

Potato late blight Control strategies based on cultivar resistance and virulence in the local *P. infestans* population

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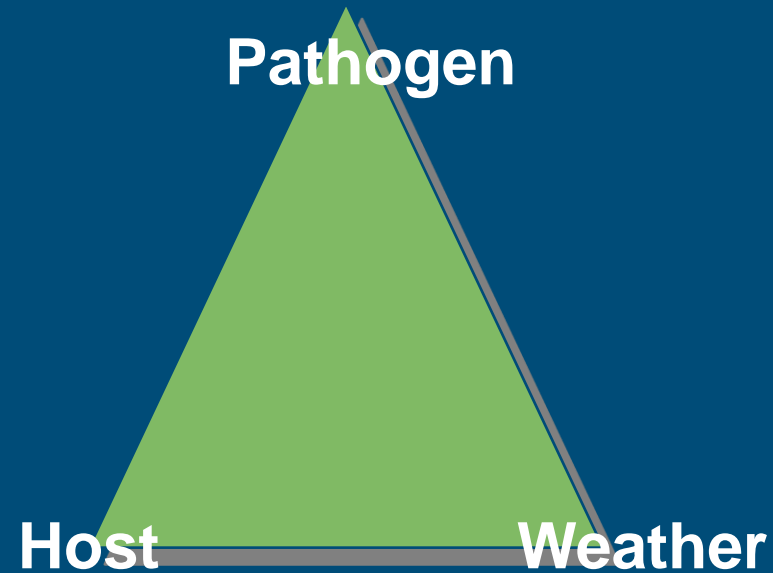


Outline

- Concepts
- (Molecular) Virulence assays
- Field experiments
- Results
- Conclusions and discussion

Spray decision ... some Concepts

- Weekly sprays
 - Host is present
- Crop protection 1.0 / DSS 1.0
 - Host is present
 - Weather is suitable for infection
- Crop protection 2.0 / DSS 2.0
 - Host is present
 - Susceptible
 - Resistant
 - Weather is suitable for infection
 - DWIP; Length critical period
 - Pathogen is present (→ quantitative disease pressure)
 - Specific pathogen genotypes are present:
 - » **Virulence**
 - » Fungicide resistance



Hypothesis

- Monitoring of virulence is an added value to PLB control
 - More efficient / cost effective with respect to resources
 - Improved durability of R-genes

Field experiments

- 2010 and 2011
- Two locations: Lelystad and Valthermond
- Range of resistance levels: S – MR – HR
- Standard WUR control strategy:
 - Critical periods → yes / no for spray
 - Fungicide degradation
 - Host Resistance → reduced protectant dose rates
 - DWIP → go / no go on resistant cultivars
 - Length of critical period → reduction of dose rate
- WUR spray advice with or without virulence information:
 - Without: Cultivars are sprayed whole season (reduced dose rates etc)
 - With: Cultivars are NOT sprayed unless virulence is detected

Field experiments

■ Proof of principle:

- 2 years
- 2 locations (Lelystad & Valthermond)
- 6 levels of cultivar resistance:

| | | | |
|--|----|----|---------------------------|
| • Bintje/Starga | S | | 100% dose rate protectant |
| • Escort (R1R3R10) or Santé (R1R10) rate protectant | | MR | 50% dose |
| • Bionica (Blb2) | HR | | 25% dose rate protectant |
| • Chc1 | HR | | 25% dose rate protectant |
| • Sto1 | HR | | 25% dose rate protectant |
| • Vnt1 | HR | | 25% dose rate protectant |

- Monitoring plots surrounding spray experiment
 - Small plots containing 6 plants of each genotype
 - 20 - 50 monitoring plots / experiment

Virulence monitoring

■ Monitoring plots

- Weekly lesion counts
- Weekly lesion samples
 - → molecular virulence assays:
 - Sto1 (2010 & 2011)
 - Vnt1 (2011)
 - Results available within 24 hours of sampling
- Bio assays in the autumn (validation)

Operational use
in spray
decisions

Vnt1 virulence assay within 5 hours

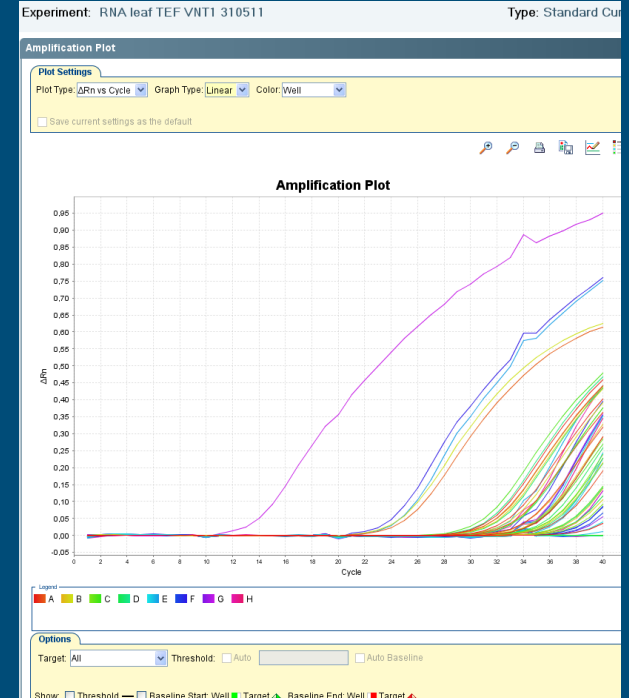
virulent avirulent



Controle

Vnt1

| 3 | 4 |
|--------------|------------|
| L+PP 10-0787 | L+NL10-422 |
| L+PP 10-0787 | L+NL10-422 |
| L+PP 10-0787 | L+NL10-422 |
| L+PP 10-0787 | L+NL10-422 |
| L+PP 10-0787 | L+NL10-422 |
| L+PP 10-0787 | L+NL10-422 |
| L+PP 10-0787 | L+NL10-422 |
| 30.24 | 31.47 |
| 30.54 | 33.77 |
| 32.21 | 33.86 |
| 32.24 | 33.91 |
| Undetermined | 33.55 |
| Undetermined | 37.70 |
| Undetermined | 38.27 |
| Undetermined | 32.16 |



Lelystad 2010



Valthermond 2010



PLANT RESEARCH INTERNATIONAL

WAGENINGEN UR

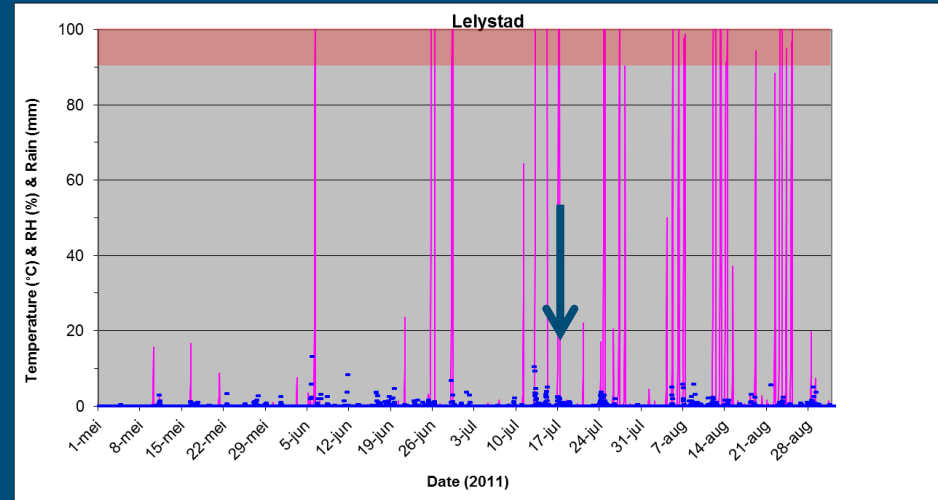
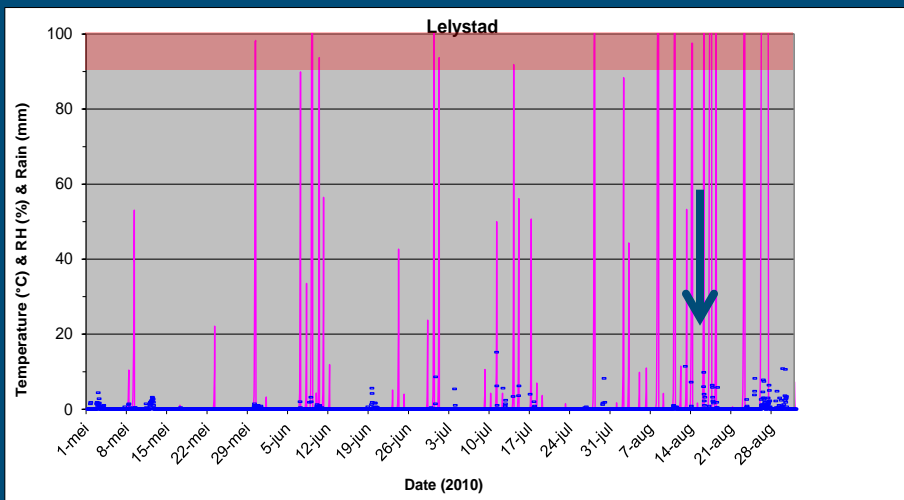
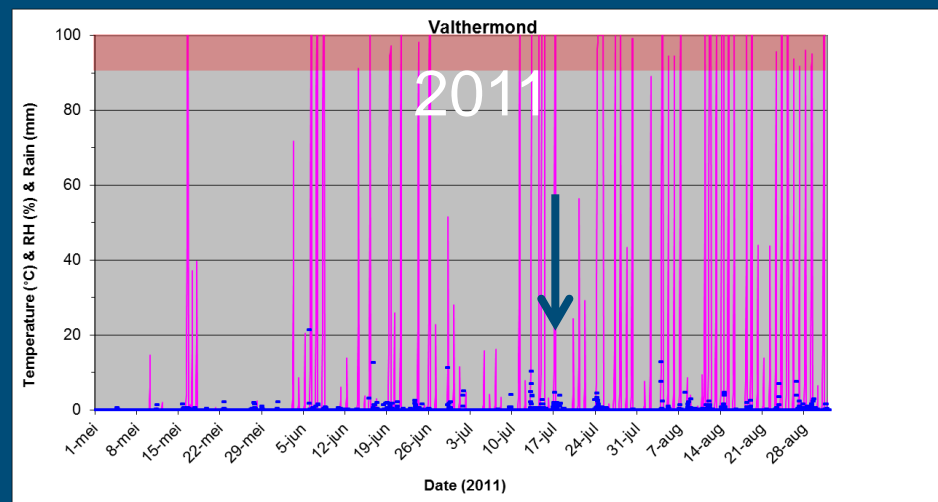
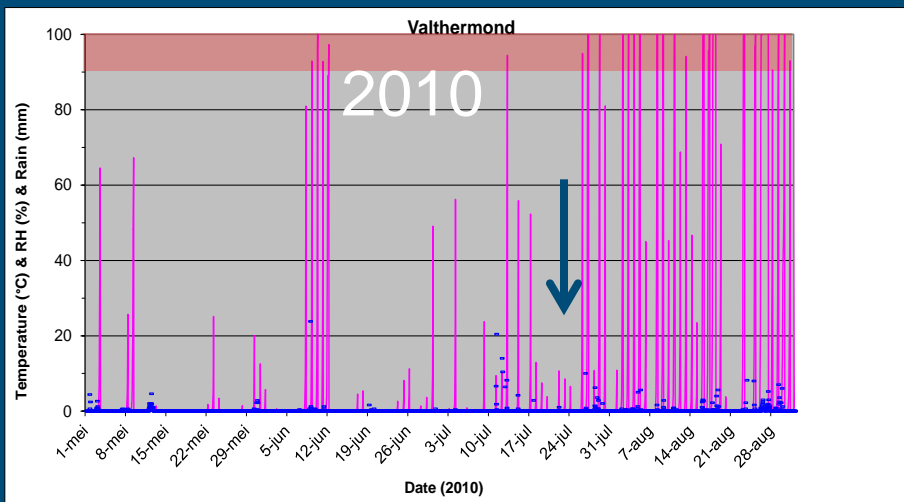
Lelystad 2011



Monitoring plots Lelystad & Valthermond



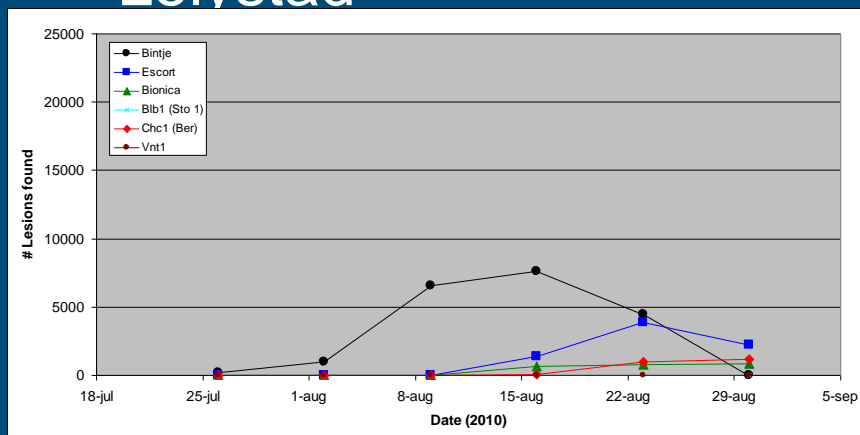
Infection risks 2010 & 2011



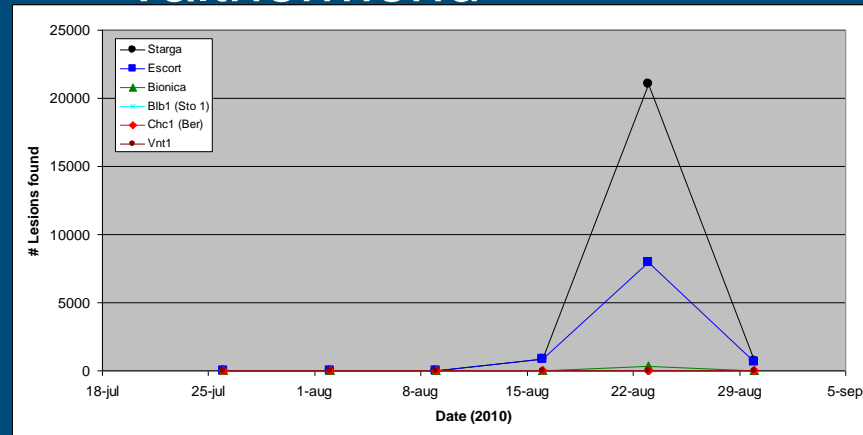
Lesion counts monitoring plots 2010

| | | Date | | | | | | | |
|-------------|------------|-------------|------------|------------|-------------|-------------|-------------|----------------------|--|
| Location | Data | 26-jul-2010 | 2-aug-2010 | 9-aug-2010 | 16-aug-2010 | 23-aug-2010 | 30-aug-2010 | Sum 26 jul - 30 Aug. | |
| Lelystad | Bintje | 194 | 959 | 6589 | 7595 | 4473 | 0 | 19810 | |
| | Escort | 1 | 3 | 3 | 1364 | 3844 | 2240 | 7455 | |
| | Bionica | 2 | 5 | 1 | 664 | 795 | 826 | 2293 | |
| | Sto1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | |
| | Chc1 (Ber) | 0 | 0 | 2 | 36 | 990 | 1158 | 2186 | |
| | Vnt1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Location | Data | 26-jul-2010 | 2-aug-2010 | 9-aug-2010 | 16-aug-2010 | 23-aug-2010 | 30-aug-2010 | Sum 26 jul - 30 Aug. | |
| Valthermond | Starga | 0 | 0 | 0 | 840 | 21061 | 699 | 22600 | |
| | Escort | 0 | 0 | 0 | 862 | 7980 | 654 | 9496 | |
| | Bionica | 0 | 0 | 0 | 3 | 317 | 2 | 322 | |
| | Sto1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Chc1 (Ber) | 0 | 0 | 0 | 0 | 1 | 3 | 4 | |
| | Vnt1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Sum | | | | | | | | 64167 | |

Lelystad



Valthermond



Lesion counts Monitoring plots 2011

| Location | Date | Starga / Bintje | Sto1 | Bionica | Chc1 | Santé | Vnt1 |
|--------------------|-----------|-----------------|------|---------|------|-------|------|
| Valthermond | 27-jun-11 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 4-jul-11 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 11-jul-11 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 18-jul-11 | 11 | 0 | 0 | 0 | 0 | 0 |
| | 25-jul-11 | 46 | 0 | 0 | 0 | 110 | 147 |
| | 1-aug-11 | 1227 | 0 | 45 | 0 | 615 | 1381 |
| | 8-aug-11 | 33 | 0 | 300 | 26 | 8 | |
| | 15-aug-11 | 2 | 18 | 179 | 7 | 10 | |
| | | | | | | | |
| Lelystad | 4-jul-11 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 11-jul-11 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 18-jul-11 | 31 | 0 | 0 | 0 | 0 | 0 |
| | 25-jul-11 | 862 | 0 | 0 | 0 | 290 | 271 |
| | 1-aug-11 | | 0 | 264 | 29 | 114 | 232 |
| | 8-aug-11 | | 4 | 44 | 25 | | 2 |
| | 15-aug-11 | | 6 | 18 | 25 | | 160 |
| | | | | | | | |

Sto1 Effector screening 2010

- 633 Lesion samples
- 75 NON *P. infestans*
- 557 avirulent foot Sto1
- 1 virulent isolate Sto1 ...
Confirmed in Bio Assay!

| Data | Lelystad | Valthermond |
|--------------|----------|-------------|
| Bintje | 19810 | |
| Starga | | 21901 |
| Escort | 5205 | 8842 |
| Bionica | 1072 | 320 |
| Chc1 (= Ber) | 288 | 1 |
| Vnt1 | 0 | 0 |
| Sto1 | 0 | 0 |

| | | | | |
|---------|---------------|-------------|------|--------------|
| Blb2 | LS-17-Bionica | | 4C10 | AVIRULENT |
| R1R3R10 | LS-17-Escort | 18-aug-2010 | 4C11 | AVIRULENT |
| R1R3R10 | LS-17-Escort | | 4C12 | AVIRULENT |
| R1R3R10 | LS-18-Escort | 18-aug-2010 | 4D1 | AVIRULENT |
| R1R3R10 | LS-18-Escort | | 4D2 | AVIRULENT |
| Blb2 | LS-18-Bionica | 18-aug-2010 | 4D3 | VIRULENT |
| Blb2 | LS-18-Bionica | | 4D4 | AVIRULENT |
| Blb2 | LS-19-Bionica | | 4D5 | NO INFESTANS |

Sto1 Effector screening 2011

| Sto1 Virulentie | | Bintje | Bionica | Sto1 | Chc1 | Santé | Vnt1 | Totals |
|-----------------|--------------------|--------|---------|------|------|-------|------|--------|
| Lelystad | 18-jul-2011 | | | | | | | |
| | Avirulent | 13 | 0 | 0 | 0 | 0 | 1 | 14 |
| | Virulent | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 25-jul-2011 | | | | | | | |
| | Avirulent | 34 | 1 | 0 | 0 | 35 | 35 | 105 |
| | Virulent | 1 | 2 | 0 | 0 | 0 | 1 | 4 |
| | 1-aug-2011 | | | | | | | |
| | Avirulent | 0 | 25 | 0 | 18 | 10 | 13 | 66 |
| | Virulent | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | 8-aug-2011 | | | | | | | |
| | Avirulent | 0 | 16 | 1 | 4 | 0 | 2 | 23 |
| | Virulent | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| | 15-aug-2011 | | | | | | | |
| | Avirulent | 0 | 5 | 0 | 1 | 0 | 8 | 14 |
| | Virulent | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Totals | | 48 | 50 | 2 | 23 | 45 | 60 |
| Sto1 Virulentie | | Starga | Bionica | Sto1 | Chc1 | Santé | Vnt1 | Totals |
| Valthermond | 18-jul-2011 | | | | | | | |
| | Avirulent | 4 | 0 | 0 | 0 | 0 | 0 | 4 |
| | Virulent | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 25-jul-2011 | | | | | | | |
| | Avirulent | 16 | 0 | 0 | 0 | 23 | 21 | 60 |
| | Virulent | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1-aug-2011 | | | | | | | |
| | Avirulent | 29 | 21 | 0 | 2 | 23 | 20 | 95 |
| | Virulent | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 8-aug-2011 | | | | | | | |
| | Avirulent | 2 | 28 | 0 | 13 | 2 | 0 | 45 |
| | Virulent | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 15-aug-2011 | | | | | | | |
| | Avirulent | 2 | 20 | 7 | 3 | 4 | 0 | 36 |
| | Virulent | 0 | 0 | 4 | 0 | 0 | 0 | 4 |
| | Totals | | 53 | 69 | 11 | 18 | 52 | 41 |

← Switch:
Not sprayed → sprayed

← Switch:
Not sprayed → sprayed

Summary Infection levels & sprays 2011

| | Ras | Monitoring | 19-jul-2011 | 25-jul-2011 | 01-aug-2011 | 08-aug-2011 | 15-aug-2011 | 22-aug-2011 | 29-aug-2011 | 05-sep-2011 | # Bespuitingen | Som relatieve doseringen | |
|-----------------|--------------------|------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|----------------|--------------------------|-------|
| Lelystad | Binthe | Met | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.00 | 10.00 | |
| | Binthe | Zonder | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.00 | 10.00 | |
| | Santé | Met | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.03 | 15.00 | 5.75 | |
| | Santé | Zonder | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.03 | 15.00 | 5.75 | |
| | Bionica | Met | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.00 | 1 | |
| | Bionica | Zonder | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 2.5 | |
| | Vnt1 | Met | 0.00 | 0.10 | 0.04 | 0.10 | 0.10 | 0.04 | 0.00 | 0.10 | 8.00 | 7.25 | |
| | Vnt1 | Zonder | 0.00 | 0.07 | 0.00 | 0.07 | 0.04 | 0.00 | 0.00 | 0.00 | 12.00 | 8.25 | |
| | Chc1 | Met | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.00 | 1.50 | |
| | Chc1 | Zonder | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 12.00 | 3.00 | |
| | Sto1 | Met | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.00 | 1.50 | |
| | Sto1 | Zonder | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 12.00 | 3.00 | |
| | Ras | Met | 19-jul-2011 | 25-jul-2011 | 01-aug-2011 | 08-aug-2011 | 15-aug-2011 | 22-aug-2011 | 29-aug-2011 | 05-sep-2011 | | | |
| | Valthermond | Starga | Met | 0.00 | 0.00 | 0.00 | 0.68 | 3.08 | 3.08 | 3.08 | 3.08 | 14.00 | 13.75 |
| | | Starga | Zonder | 0.00 | 0.01 | 0.09 | 1.86 | 2.00 | 2.00 | 2.00 | 2.00 | 14.00 | 13.75 |
| | | Santé | Met | 0.00 | 0.00 | 0.03 | 0.76 | 3.42 | 3.42 | 4.25 | 4.50 | 13.00 | 9.75 |
| Santé | | Zonder | 0.00 | 0.00 | 0.05 | 0.92 | 4.17 | 4.17 | 4.17 | 4.17 | 12.00 | 9.00 | |
| Bionica | | Met | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.02 | 0.03 | 0.03 | 5.00 | 3.5 | |
| Bionica | | Zonder | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 12.00 | 5.25 | |
| Vnt1 | | Met | 9.18 | 0.40 | 3.25 | 7.00 | X | X | X | X | 3.00 | 3.00 | |
| Vnt1 | | Zonder | 0.00 | 0.03 | 0.53 | 3.18 | X | X | X | X | 9.00 | 4.50 | |
| Chc1 | | Met | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.08 | 5.00 | 2.00 | |
| Chc1 | | Zonder | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 13.00 | 4.00 | |
| Sto1 | | Met | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.00 | 1.75 | |
| Sto1 | | Zonder | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 13.00 | 4.00 | |



Results 2010

| Plaats | Ras | Resistentieniveau | Monitoring? | Aantasting eind seizoen | Aantal bespuitingen | TFI ¹ | Reductie door resistentie ² | Reductie door monitoring ³ | |
|----------|--|--|-------------|-------------------------|--|------------------|--|---------------------------------------|----|
| Lelystad | Bintje | Vatbaar | Nee | << 0.1% | 10 | 7.5 | 0% | | |
| | Bintje | Vatbaar | Ja | << 0.1% | 10 | 7.5 | | 0% | |
| | Escort | Matig resistent | Nee | 0 | 9 | 6 | 20% | | |
| | Escort | Matig resistent | Ja | 0 | 9 | 6 | | 0% | |
| | Bionica | Hoog Resistent | Nee | 0 | 6 | 1.5 | 80% | | |
| | Bionica | Hoog Resistent | Ja | 0 | 4 | 1 | | 33% | |
| | Sto1 | Hoog Resistent | Nee | 0 | 7 | 1.75 | 77% | | |
| | Sto1 | Hoog Resistent | Ja | 0 | 0 | 0 | | 100% | |
| | Chc1 | Hoog Resistent | Nee | n.d. | n.d. | n.d. | n.d. | | |
| | Chc1 | Hoog Resistent | Ja | n.d. | n.d. | n.d. | | n.d. | |
| | Vnt1 | Hoog Resistent | Nee | 0 | 7 | 1.75 | 77% | | |
| | Vnt1 | Hoog Resistent | Ja | 0 | 0 | 0 | | 100% | |
| | Valthermond | Starga | Vatbaar | Nee | << 0.1% | 11 | 10 | 0% | |
| | | Starga | Vatbaar | Ja | << 0.1% | 11 | 10 | | 0% |
| Escort | | Matig resistent | Nee | 0 | 11 | 6.75 | 33% | | |
| Escort | | Matig resistent | Ja | 0 | 11 | 6.75 | | 0% | |
| Bionica | | Hoog Resistent | Nee | 0 | 9 | 3 | 70% | | |
| Bionica | | Hoog Resistent | Ja | 0 | 4 | 1.75 | | 42% | |
| Sto1 | | Hoog Resistent | Nee | 0 | 9 | 3 | 70% | | |
| Sto1 | | Hoog Resistent | Ja | 0 | 0 | 0 | | 100% | |
| Chc1 | | Hoog Resistent | Nee | 0 | 9 | 3 | 70% | | |
| Chc1 | | Hoog Resistent | Ja | 0 | 3 | 0.75 | | 75% | |
| Vnt1 | | Hoog Resistent | Nee | 0 | 9 | 3 | 70% | | |
| Vnt1 | | Hoog Resistent | Ja | 0 | 0 | 0 | | 100% | |
| 1 | | Treatment Frequency Index: | | = | Equivalent aantal bespuitingen met 100% dosering | | | | |
| 2 | | Reductie in benodigde fungiciden input t.o.v. het vatbare ras zonder gebruik van monitoringsinformatie | | | | | | | |
| 3 | Reductie in benodigde fungiciden input t.o.v. hetzelfde ras zonder gebruik van monitoringsinformatie | | | | | | | | |



Conclusions

- 2010: Severe infection pressure 2nd half of the season
- 2011: Severe infection pressure since June
- Monitoring plots:
 - 2010: Infection on all genotypes except Vnt1
 - 2011: Infection on all genotypes
 - More resistant → increasing delay of infection
- Molecular monitoring Sto1 virulence:
 - 1x in 2010 (Lelystad)
 - 10x in 2011, Lelystad and Valthermond
 - On any variety of potato / genotypes, especially in 2011
- Control strategies
 - Lelystad: OK in both years
 - Valthermond:
 - OK in 2010 and 2011 on R material
 - insufficient on S & MR objects in 2011



Conclusions

- Resistance:
 - Highly valuable addition to PLB control strategy
 - More efficient use of available resources (Fungicides & R-genes)
 - Better results (compared to S / MR material)

- Monitoring of virulence is an added value to PLB control strategy
 - More efficient way of using resources / more cost effective
 - Durability of resistance

- Robustness of molecular assays

The complete control strategy

- Resistance: stacking → R-gene cassettes
- Virulence monitoring
 - No virulence → do not spray
 - Virulence → Spray reduced dose rates before CP's
 - Exchange the R-gene (cassette) ... Dynamic cultivars: GM approach
- PLB buffering agricultural fields / landscapes