Estimating virulence costs from population data in *Phytophthora infestans*

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EuroBlight Workshop, Hamar, Norway
28-31 October 2008

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Outline

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Interpretation and hypotheses

> costs or no costs?

> implications for R gene management

Virulence costs

Virulence cost (fitness cost, fitness penalty)

= disadvantage to individuals bearing the virulence allele when this allele is useless

Consequences

> stabilising selection *sensu* Vanderplank
prevents population invasion by virulent isolates

> basis for gene management strategies
alternance, refuges, etc...

Research questions

- Do virulence costs exist?
  - > if they do:
    - Are they quantitatively high?
    - Are they dependent upon resistance genes/ pathogen populations?
- How to measure them?
  - > Ideally – pairs of isogenic isolates
    - How to deal with clonal, hard to transform pathogens?
- What consequences?
  - > if costs are found:
    - How to explain the persistence of unnecessary virulences?
  - > what gene deployment strategies to use?

Methodological approach

Material

- Plant material
  - > cultivars with no known R gene(s)

    - 4 cultivars differing in partial resistance levels

Bintje > Ostara >> Kaptah Vandel > Saturna

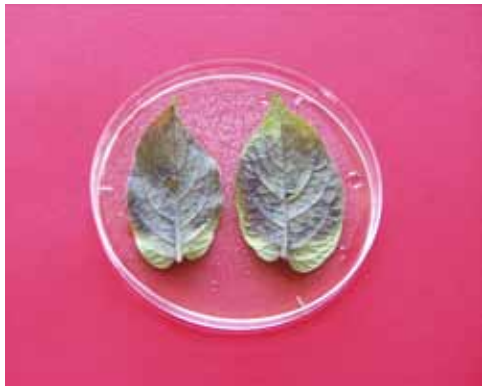
Increasing resistance

- Isolates
  - > as 'isogenic' as possible

    - 150 isolates with the same SSR profile (10 polymorphic loci)
    - clustering according to presence/absence of virulence to each of the 11 R genes from *S. demissum*

Methodological approach

Methods



Aggressiveness components:

- Latent period
- Lesion size 7 dai
- Spore production 7 dai

Methodological approach

Data analysis

- Statistical tests

  - > **<u>contrasts between virulent/avirulent bulks</u>**

    - Separately for each component & cv
    - On a composite aggressiveness index for each cv

      » *Ai = ln [LS*SP/LP]*

Main results

Results

		Bintje			
		lp	ls	sp	Ai
R1	Av (n=20)	3,38	**14,02**	**352445**	**14,13**
	V (n=112)	**3,16**	12,68	294259	13,93
	($F_{1,130}$; P)	9.44 / 0.0026**	11 / 0.0012**	6.44 / 0.0123*	4.64 / 0.0331*
R3	Av (n=13)	3,28	**13,55**	**313366**	**14,01**
	V (n=119)	**3,18**	12,81	301950	13,96
	($F_{1,130}$; P)	1.37 / 0.2438	2.18 / 0.1421	0.16 / 0.6868	0.24 / 0.6274
R4	Av (n=5)	3,37	**14,23**	**349906**	**14,11**
	V (n=127)	**3,18**	12,83	301231	13,96
	($F_{1,130}$; P)	1.81 / 0.1804	3.25 / 0.0738	1.23 / 0.2697	0.76 / 0.3846
R6	Av (n=128)	3,19	**12,92**	**303997**	**13,97**
	V (n=4)	**3,04**	11,74	273570	13,76
	($F_{1,130}$; P)	0.94 / 0.3331	1.81 / 0.1803	0.38 / 0.5362	1.15 / 0.2862
R7	Av (n=5)	3,40	**13,53**	287749	13,90
	V (n=127)	**3,18**	12,86	**303678**	**13,96**
	($F_{1,130}$; P)	2.53 / 0.1141	0.73 / 0.3943	0.13 / 0.7185	0.16 / 0.6941
R8	Av (n=80)	3,27	**13,22**	**309604**	**13,98**
	V (n=52)	**3,08**	12,36	293030	13,93
	($F_{1,130}$; P)	14.87 / 0.0002***	8.20 / 0.0049**	0.93 / 0.3363	0.51 / 0.4781
R10	Av (n=94)	3,22	**12,98**	**322465**	**14,03**
	V (n=38)	**3,11**	12,63	255109	13,79
	($F_{1,130}$; P)	4.09 / 0.0453*	1.16 / 0.2828	14.58 / 0.0002***	11.82 / 0.0008***
R11	Av (n=50)	3,25	**13,00**	**323616**	**14,03**
	V (n=82)	**3,15**	12,81	290550	13,92
	($F_{1,130}$; P)	3.39 / 0.0680	0.38 / 0.5392	3.73 / 0.0556	2.65 / 0.1061

On Bintje:

Two situations:

Ø **Compensation** (R1, R8, R10)

Ø **No cost** (R3, R4, R6, R7, R11)

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Main results

Results

		Variété test : Bintje			Kaptah-Vandel			Saturna		
		lp	ls	sp	lp	ls	sp	lp	ls	sp
	Av (n=20)	3,38	**14,02**	**352445**	4,08	**12,71**	167365	3,91	**10,68**	**145309**
R1	V (n=112)	**3,16**	12,68	294259	**3,77**	11,59	**189316**	**3,84**	10,57	136709
	($F_{1,130}$; P)	9.44 / 0.003	11 / 0.001	6.44 / 0.012	5.26 / 0.023	7.60 / 0.007	1.16 / 0.284	0.28 / 0.595	0.07 / 0.785	0.53 / 0.470
	Av (n=13)	3,28	**13,55**	**313366**	3,82	**13,19**	**194131**	3,97	**11,11**	**145793**
R3	V (n=119)	**3,18**	12,81	301950	**3,81**	11,61	185325	**3,84**	10,53	137162
	($F_{1,130}$; P)	1.37 / 0.244	2.18 / 0.142	0.16 / 0.687	0.00 / 0.971	10.29 / 0.002	0.12 / 0.725	0.82 / 0.368	1.55 / 0.215	0.36 / 0.547
	Av (n=5)	3,37	**14,23**	**349906**	3,93	**12,23**	177089	3,97	10,07	136163
R4	V (n=127)	**3,18**	12,83	301231	**3,81**	11,73	**186491**	**3,84**	**10,61**	**138085**
	($F_{1,130}$; P)	1.81 / 0.180	3.25 / 0.074	1.23 / 0.270	0.23 / 0.629	0.42 / 0.520	0.06 / 0.803	0.28 / 0.598	0.56 / 0.456	0.01 / 0.932
	Av (n=128)	3,19	**12,92**	**303997**	3,82	**11,78**	185817	**3,85**	10,59	**139384**
R6	V (n=4)	**3,04**	11,74	273570	**3,58**	10,92	**196118**	3,96	**10,69**	94107
	($F_{1,130}$; P)	0.94 / 0.333	1.81 / 0.180	0.38 / 0.536	0.70 / 0.405	1.03 / 0.313	0.06 / 0.806	0.19 / 0.661	0.02 / 0.898	3.40 / 0.067
	Av (n=5)	3,40	**13,53**	287749	4,20	**12,04**	**188632**	3,97	10,22	134604
R7	V (n=127)	**3,18**	12,86	**303678**	**3,80**	11,74	186033	**3,84**	**10,60**	**138146**
	($F_{1,130}$; P)	2.53 / 0.114	0.73 / 0.394	0.13 / 0.718	2.50 / 0.116	0.15 / 0.699	0.00 / 0.945	0.28 / 0.598	0.28 / 0.598	0.03 / 0.874
	Av (n=80)	3,27	**13,22**	**309604**	3,91	**12,21**	181049	3,92	**10,74**	134533
R8	V (n=52)	**3,08**	12,36	293030	**3,67**	11,06	**193855**	**3,74**	10,35	**143364**
	($F_{1,130}$; P)	14.87 / 0.000	8.20 / 0.005	0.93 / 0.336	5.90 / 0.016	16.25 / 0.000	0.76 / 0.385	3.80 / 0.054	2.02 / 0.158	1.03 / 0.312
	Av (n=94)	3,22	**12,98**	**322465**	3,87	**11,85**	**189169**	3,88	10,52	**143729**
R10	V (n=38)	**3,11**	12,63	255109	**3,67**	11,51	178700	**3,78**	**10,77**	123868
	($F_{1,130}$; P)	4.09 / 0.045	1.16 / 0.2828	14.58 / 0.000	3.47 / 0.065	1.09 / 0.298	0.44 / 0.510	0.97 / 0.326	0.67 / 0.413	4.61 / 0.034
	Av (n=50)	3,25	**13,00**	**323616**	3,93	**11,99**	176696	3,94	10,38	133892
R11	V (n=82)	**3,15**	12,81	290550	**3,75**	11,61	**191770**	**3,80**	**10,72**	**140524**
	($F_{1,130}$; P)	3.39 / 0.068	0.38 / 0.539	3.73 / 0.056	3.24 / 0.074	1.54 / 0.217	1.03 / 0.312	2.34 / 0.129	1.38 / 0.242	0.57 / 0.451

On the other cvs :

- Same two situations
  - Ø Compensation
  - ØNo cost
- Fewer significant costs than on Bintje
- No effect on Ai

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So what?

Interpretations & hypotheses

- **Two ways of having no cost**

Œ Have no cost on any component
- Compensate
  - > trade off LP/ LS*SP

Ü **<u>Different evolutionary consequences</u> (Vanderplank revisited)**

If Œ :

no (negative) selection
> stable polymorphism for virulence in mixed cv landscapes (R :r)
> invasion by virulent races after use of matching R genes
ex: R4; R7 = fossil virulences?

If • :

divergent selection
'super-agressive' isolates may emerge if recombination occurs

So what?

Interpretations & hypotheses

- **Stronger costs on very susceptible cvs**
  - Artifact or reality?
    - see Montarry et al., 2008 JEB > adaptation to prevailing cvs

Ü **<u>Consequence for R gene management</u>**

simply do not care?

favor cvs with high levels of partial resistance?

diversify cvs?

Special thanks to:

- **INRA blighters**
  - Le Rheu
    - Roselyne, Isabelle, Bruno, Hervé, Claudine
    - **Josselin**
  - Ploudaniel
    - Daniel, Roland, Jean- Eric

- **Collaborators**
  - SRPV Nord Pas de Calais
    - Ludovic, Delphine, Serge

- **Colleagues we talked with**:
  - Jérôme Enjalbert,
  - Christian Lannou

- **Some generous sponsors**

INRA:	projets SPE (2004-...)
ACVNPT:	CIFRE J. Montarry
MA(A)P(AR):	contrats de Branche 'Alimentarité' et 'Résistance'