Tactical sciences for plant viruses to foster food security: the potato case

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Belgian scientific plant health symposium
15/10/2020 - Online

Food security and plant pathogens/pests in 2020

for a fair, healthy and environmentally-friendly food system

Healthy production
Healthy environment

Healthy processing
Healthy consumption
Healthy socio-economic relations
Plant health in 2020, the covid-19 year

“Pay a little now or pay a lot more later”

Prevention is significantly less expensive than containing and eradicating an outbreak.

Pandemics may cause significant global economic slowdown.

The eradication of a disease can take several years and cost millions of dollars.

Acting before a crisis averts is a far more cost-effective approach.

Access to a safe and stable supply of food is now more crucial than ever.

While Covid-19 is affecting human health, plant pests and diseases continue to pose a threat to food security.

A threat to plant health is a threat to the health and prosperity of people, especially the most vulnerable.
Plant Health threats

- **Well-known established, yet continuous threats**
  
  *Phytophthora infestans* – late blight in potato

- **New emerging threats**
  
  *Changing conditions, changing food consumption patterns, etc.*
  
  ‘*Candidatus Liberibacter solanacearum*’ - zebra chip

- **Introduced threats**
  
  Globalisation & international trade
  
  Sweet potato diseases

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Food safety & (bio)security

*It starts at the ports of entry*
### Phytosanitary risks by “uncontrolled” introductions

#### E-commerce as a pest pathway

- Internet is a convenient means for products to bypass the application of phytosanitary measures or scrutiny through PRA
- Few NPPOs used to factor this pathway into their risk analyses
- There is no effective mechanism for detecting products holding phytosanitary risks sold online

#### How to deal with this??

<table>
<thead>
<tr>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Books infused with seeds</td>
</tr>
<tr>
<td>Bulbs</td>
</tr>
<tr>
<td>Dirty camping gear &amp; trekking clothes</td>
</tr>
</tbody>
</table>

#### Growing internet shop market shares

- **Buy Sweet Potatoes Online - Best Price, Fast Delivery...**
  - [Link](https://www.buy-sweetpotatoes.com/)
  - “Sweet Potatoes are a healthy, nutritious food!”

- **Sweet Potato - Bharatshop / Ecommerce Shop / Online...**
  - [Link](https://www.bharatshop.com/)
  - “We source our potatoes from reliable farmers!”

- **Shop for Sweet Potatoes & Yams for Fast Delivery / FreshDirect**
  - [Link](https://www.freshtrends.com/sweet-potato)
  - “Fresh, organic, and delicious!”
Food safety & (bio)security

We are also to blame!

How you can help

- Never even illegally bring home plants, seeds, flowers, fruit and vegetables.
- If you do wish to import plants into your country, contact your local Plant Health authorities to find out what you can or legally.
- If you are carrying any plants, seeds, flowers, fruit and vegetables, declare them to the Customs official.
Food safety & (bio)security

Self-sustainable long-term network that supports coordination and collaboration in the area of phytosanitary research

Science diplomacy for plant health

The battle between humans and plant pests is as old as agriculture, but the movement of pests as a consequence of human activities has been exacerbated only recently. International research collaboration is increasingly important to tackle pests causing serious damage to economies.

Baldovino Giovannii, Sylvie Blomel, Ralf Luesch, Daniel Taevel, Stephanie Bloem, Cristino Galindo Martínez Camille Beltrán Montoya, Carlos Ramón Martínez Morales, Sidhu Dhammapuri, Vincenzo Timoteo, Nico Horn, Meekh Choudhuri, Jean-Gerard Merlin MBiH, Veronica Hernes, Aurélie Casbi, Cin Gould,
Catherine Moller, Ian MacInnes, Guiseppe Sestuelli, Stef Encomyer, Sara Tramontin, Philip MacDonald, Loren Vietti, Caroline Anthoine, Kira De Jonghe, Marijo Scharf, Silke Stasimoller, Elena Rodriguez, Maria Leonor Cruz, Jo Looy, Greg Frater, Sanish Bussel, Mirok Moshuuri, Craig Pedchock, Elspeth Steel, Helen Grace Pennington, Roger Day, Jean Pierre Rossi, and Jingyou Xua

Tactical sciences?

Generating knowledge and information on how crises can emerge and evolve and how they can be anticipated, resolved or managed
1. The rise of sequencing technologies

**routine plant virus diagnostics**

- ELISA
- Q(RT-)PCR
- LAMP (Loop mediated isothermal amplification)
- Mechanical inoculation on indicator plants
- Q(RT-)PCR
- Electron microscopy TEM - SEM

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1. The rise of sequencing technologies

**Sequencing nucleic acids from 2000 to 2020**

<table>
<thead>
<tr>
<th>90’ies</th>
<th>2020</th>
<th>1.700.000.000.000</th>
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<tbody>
<tr>
<td>1.000</td>
<td></td>
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</table>
1. The rise of sequencing technologies

Sequencing nucleic acids from 2000 to 2020?

CLEARANCE SALES: 99.999 % OFF & Better quality

Pay only 0.001 % of original genome price

1. The rise of sequencing technologies

What are the scientists doing?
1. The rise of sequencing technologies

Genomes & Pathogens?

**Potato virus Y:**
- 460 full genomes (10 kb)
- 3,300 sequences

**Ralstonia solanacearum** species complex
- 102 full genomes (5.8 Mb)
- 42,000 sequences

Traceback the origin and timing of emergence of the different strains (O, N...)

Show that human activities have shaped the diversity of PVY
1. The rise of sequencing technologies

Genomes of known plant pests?

Potato virus Y:
- 460 full genomes
- 3,300 sequences

Belgium: Strain differentiation in support of seed potato certification

- Since 1984, first description of the mild PVY Wilga recombinant strain in Poland
- Since than, gradual increase in importance.
- Currently NTN and N-Wilga most important strains in Europa and Belgium

1. The rise of sequencing technologies

2016 – FAO-WHO

Genome sequencing is potentially a powerful tool in all relevant sectors in food, public health and animal/plant health.

Strong relevance to a One Health approach.
1. The rise of sequencing technologies

From Research to diagnostics:

2020:

Hundreds of new viruses discovered on Prunus sp.

30ies 40ies 50ies 60ies 70ies 80ies 90ies 2000 2010

- 39 (0.6 per year)
- 8 (1.6)
- 9 (4.5)

Discovery of new plant pests?
2. Risks posed by new viruses?

Which one of the new plant viruses represents a risk for plant trade and production?

A Framework for the Evaluation of Biosecurity, Commercial, Regulatory, and Scientific Impacts of Plant Viruses and Viroids Identified by NGS Technologies


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2. Risks posed by new viruses?

<table>
<thead>
<tr>
<th>Micro-scale</th>
<th>Weeks</th>
<th>Months</th>
<th>Years</th>
</tr>
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<tbody>
<tr>
<td>Stakeholder consultations and prioritisation</td>
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</tbody>
</table>

- Preliminary
  - Confirmation
  - Taxonomy
  - Sample information
  - Bibliography

- Intermediate
  - Full genome
  - Diagnostic
  - Local prevalence

- Long term
  - Koch postulate
  - Host range
  - Vector
  - Large survey
2. Risks posed by new viruses?

Which one of the new plant viruses represents a risk for plant trade and production?

- Discovery of a new potyvirus on breeding line of potato
- Host range of PYBV similar to PVA (solanaceous and indicator plants)
- Screening commercial seeds during 5 years: no detection

Not the highest risk?

3. Bioinformaticians: the new stakeholder

Sequences available in Genbank database

1 week 2020

1982-1997
3. Bioinformaticians: the new stakeholder

Impact of data analysis on pest detection?

Virus Detection by High-Throughput Sequencing of Small RNAs: Large-Scale Performance Testing of Sequence Analysis Strategies


- A potato sample from Peru was sequenced and 2 viruses identified: PVX and a new nepovirus (not present in database and further identified as PVB)
- Two other samples: Grapevine and apple
- Identical datasets (10) sent to 13 laboratories (double blind test) -> application of bioinformatics tools to identify viruses present in the sample
- Worst case scenario (less sequences than expected – down to 50,000)

<table>
<thead>
<tr>
<th>labID</th>
<th>Sensitivity</th>
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<tbody>
<tr>
<td></td>
<td>50,000</td>
</tr>
<tr>
<td>A</td>
<td>10%</td>
</tr>
<tr>
<td>B</td>
<td>30%</td>
</tr>
<tr>
<td>C</td>
<td>60%</td>
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<td>D</td>
<td>50%</td>
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<td>E</td>
<td>30%</td>
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<tr>
<td>F</td>
<td>80%</td>
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<tr>
<td>G</td>
<td>20%</td>
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<td>H</td>
<td>30%</td>
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<td>J</td>
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<td>40%</td>
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<td>90%</td>
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<td>V</td>
<td>60%</td>
</tr>
<tr>
<td>W1</td>
<td>40%</td>
</tr>
<tr>
<td>W2</td>
<td>60%</td>
</tr>
<tr>
<td>X</td>
<td>30%</td>
</tr>
</tbody>
</table>

- 70% sensitivity overall
- Huge differences between laboratories
- Sensitivity increased with sequencing depth and quantity of sequences from the viral species
- Potato viruses?
3. Bioinformaticians: the new stakeholder

Impact of data analysis on pest detection?

Ability to detect the virus was reduced for the unknown virus compared to PVX or GLRaV-1.

Bioinformatics has a tremendous impact on virus detection.

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3. Bioinformaticians: the new stakeholder

**Euphresco** project (15 partners + 13 associated partners)
Coordination: A. Haegeman (ILVO)

The Plant Health Bioinformatic Network (PHBN)

1. Develop training material
2. Bioinformatics challenge on HTS data
3. Data mining

Seed for networking the new stakeholder
3. Bioinformaticians: the new stakeholder

Guiding PRA by genome sequences?

**EPIDEMIOLOGY**

**Predicting reservoir hosts and arthropod vectors from evolutionary signatures in RNA virus genomes**

Simon A. Babayan1,2, Richard J. Orton3, Daniel G. Streicker3,4,

Predicting the hosts and the vectors of mammalian viruses thanks to the genome sequence?

Predictive accuracy: 72% for reservoir host & 99% for vector group

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**GENOPREDICT concept for plant viruses**

<table>
<thead>
<tr>
<th>Genomes</th>
<th>Proteins</th>
</tr>
</thead>
<tbody>
<tr>
<td>TGAATGAGGTAGAGAAGAAATGTCCCATAC</td>
<td>ILKYVCKTYFPASNVYMKFLVTRVNTW</td>
</tr>
<tr>
<td>GTGCTATGCGGGCTTTCCACTTCTGAGA</td>
<td>FCKFSRIDTFLLYKGVAHKSVDSEQFY</td>
</tr>
<tr>
<td>ACCGCCTTTGATTTCGTAAGA</td>
<td></td>
</tr>
</tbody>
</table>

Protein information = Modules

1) Function
2) Signature (amino acids)
3) 3-D conserved structures

Genopredict dB
3. Bioinformaticians: the new stakeholder
Guiding PRA by genome sequences
What about plant viruses?

- Data Mining & Machine learning algorithms
- Interesting results & variable depending on the biological properties
- Sensitivity >> specificity (risk of FP > FN)

PhD of Rachid Tahzima finishing & ongoing story

4. SEVIPLANT project
HTS as an untargeted diagnostic tool for virus screening
A case study for the identification of new harmful plant viruses in Solanaceae in Belgium
4. SEVIPLANT project

National survey of viruses infecting Solanaceae

**Crop**
- Potato, tomato, eggplant, pepper, etc.

**Wild**
- Black nightshade, Datura, etc.

**Ornamental**
- Petunia, Brugmansia, etc.

SEVIPLANT
National project to scan the virome of commodities

17,000 samples of Solanaceae

High Throughput Sequencing

“Solanaceae Virus Wikipedia”
4. SEVIPLANT project

1,300 samples sequenced
10 viral species detected
5 new species for Belgium
New host for 3 viruses

Physostegia chlorotic mottle virus

4. SEVIPLANT project

PhCMoV: informal EU network

Present in many countries
& from 20 years
Host range expansion
Low diversity
5. Surveys and status projects

Fyliber (RF14/6290) & VECTRACROP (2015 – D -168)

Status of ‘Ca. Liberibacter solanacearum’ and phytoplasma in carrot and potato

Sampling in potato
Sampling in carrot
Sampling in both potato & carrot

6. PRONC project

Phytosanitary risks of new crops in Belgian horticulture

National project (2 partners: ILVO & PCG)
Transnational project (7 partners)


Increasing interest in growing and commercializing new crops, including some “forgotten” crops. =>

eg. tuber crops => **no info on phytosanitary status** & mostly vegetatively propagated

niche markets & “short chain circuits” - eg CSA farms

Examples: Yacon, ulluco, sweet potato, crosne, mashua, oca (new crops) and Jerusalem artichoke (forgotten crop)

**RISK for our potato crops?**
6. PRONC project

Phytosanitary risks of new crops in Belgian horticulture

National project (2 partners: ILVO & PCG)  Transnational project (7 partners)  PRONC – BE (2018-A-293)

Focus national project: VIRUSES & NEMATODES

- Where are these new crops cultured in Belgium, what are the varieties and how is the planting material distributed?
- What is the origin of planting materials of new crops?
- Which viruses and nematodes are associated with propagation materials and marketed new crops?
- What are the phytosanitary risks of these organisms?  Biological characterization
- Which phytosanitary measures can reduce the introduction and distribution of some of these new plant pathogens?

7. Training professionals

Training services

- Sampling
- Identity and regulation
- Biology & epidemiology of diseases/pests
  - Symptomatology
  - Geographic distribution
  - Host range
Facilitate collaboration amongst institutes around the world,

Focus on linking botanic gardens and arboreta, National Plant Protection Organisations (NPPOs) and plant health scientists.

The International Plant Sentinel Network (IPSN)

- Training professionals
- Surveys
- Database

The Belgian Plant Sentinel network (BE-PSN)

- Trainings & workshops
- Surveys
- Database

Tactical sciences for plant viruses to foster food security

- Technological innovation brings new tools and generates new knowledge
- Integration of these tools and knowledge improve Plant Health management
- Optimizing resource utilisation
- International networks like Euphresco build synergies and accelerate diffusion of innovation
- Better food security through better plant health
Thank you for your attention

Prof. Sébastien Massart – Gembloux Agro-Bio Tech – Liege University

Dr. Kris De Jonghe – ILVO Plant Sciences