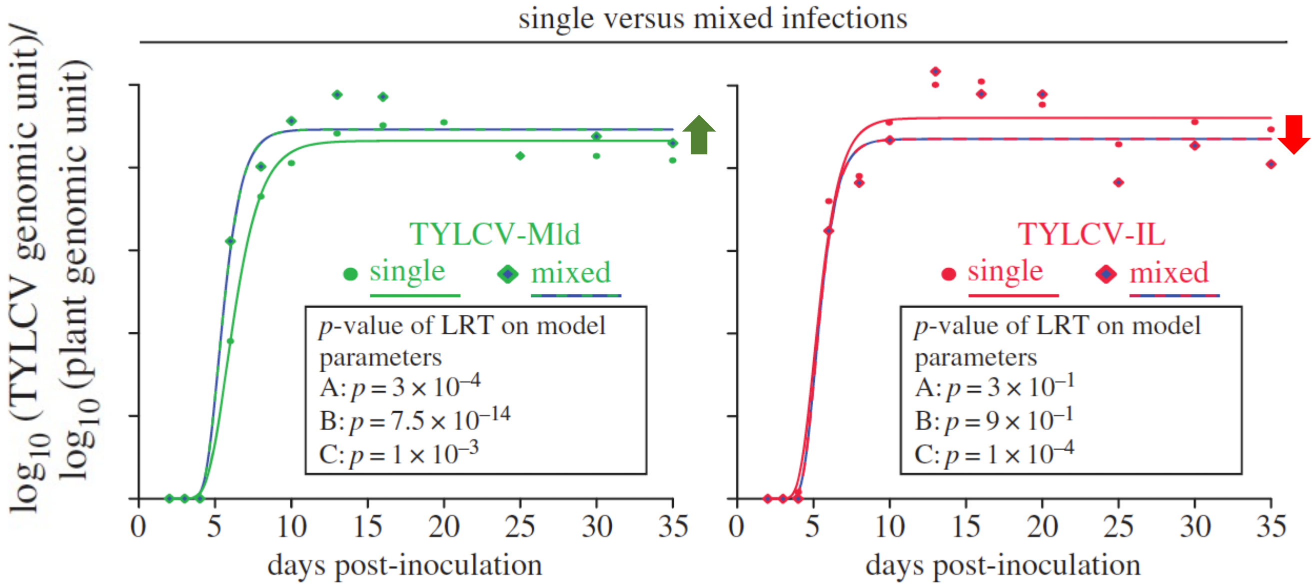
- Diversity of plant pathogens
- Several viruses or strains infecting a single host
- Interactions between viruses
  - Often characterized in the lab
  - Epidemiological consequences ?

Péréfarres et al. 2014 Proc-B

TYLCV-Mld was introduced before TYLCV-IL in La Réunion.



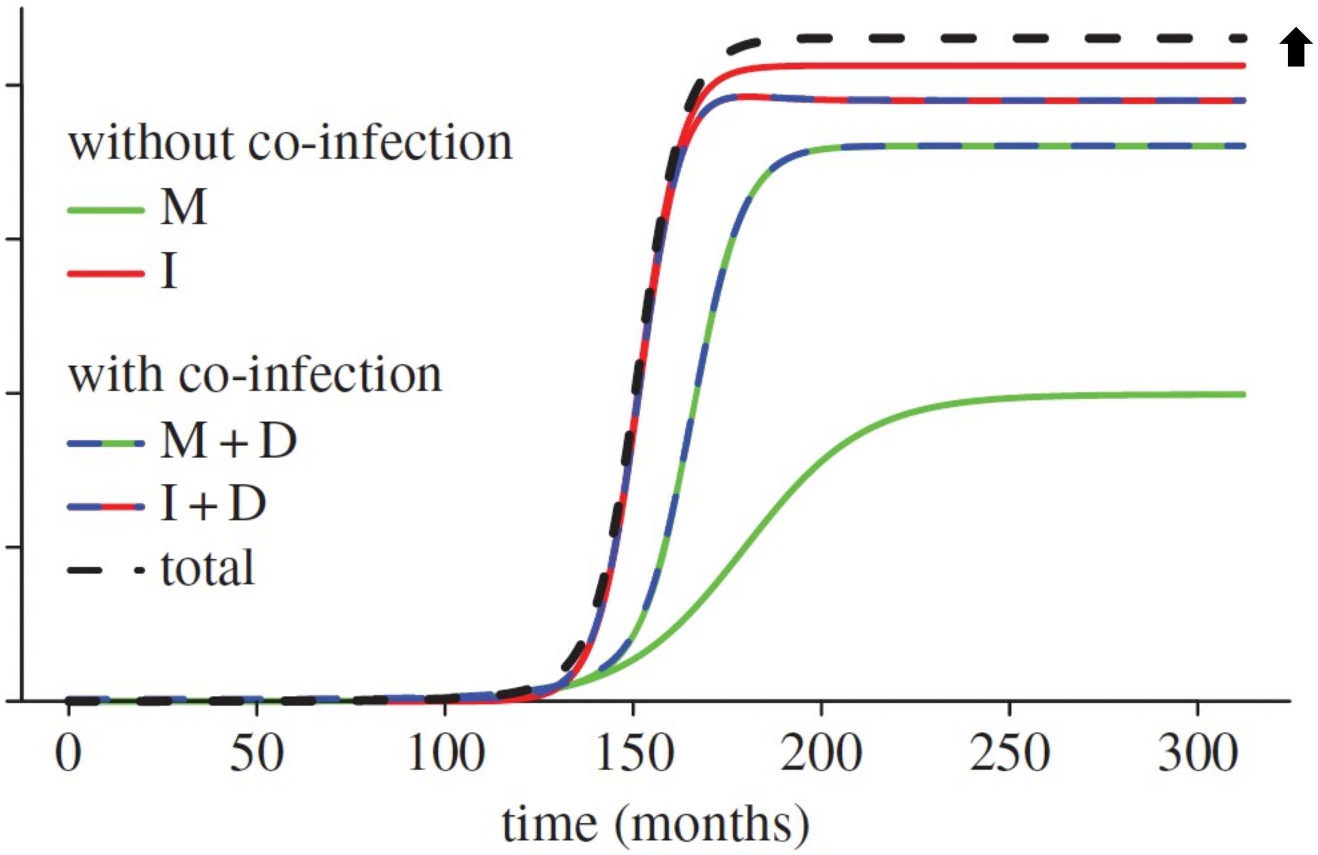
TYLCV-IL transmits better than TYLCV-Mld but TYLCV-Mld beneficiates from co-infection



TYLCV-IL accumulates better in single infection than TYLCV-Mld but not in mixed infection

Epidemiological consequences of the interactions between both TYLCV strains ?

Péréfarres et al. 2014 Proc-B



- Both strains co-exist at equilibrium
- Larger disease prevalence when both strains co-exist

Insights from combining data and epidemiological model

Detecting virus interactions from field data

- Screening of pathogen occurrence in the field
- Statistical independence between infection events

(Vaumourin et al. 2014 Front. Cell. Infect.)

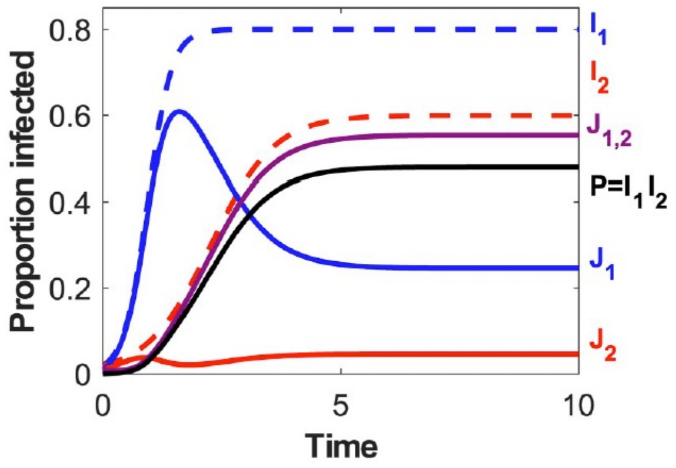
$$p(A \cap B) = p(A)p(B)$$

- Using epidemiological model

(Hamelin et al. 2019 Plos Biol.)

  - **H0**
    - **Chronic infection**
    - **No virus-induced mortality**
    - **System at the endemic equilibrium**
    - **No interaction between pathogens**
  - Statistical independence is not met under H0

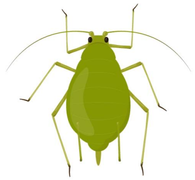
$$p(A \cap B|H0) > p(A)p(B)$$



Multiple PPV infection

- Perennial plants
  - Hard to use in experiments
  - Common multiple virus infections
- Sharka disease on *Prunus* trees
- Mainly three plum pox virus strains in Europe
  - PPV-M
  - PPV-D
  - PPV-Rec

Rimbaud et al. 2015
Annu. Rev. Phytopathol.



Question

- What are the epidemiological consequences of interactions between PPV strains in multiple infections ?
- How do interactions between PPV strains change over a tree lifespan ?

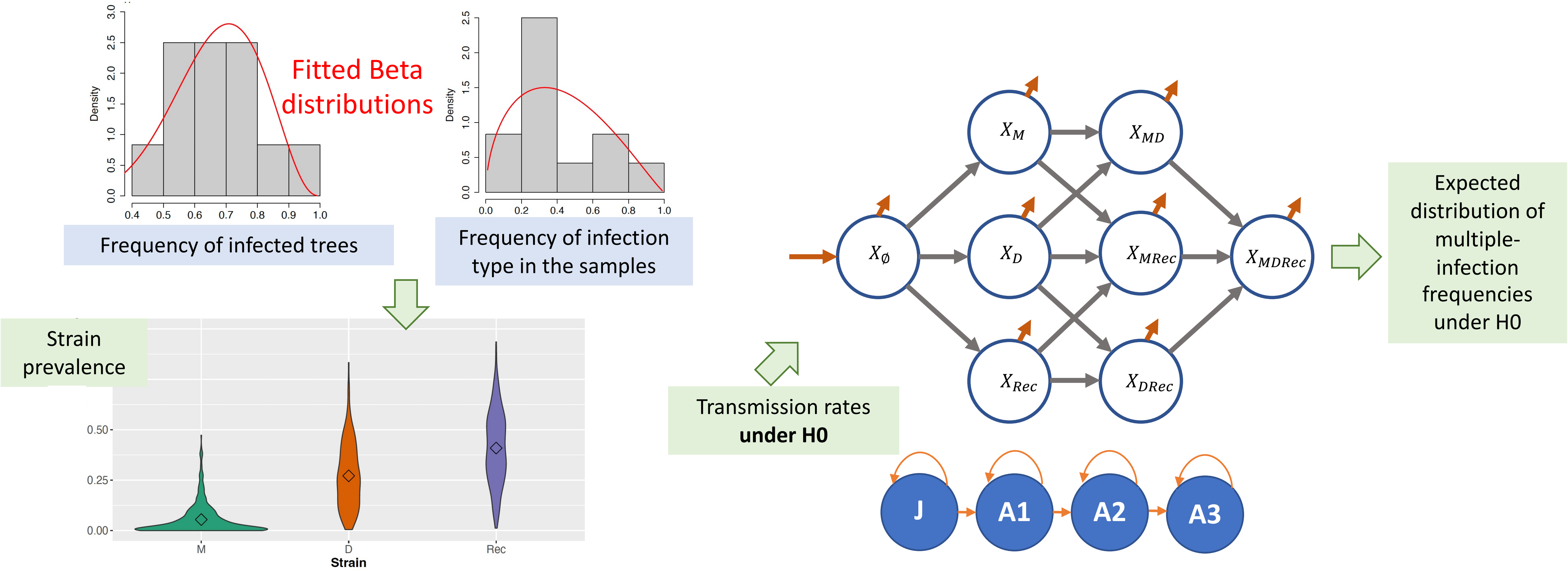
A survey of multiple PPV infections in Serbia

- No sharka management in Serbia : endemic equilibrium
- Plum trees
- Estimation of the fraction of infected trees in each visited orchard (N = 91)
- Leave sampling of three infected trees per orchards
- PPV strains identified in the lab

All multiple infections where found in the collected samples

A multi-strain epidemiological model

- Density probability of parameters
- Epidemiological model with age structure

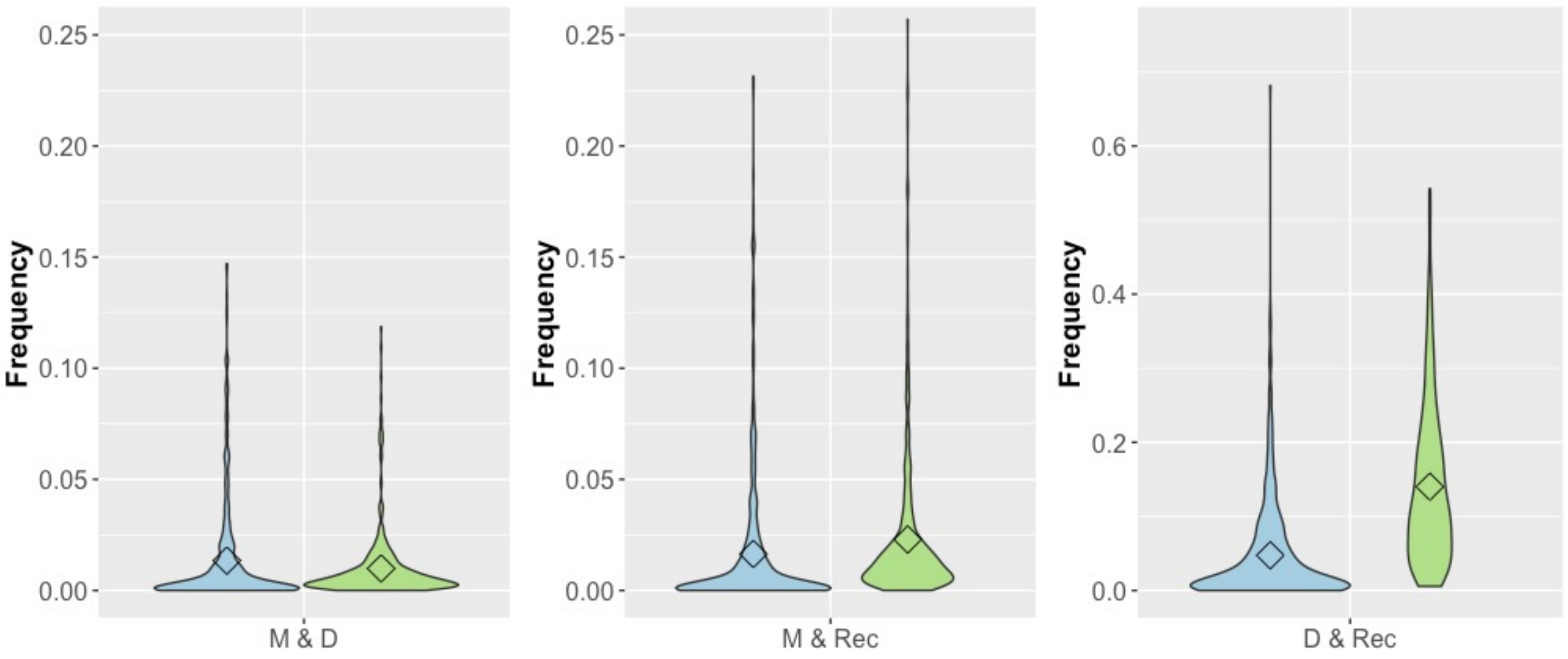


Results

- Overall

Less co-infections involving PPV-Rec than expected under H0

Probability distribution of the frequencies of co-infections



Observed

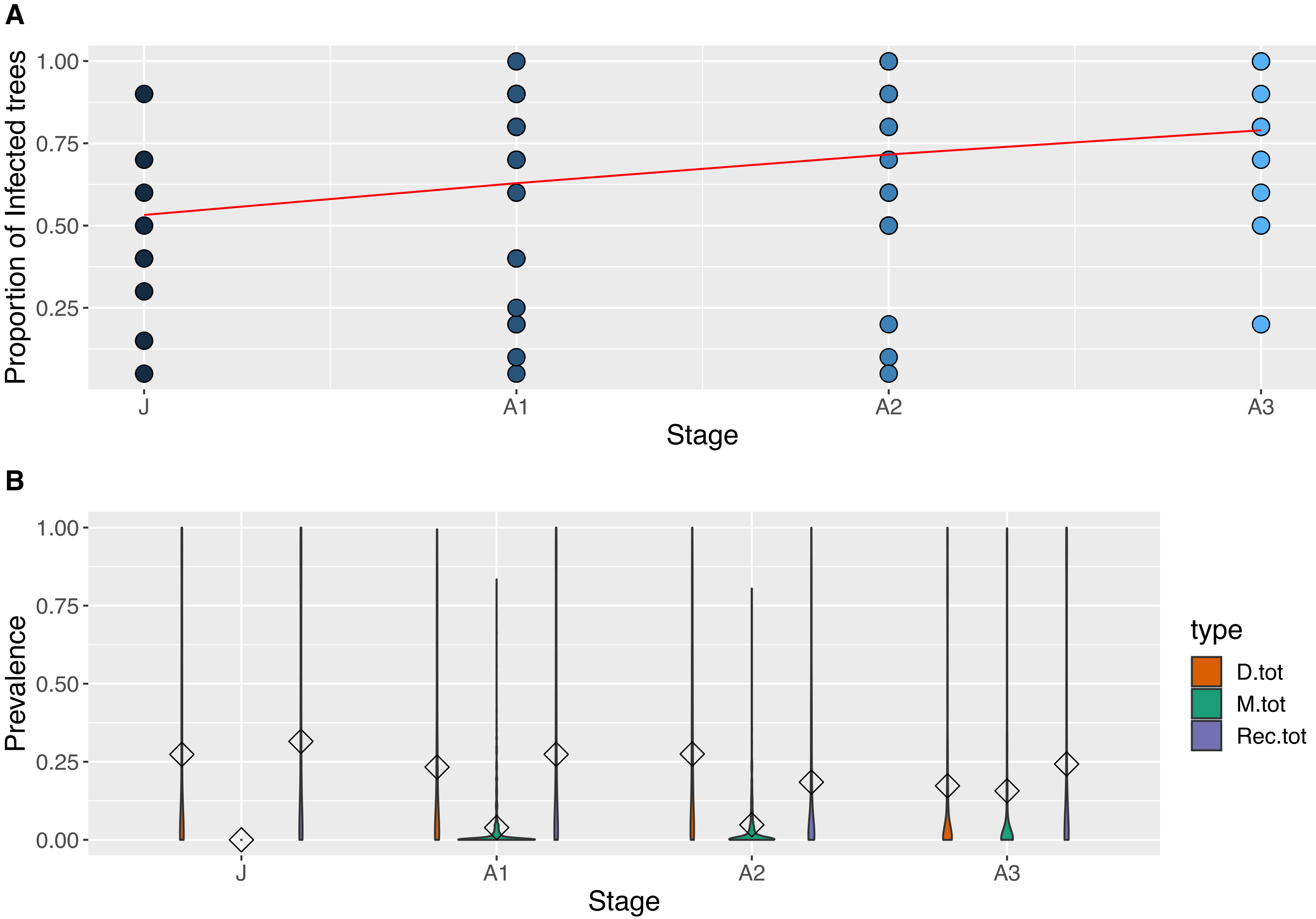
Predicted by the model under H0

Results

- By age

Proportion of infected trees increases with age

No clear trend in strain prevalence as a function of age

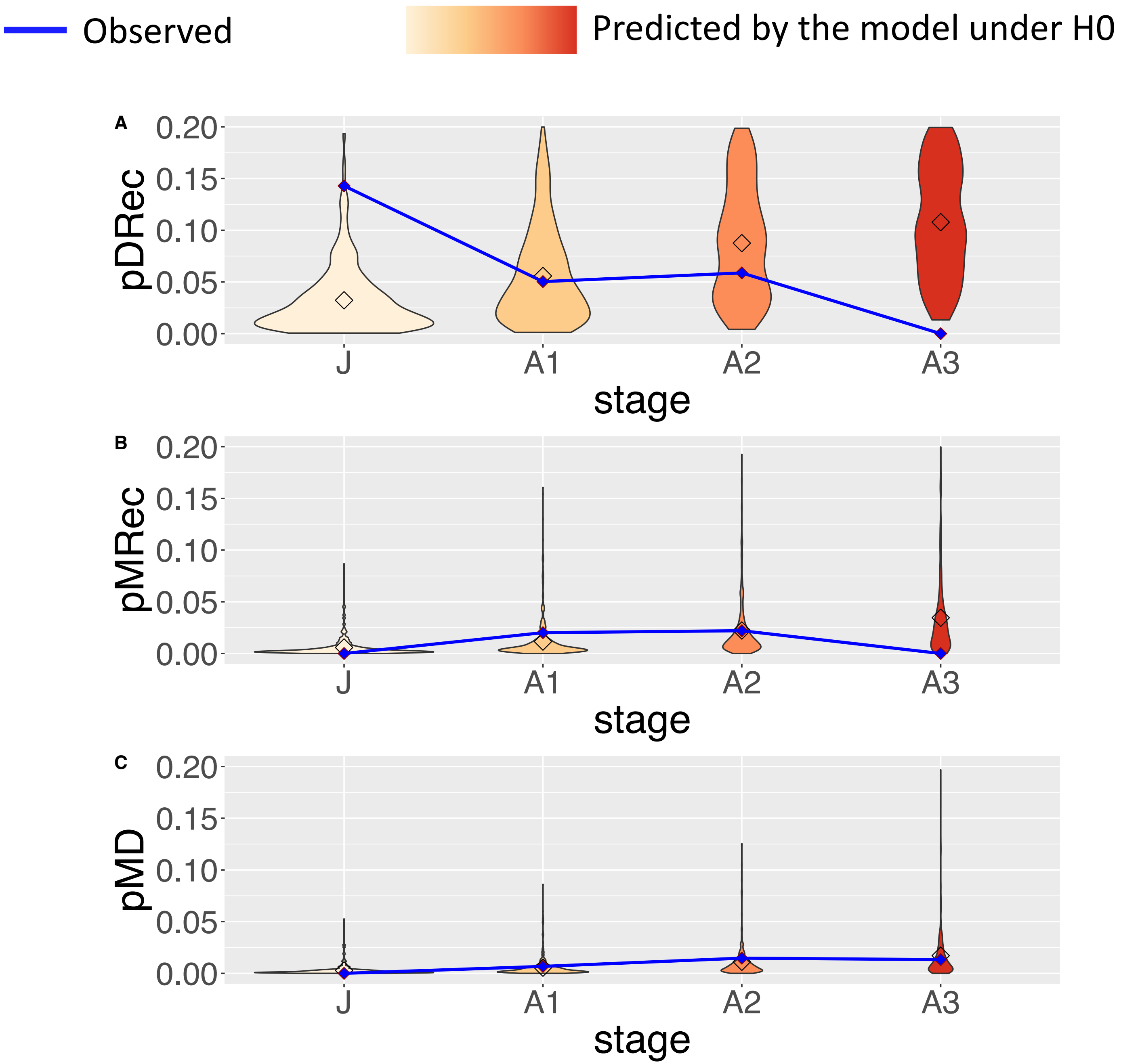


Results

- By age

Probability of co-infection PPV-D + PPV-Rec decreases with tree age !

Less co-infections involving PPV-Rec in aged trees than expected



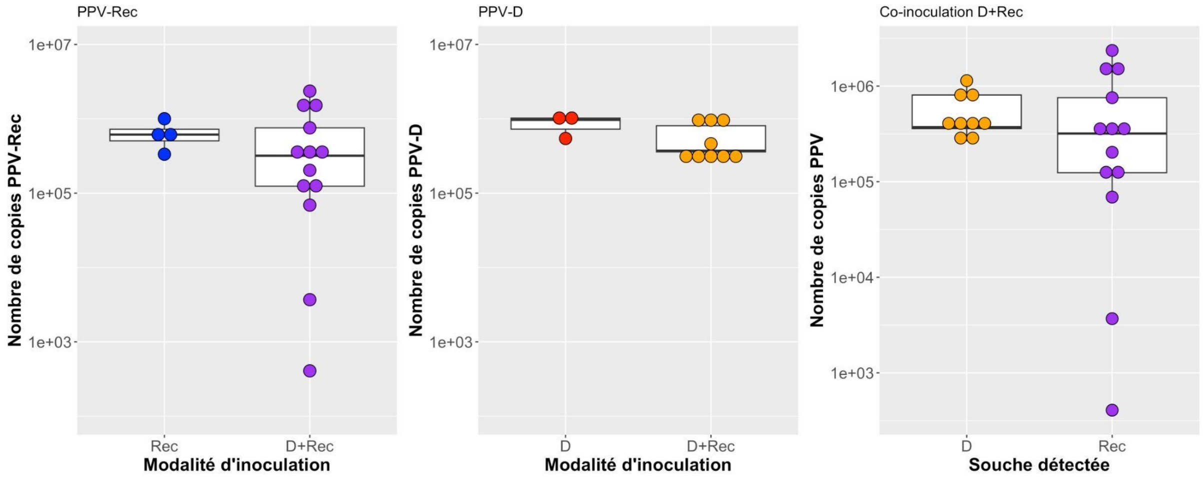
Conclusions

- Multiple infections involving PPV-Rec do not satisfy H0
- The age-structured model provides insights on the possible sources of discrepancies
- Possible sources of discrepancies
  - PPV-Rec is **outcompeted** over time (but PPV-Rec is a recombinant from M and D)
  - Trees develop a **resistance** to PPV-Rec when aging
  - PPV-Rec is **not at endemic equilibrium**
  - Others ?

Perspectives

- Combining field data analyses and lab experiments

Preliminary data
Amaury Beuzelin (Master 1) & Sylvie Dallot



Thank you

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