

Trade-offs between sporulation and virulence in *Phytophthora ramorum*

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Phytophthora ramorum exhibits a wide host range

- More than 23 hosts reported in woodlands and forests of the Pacific Coast of the USA (Davidason *et al.*, 2003)
- 117 hosts listed by USDA-APHIS (<http://www.aphis.usda.gov/>)
- More than 100 potential hosts reported for Europe (Rapra project <http://rapra.csl.gov.uk/>)
- The list of hosts includes a broad diversity of botanical families and different plant organs
 - Angiosperms
 - Gymnosperms
 - Ferns





Quercus ilex



Pinus halepensis



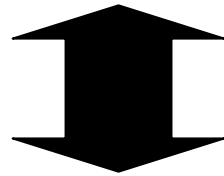
Arbutus unedo



Olea europaea

Such infection capacities suggest:

- The pathogen's multiple-host strategy preceding invasion



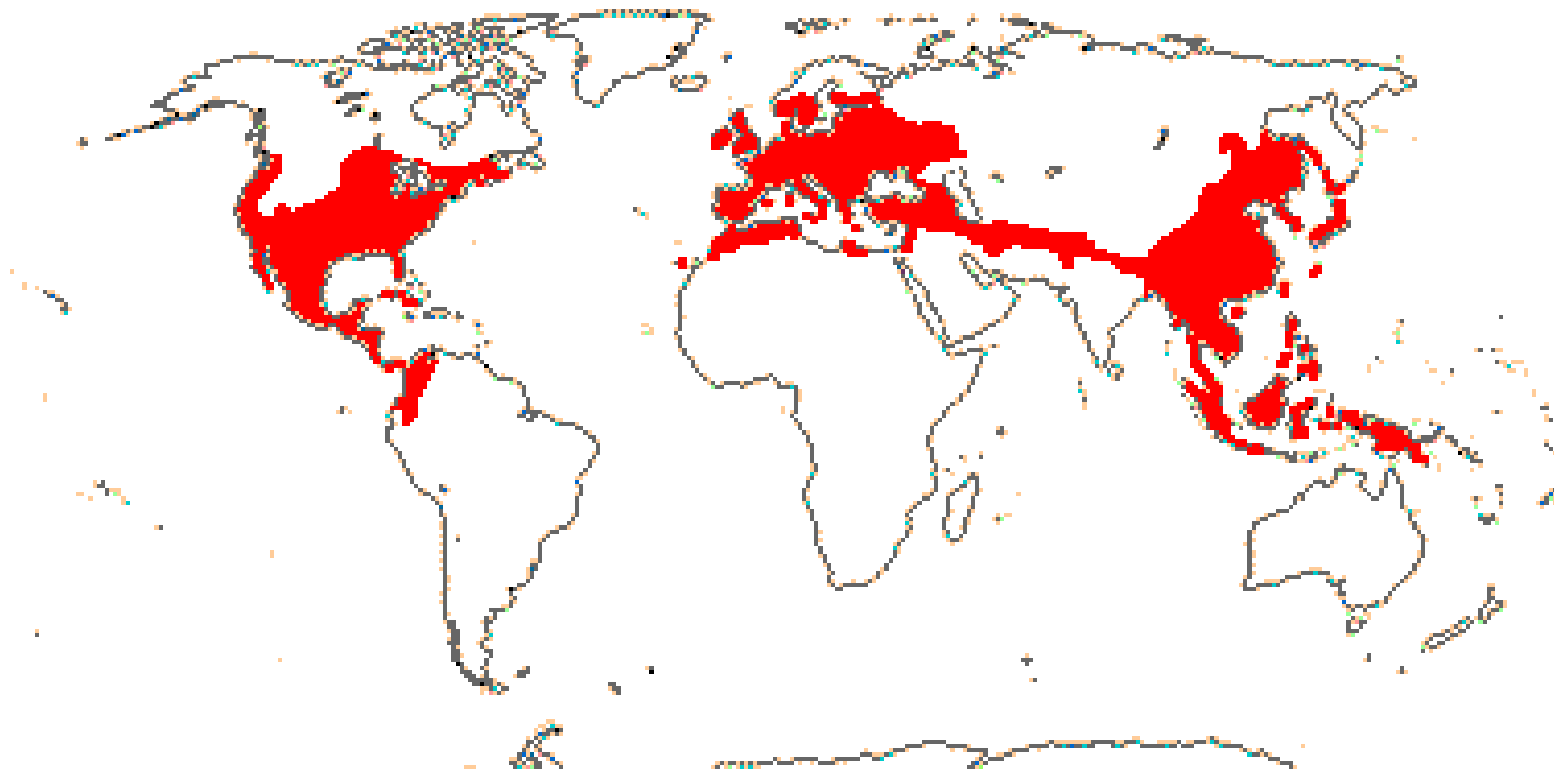
- A common basal defence system in plants which *Pr* would be 'trained' to overcome



***P. ramorum* is widely distributed in nurseries**

- Since *ca.* 1993 in Europe
- To date in 15 European countries
- Probably since 2000 or before in California
- More than 30 states in the USA and in Canada

So why *P. ramorum* has not yet become pandemic?



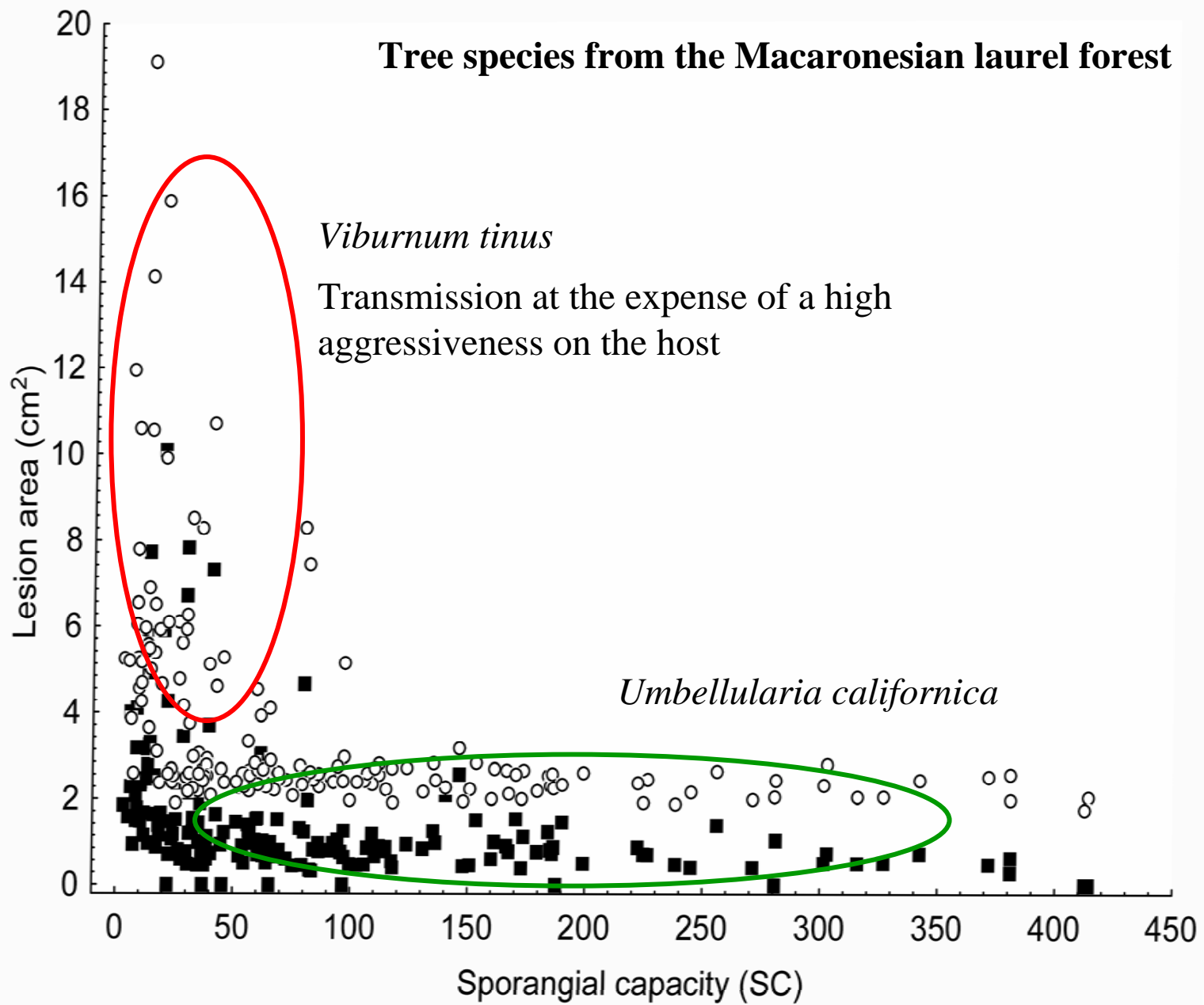
A clue to the answer: the lifestyle and mode of sporulation on their main hosts

- A large number of sporangia are formed on carrot agar at 10-25°C (> ca. 70.000 sp cm²).

Table 1 Sporangial density ranges of *P. ramorum* isolates grown on carrot agar in 90 mm diam Petri dishes under continuous fluorescent white light at 20°C

<i>P. ramorum</i> isolates	Original host	Mating type	Sporangial density (cm ⁻²)
P1376	<i>Viburnum tinus</i> cv. Eve Price (EU)	A1	38 482–112 675
P1403	<i>Vaccinium ovatum</i> Oregon (USA)	A2	35 275–127 712
P1577	<i>Rhododendron catawbiensis</i> (EU)	A1	45 877–118 555
P1578	<i>Rhododendron grandiflora</i> (EU)	A1	37 673–113 265
P1579	<i>Quercus agrifolia</i> (USA)	A2	34 444–112 399

- However, there is 100-1000 fold reduction in sporangial production on leaf infections.





Phytophthora infestans sporulation

- *P. infestans* produces similar number of sporangia on Rye A agar (> 100.000) and a 2-10 fold reduction on its main host, *Solanum tuberosum* (50.000-10.000 sporangia cm²).
- When *P. infestans* occasionally infects other hosts within the genus *Solanum* or other closely related genera, the number of sporangia developed on these hosts is reduced by 10-100 fold (Flier et al. 2003).

If *P. ramorum* formed on its foliage hosts similar numbers of sporangia as *P. infestans* does on potato leaves, it would become pandemic and a massive destructor in forests



Pathogen and host(s) environment

P. ramorum cardinal temperatures are about 2-20-30 °C;
Optimum around 20 °C

- Its propagules are mainly dispersed by rain splash mechanisms which implies short distance transmission.
- The effectiveness of this mode of dispersal increases with total rainfall at temperatures favourable for sporulation (> 600 >>2000 mm).



These environmental conditions promote a high diversity of tree species in forests in those areas where climate has hardly fluctuated over time.
> 20 tree species per 100 square metres (mountain laurel forest)



Why the average sporulation capacity of *P. ramorum* is reduced as the number of hosts increases?

- ➔ Virulence factors target common basal defence systems (non-host resistance) that are phylogenetically conserved in plants.
- *P. ramorum* poorly modulates the expression of host genes (for its benefit) compared with other biotrophic fungal pathogens
- There could be a pleiotropic effect between the expression of genes related to pathogenesis and sporulation.
- Overall between-host trade-offs in performance of multiple-host pathogens such as *Pr* are expected to increase under stabilising selection as the number of hosts and their phylogenetic distance increase in a plant community (Frank, 1993).



Conclusions

- The lifestyle of *Pr* in its centre of origin might be shaped by the constraint of short-distance spore dispersal in a high diversity species forest and the fitness costs caused by the need for a multiple-host strategy associated with reduced sporulation.
- Such reduced sporulation, however, could be enough for the effective spread of *Pr* in areas where environmental conditions are similar to those expected in its native habitat.



Conclusions

- The low sporangial production of *Pr* on host leaves compared to its high capacity for sporangial formation in culture strongly suggests a negative trade-off between transmission and virulence.
- Coevolution would have favoured the selection for a broader virulence of *Pr* at the expense of an average lower aggressiveness and sporangial production on their main hosts.



Thank for your attention

- Acknowledgements:
 - José Andrés García Muñoz (technical work)
 - Sandra Denman, Forest Research, UK

- This research has been funded by the EU (Rapra Project)