Durable deployment of potato late blight resistance genes from an epidemiological perspective

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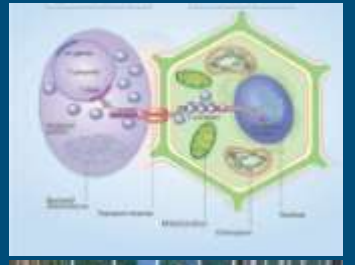
DuRPh duurzame resistentie tegen *Phytophthora* in aardappel door cisgene merkervrije modificatie

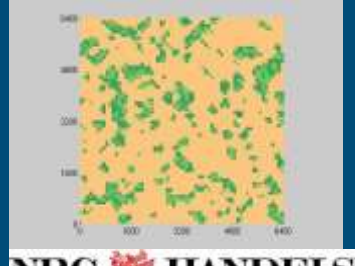
DuRPh, Healthy potato production

- A GMO approach to breeding *P. infestans* resistant potatoes
- Proof of concept
  - Technology
  - Durability
- Cis-gene & marker free approach

Overview DuRPh

- Project/Programme:
  - Goal: Durable resistance against potato late blight
  - Cis-gene (intragenic) R-genes, stacked, marker free
  - Approach (work packages)
    - Cloning
    - Transformation
    - Selection
    - R-gene deployment
    - *P. infestans* monitoring
    - Communication
  - Budget 2006 – 2015, 10 M€





NRC HANDELSBLAD

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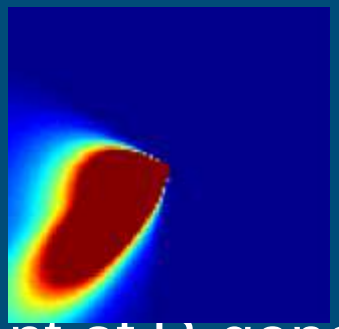
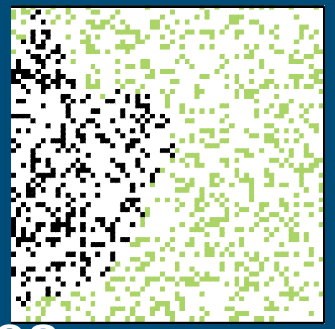
Genes for potato late blight resistance

Resistance in future PLB management

- Combined results Umbrella Plan + DuRPh:
- Fungicides as extra protection on top of resistance
  - Reduced dose rates protectants
  - Adapted spray intervals
- *P. infestans* buffering growing systems
  - Dynamic cultivars
  - Mixing of “resistance” within fields & regions
  - Goal: minimize *P. infestans* population
    - Lower disease pressure for the region
    - Lower probability of adaptation by *P. infestans*
  - P. infestans monitoring

Resistance management / R-gene deployment





2 projects:

- A) Spatial and temporal deployment of R-genes
  - Scenario studies using models (including time & space up to regional level)
  - Field experiments

- B) *P. infestans* population development / monitoring
  - Genotypic characterization
  - Phenotypic characterization

Sample Name	Pi02	Pi02	Pi02	D13	D13	D13	Pi33	Pi33	Pi33	Pi04	Pi04	Pi04	Pi4B	Pi4B	Pi4B	Pi16	Pi16	Pi16	G11	G11	G11	Pi56	Pi56	Pi56	Pi63	Pi63	Pi63	Pi70	Pi70	Pi70	Pi89	Pi89	Pi89
NL_00_GNVM_48_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NL_00_Olland_4_1	0	0	0	136	154	0	203	203	0	166	170	0	0	0	0	178	178	0	156		0	174	176	0	151	157	0	192	192	0	0	0	0	0
NL_00_Kamp_1_2_2	0	0	0	136	136	0	203	203	0	166	170	0	0	0	0	176	178	0	158	158	0	176	176	0	157	157	0	192	192	0	0	0	0	0
NL_00_Olland_15_1	152	162	0	136	136	0	203	203	0	170	170	0	213	213	0	178	178	0	150	160	0	176	176	0	157	157	0	192	192	0	179	179	0	0
NL_00_Maas_II_7_1	152	162	0	136	136	0	203	203	0	166	170	0	217	217	0	176	178	0	154	156	206	174	176	0	148	151	157	192	195	0	179	179	0	0
NL_00_Zuidzee_4	152	162	0	136	136	0	203	203	0	166	170	0	217	217	0	176	178	0	154	156	206	174	176	0	148	151	157	192	195	0	179	179	0	0
NL_00_Zuidzee_8	152	162	0	138	138	0	203	203	0	166	170	0	217	217	0	176	178	0	154	156	206	174	176	0	148	151	157	192	195	0	179	179	0	0
NL_00_Haps_vd_Bosch	152	162	0	136	136	0	203	203	0	166	170	0	205	217	0	176	178	0	160	160	0	176	176	0	157	157	0	192	192	0	179	179	0	0
NL_00_Kamp_4_5	152	162	0	136	136	0	203	203	0	166	170	0	205	217	0	176	178	0	160	160	0	176	176	0	157	157	0	192	192	0	179	179	0	0
NL_00_Kamp_2_10	152	162	0	136	136	0	203	203	0	166	170	0	205	217	0	176	178	0	162	162	0	176	176	0	157	157	0	192	192	0	179	179	0	0
NL_00_Kamp_2_2	152	162	0	136	136	0	203	203	0	166	170	0	205	217	0	176	178	0	162	162	0	176	176	0	157	157	0	192	192	0	179	179	0	0

Spatial and temporal deployment of R-genes

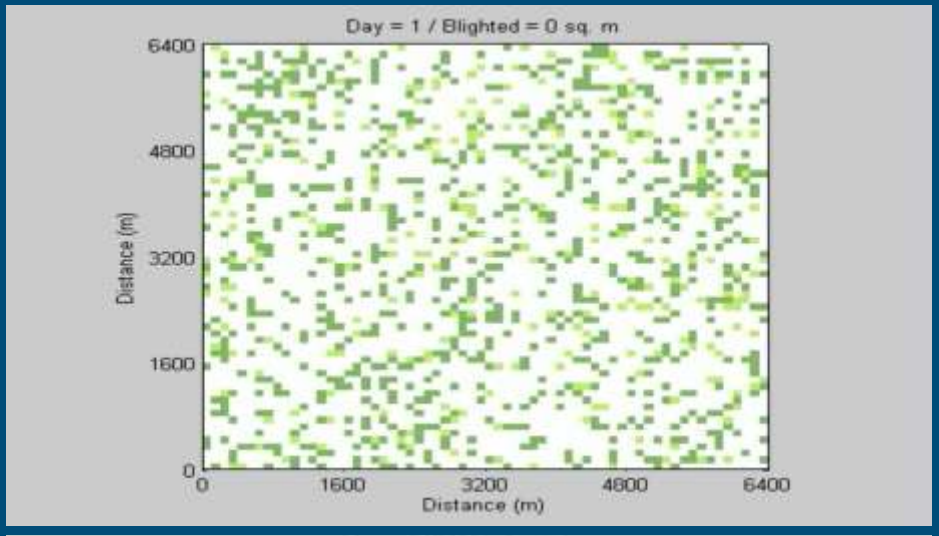
- Concept:
  - Stacking R-genes in dynamic cultivars

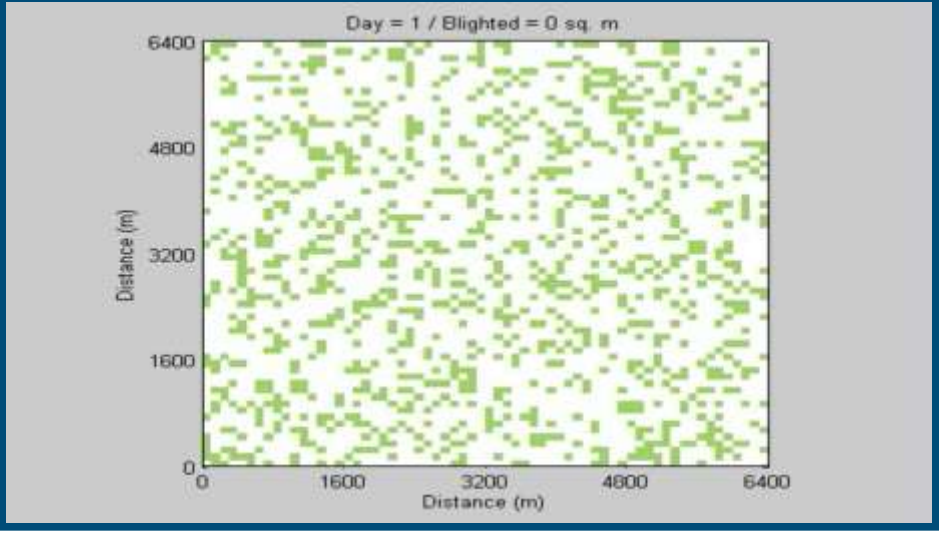
    Desiree^{+} containing five lines with differential R-gene(s) (cassettes)

    R-gene cassettes can be exchanged when broken
    - How many lines?
    - How many R-genes in a cassette?

- Break through scenario's
  - *P. infestans* buffering landscapes?
  - Limit build up of rare virulences & disease pressure
  - Mixing of R-gene (cassettes) possible at many spatial scales
  - Fungicides remain but input MUCH lower (down to e.g. 20% a.i.)
    → Interaction with Umbrellaplan Phytophthora

Simulation of a PLB buffering landscape





- Identical plant material
- Break through scenario's:
  - default landscape:
    - 1 ha
    - ¼ potato
    - ¼ susceptible fields
    - ¾ "resistant" fields
  - Within field mixing:
    - 1 ha fields
    - ¼ potato
    - ¼ susceptible & ¾ "resistant" mixed within fields

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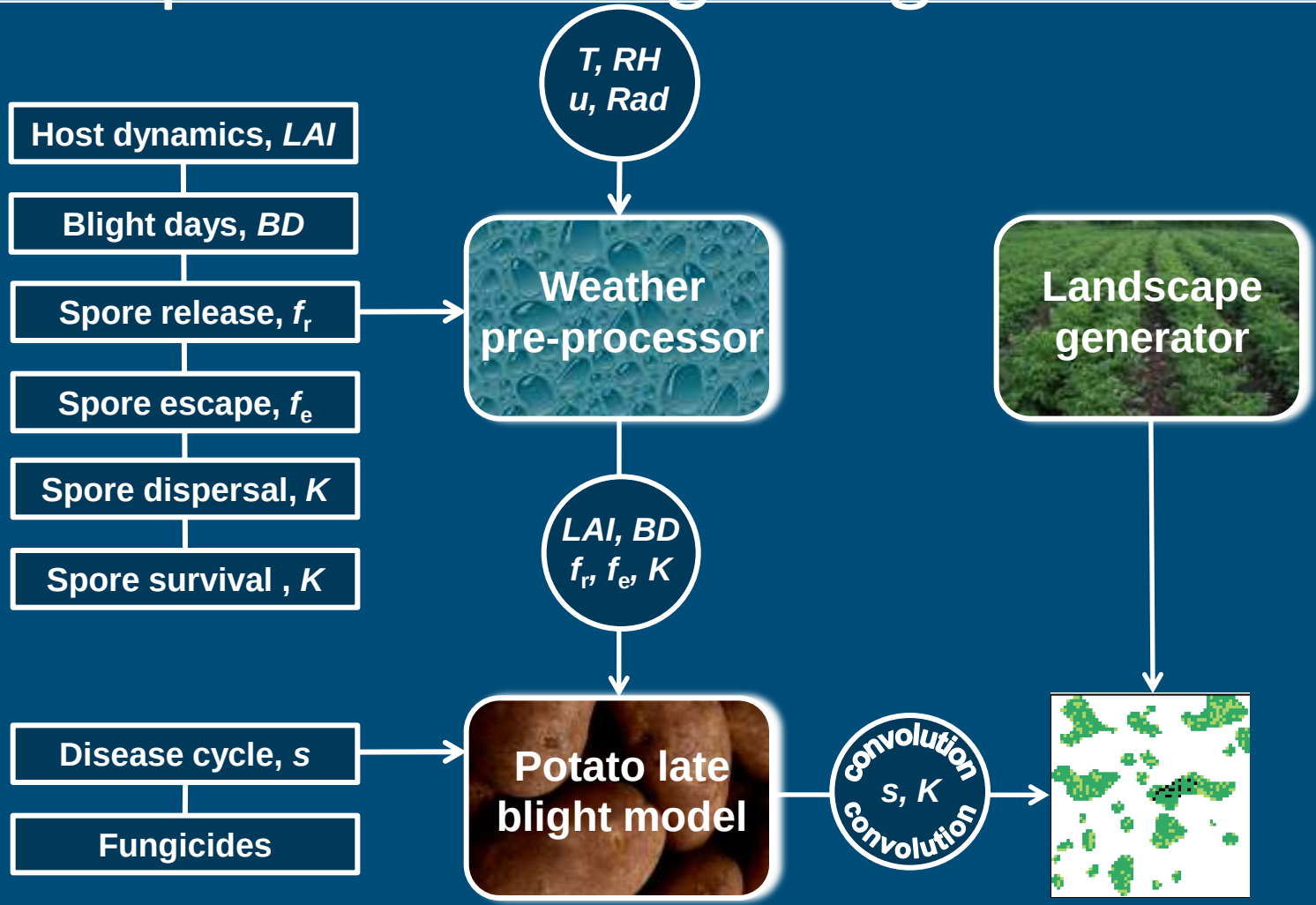
Helicopter Screening using simulation

Simulation framework



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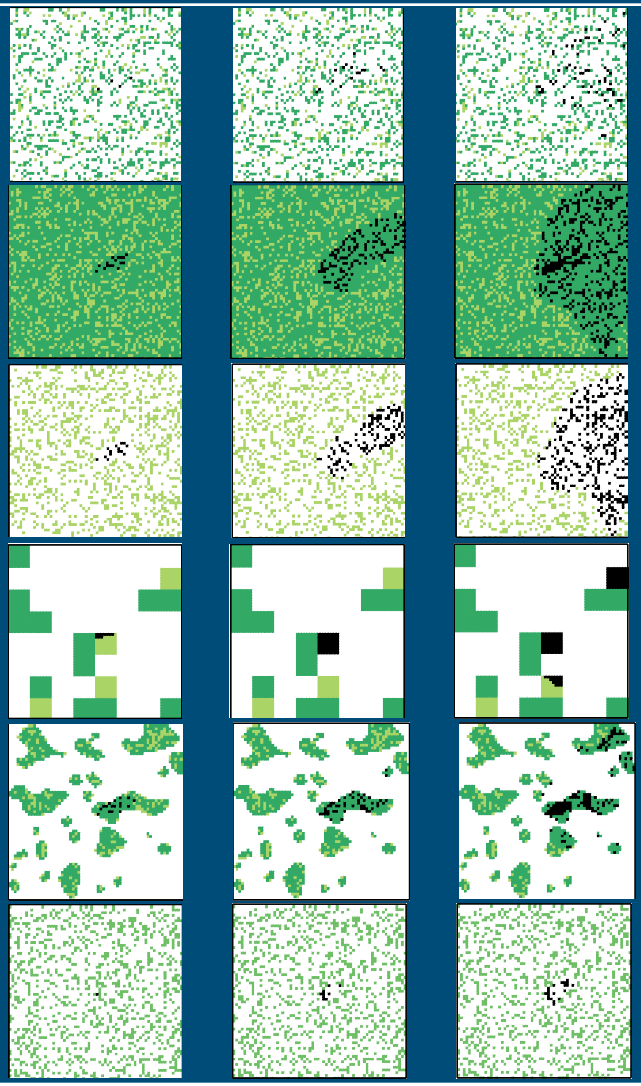
Summary of results

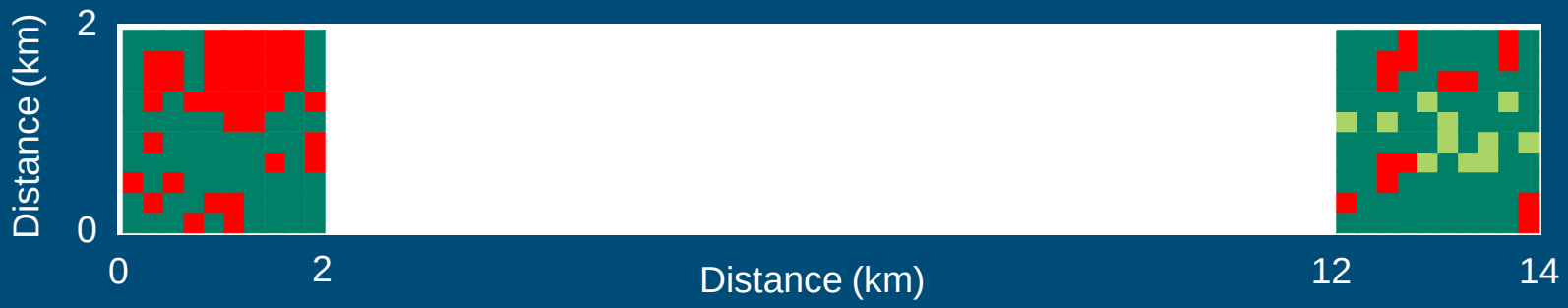
- 6.4 x 6.4 km / ¼ potato / ¼ susceptible / 1 ha fields / random
- 6.4 x 6.4 km / 100% potato / 1/4 susceptible / 1 ha fields / random
- 6.4 x 6.4 km / ¼ potato / 100% susceptible / 1 ha fields / random
- 6.4 x 6.4 km / ¼ potato / 1/4 susceptible / 64 ha fields / random
- 6.4 x 6.4 km / ¼ potato / ¼ susceptible / 1 ha fields / clustered
- 6.4 x 6.4 km / ¼ potato / mengsels / 1 ha fields / random

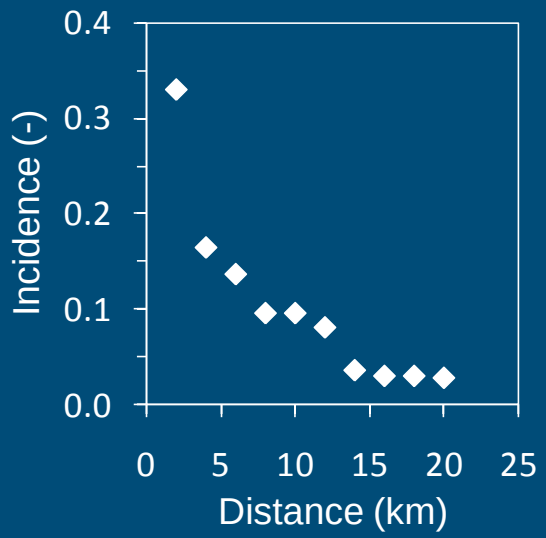


- I = 0.06
- I = 0.15
- I = 0.34
- I = 0.11
- I = 0.11
- I = 0.02

Separation of growing regions

- Can we create spatial barriers that completely prevent spread?

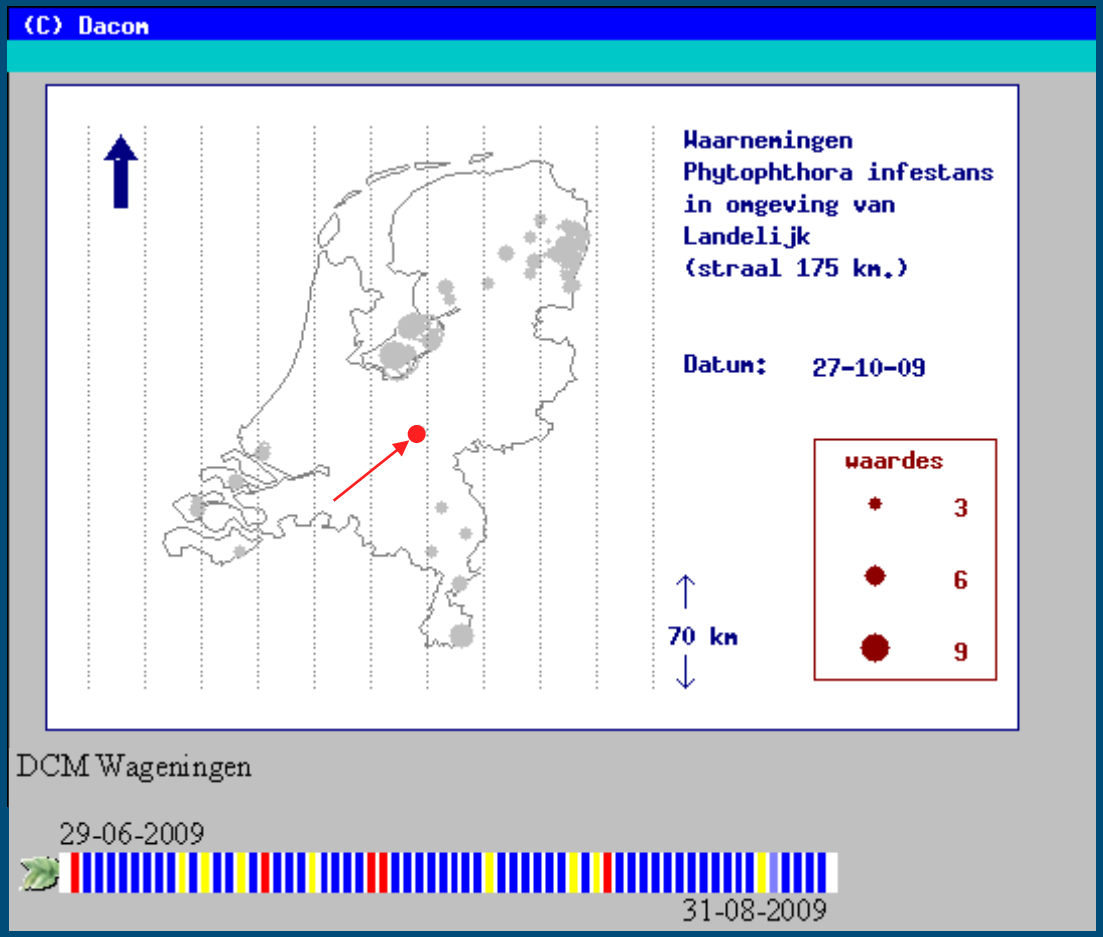




Some Early Conclusions

- Large fields containing 1 potato genotype maximize the chance for P. infestans to deposit sporangia on susceptible hosts.
- Mixing within fields minimizes the chance that sporangia are deposited on susceptible hosts.
- Large fields result in faster colonization of the region than small fields.
- Mixing at smaller spatial scales is more effective.
- P. infestans has an enormous ability to spread over large distances. All geographic barriers tested were overcome (in the end).
- P. infestans populations can be significantly reduced through smart spatial deployment of R-genes.

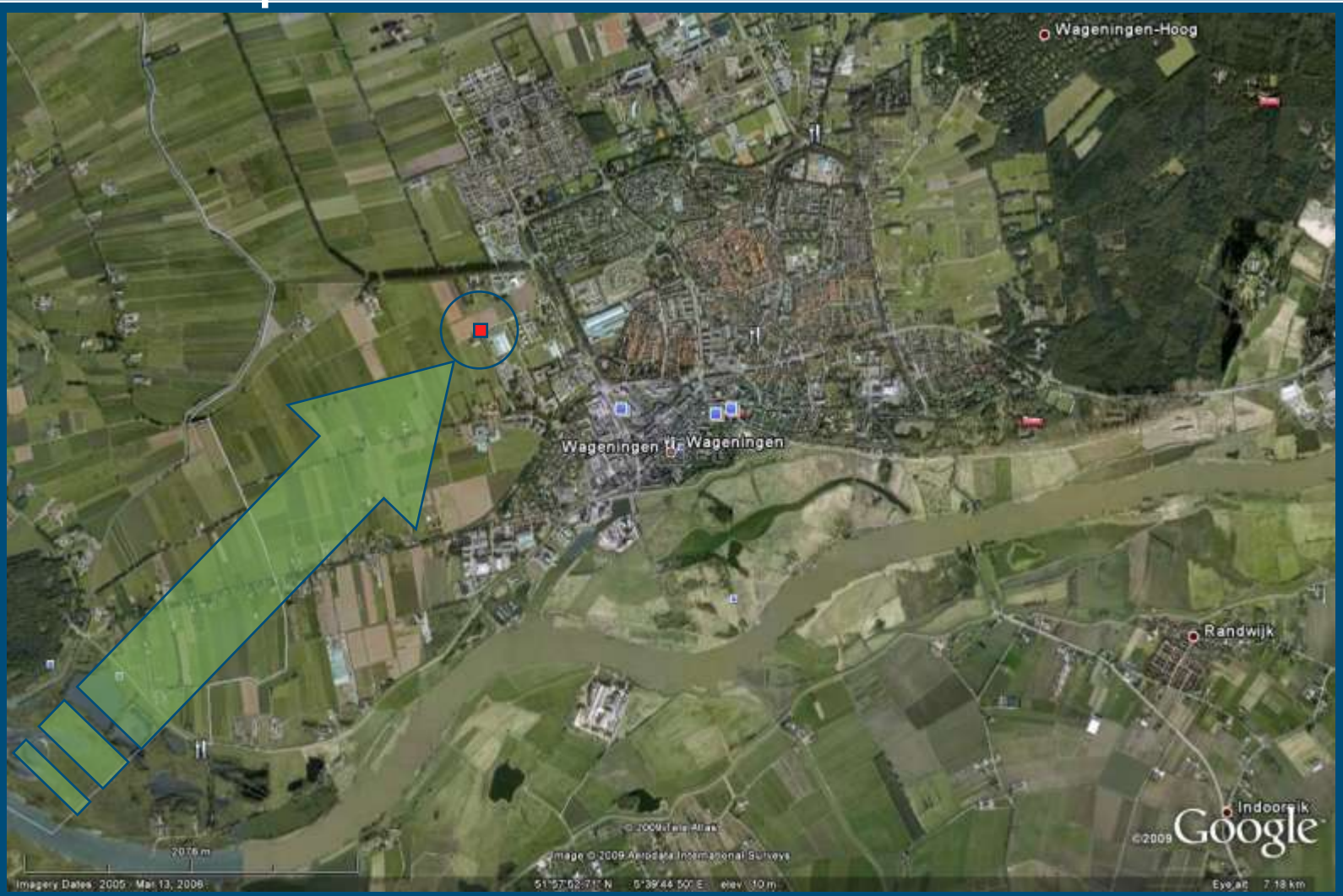
DuRPh Field experiment 2009



Effect of mixing ratios S/R on focal expansion potato late blight infection

www.kennisakker.nl

Field experiment 2009



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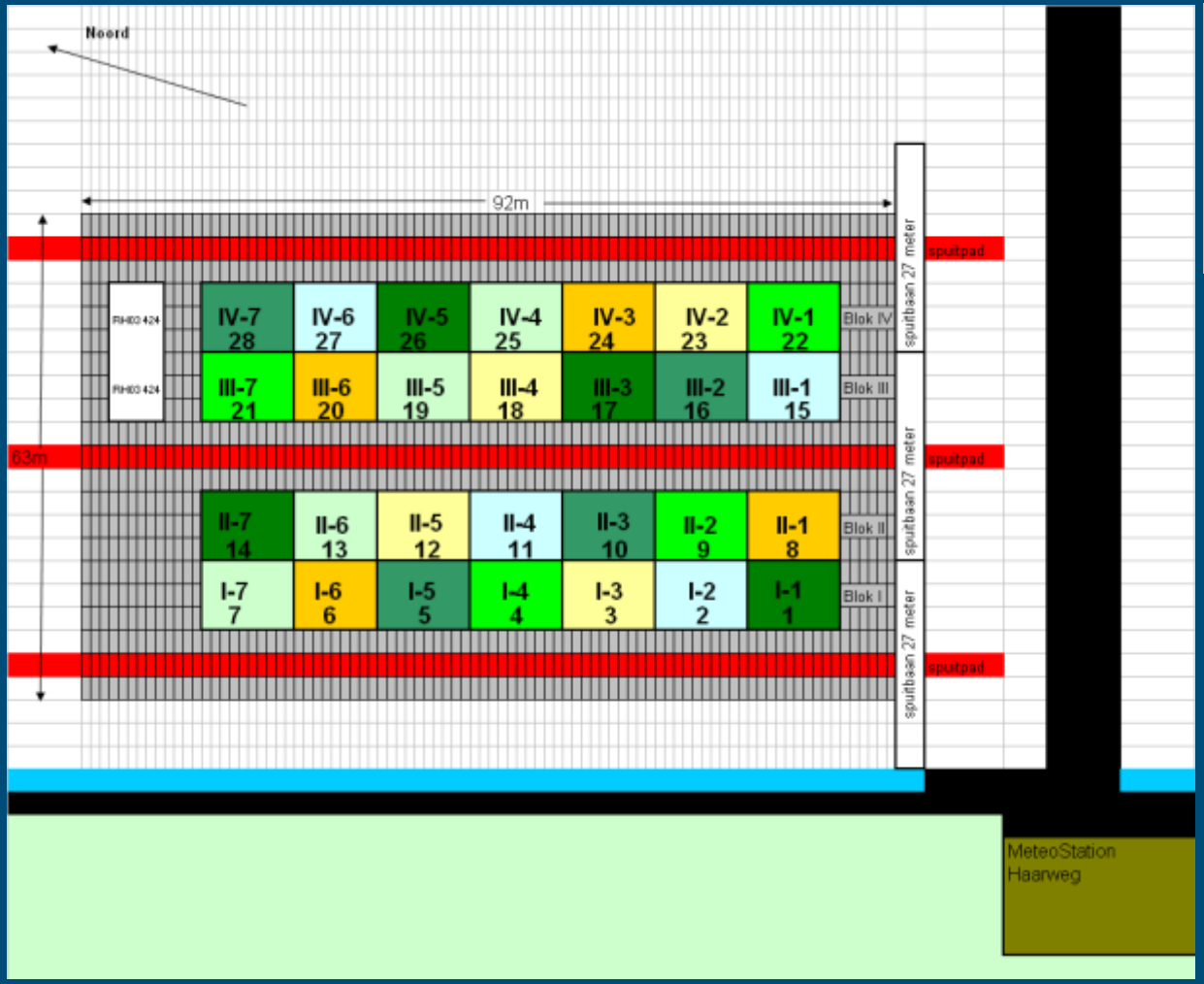
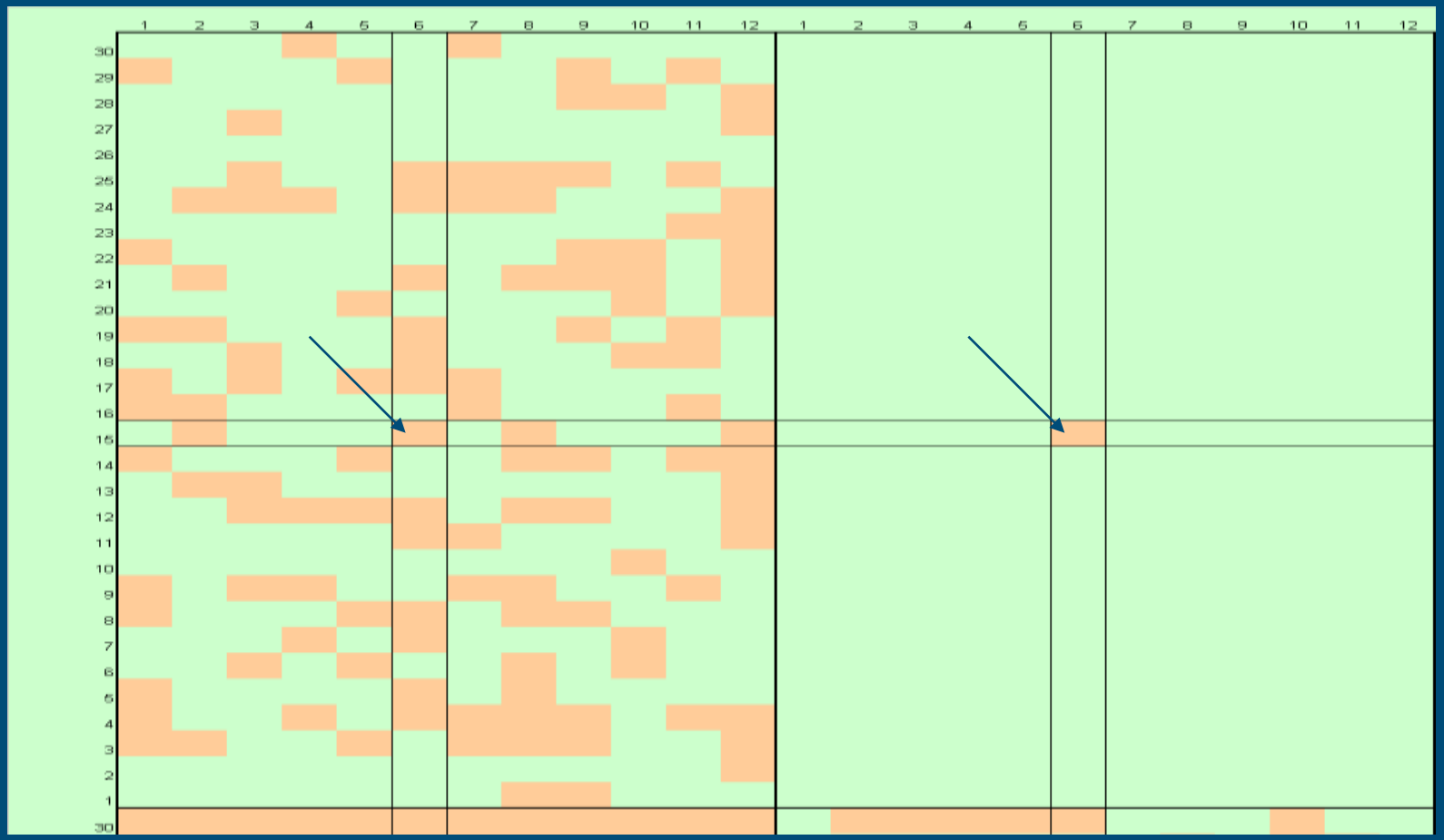
Field experiment 2009

Field experiment 2009 Lay out



7	mengverhoudingen		
Nr	Bionica	Lady Rosetta	% resistentie
A	0	1	0.0
B	1	2	33.3
C	1	1	50.0
D	2	1	66.7
E	3	1	75.0
F	4	1	80.0
G	1	0	100.0

Random distribution of S & R



Plot: 10 x 10m

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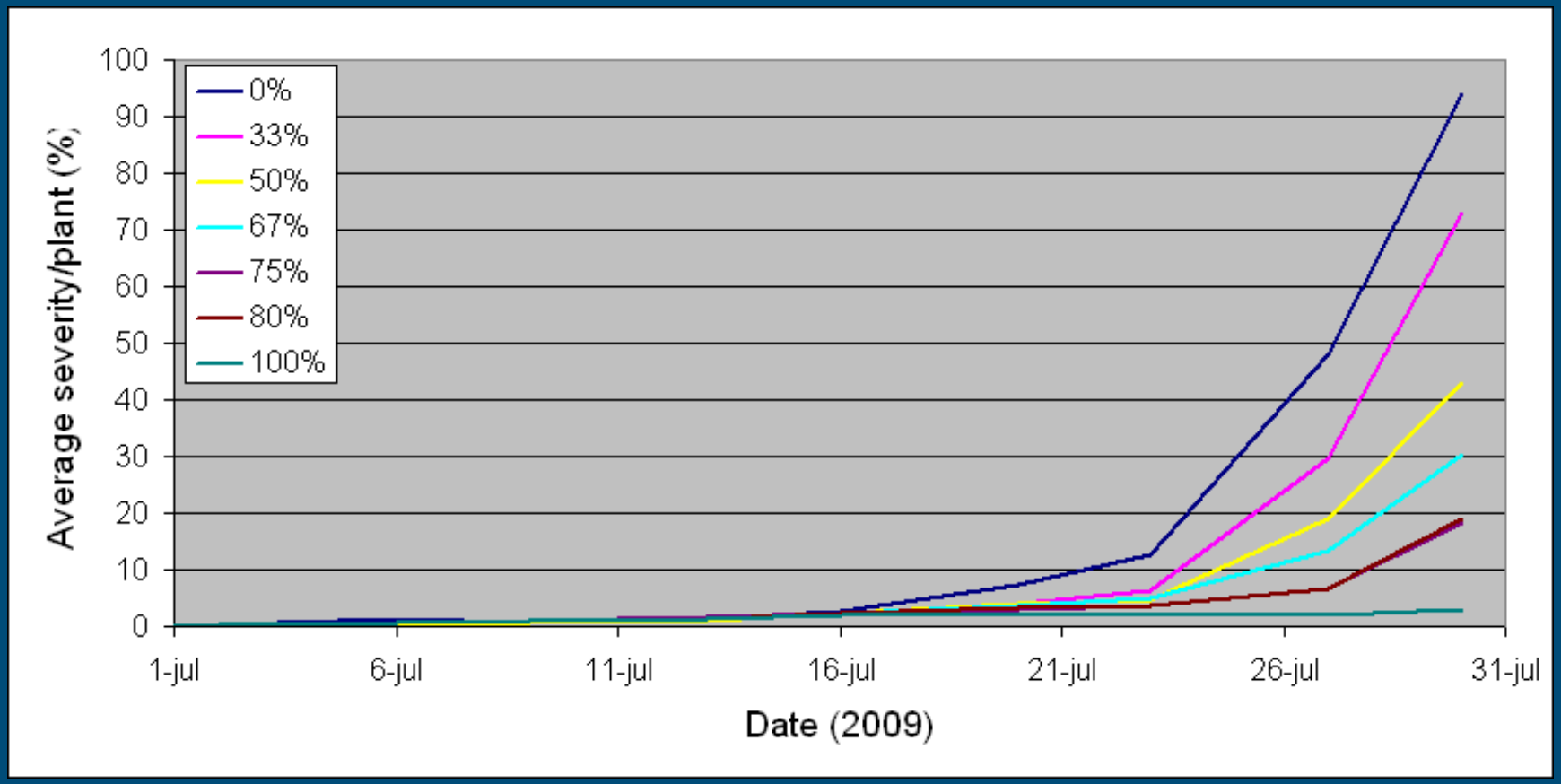
P. infestans NL08158 on Lady Rosetta and Bionica

Lady Rosetta (S)

Bionica (Blb2)

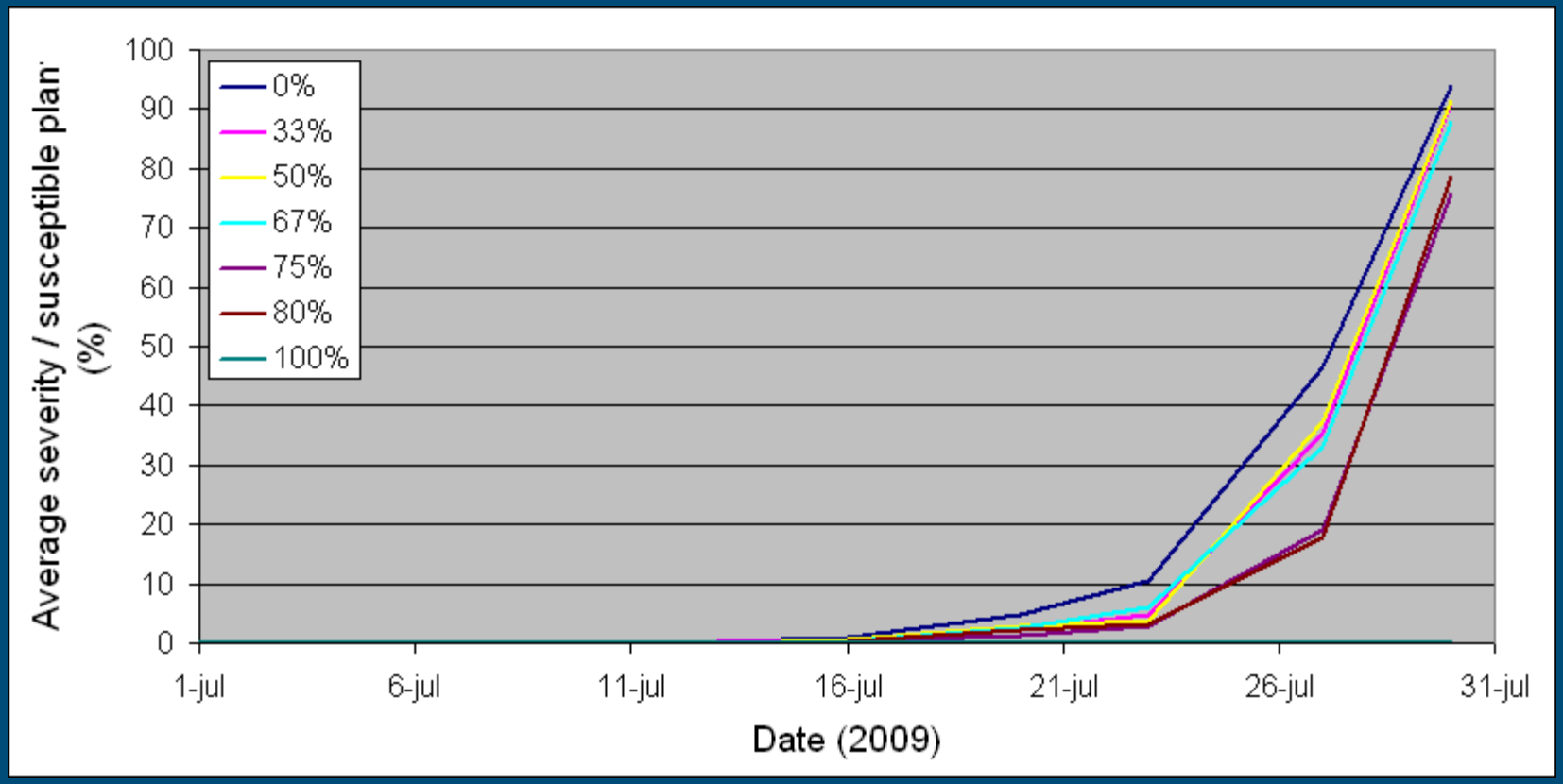
Field experiment 2009

Average severity per plant (S + R)



Veldproef 2009

Average severity per susceptible (!) plant



Infection on 30 july 2009

30 july 2009

Bionica

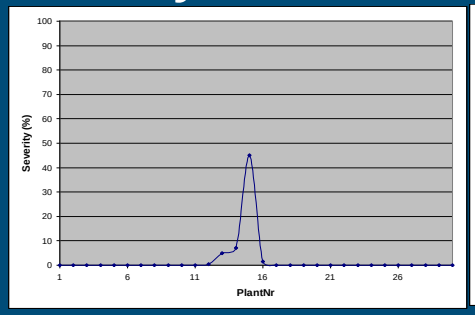
RH03-424 / S. mira / Toluca

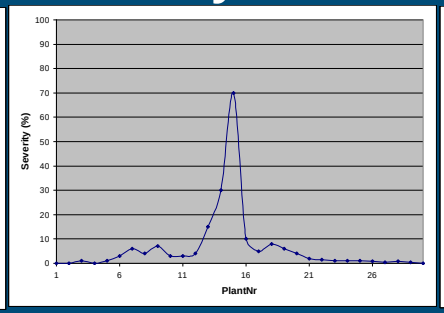
Toluca

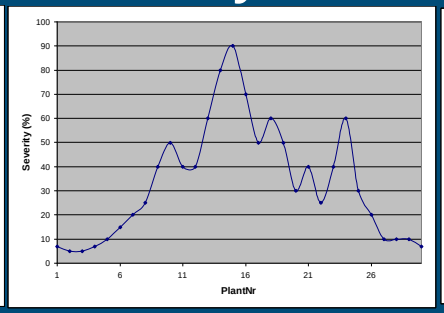
Epidemic development

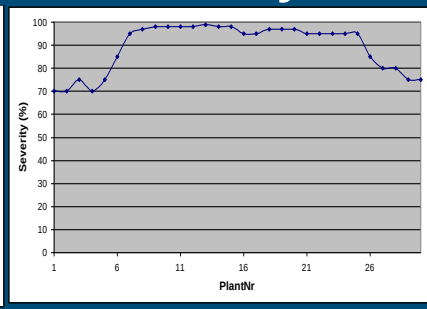
13 July | 20 July | 27 July | 30 July

0% R

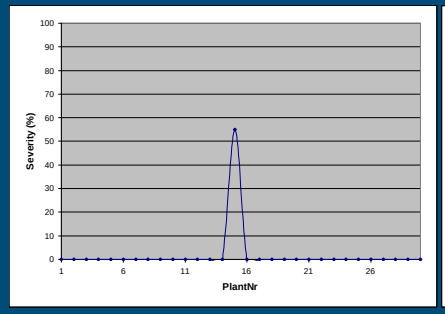


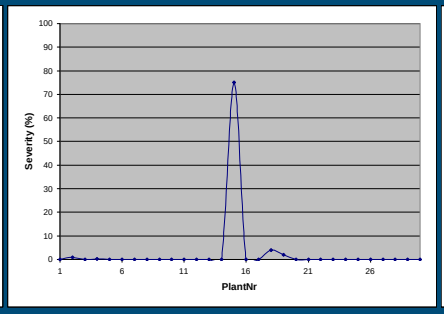


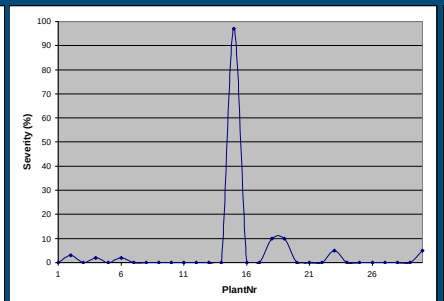


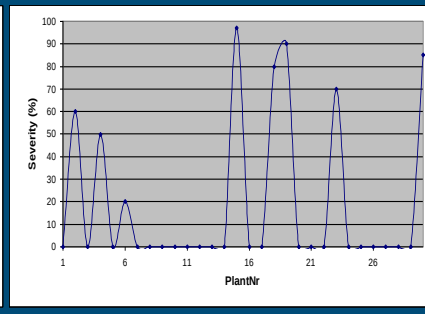


80% R









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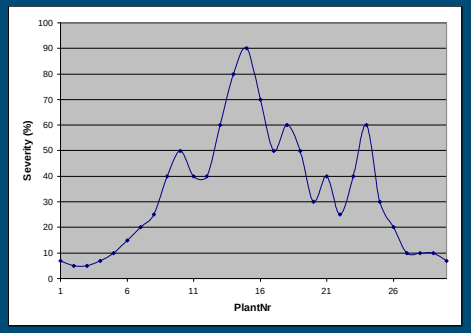
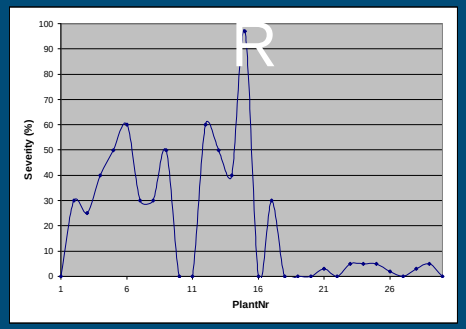
Field experiment 27 july 2009

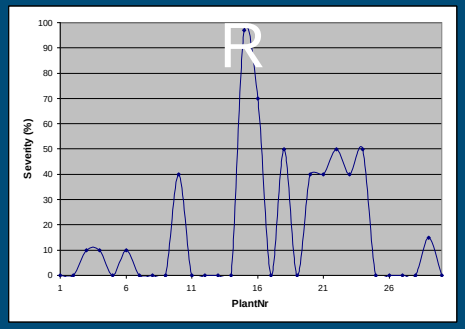
0% R



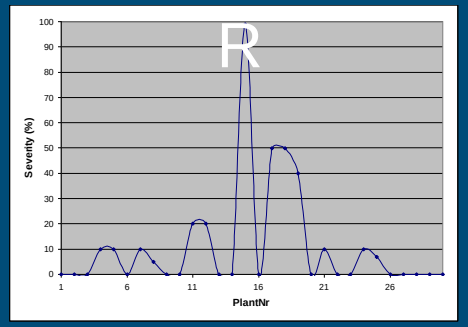
33%



50%



67%



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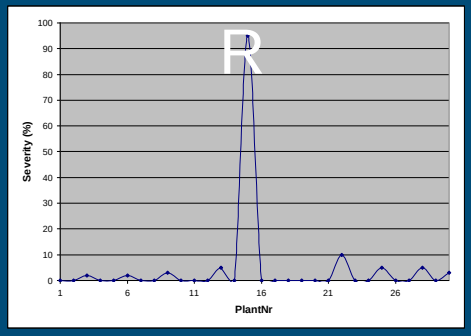

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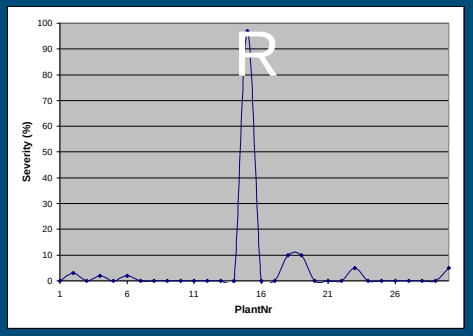

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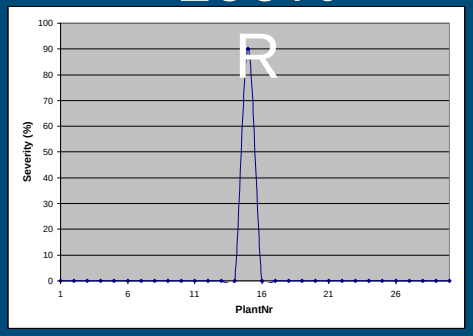

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Conclusions

- Effects of mixing R/S visible up to late in the epidemic
- Mixing of R/S significantly reduces the average severity per plant and thus also the spore production per m2 soil
- Mixing also reduces average severity of susceptible plants
- Overall: Mixtures >= 75%R can be valuable to control PLB
  → 4 – 5 lines in a dynamic cultivar
- Bionica & Lady Rosetta combined well in terms of earliness and plant type
- Bionica infected in the end

Thank you for your attention!