2012 Aster yellow outbreak in Saskatchewan

Chrystel Olivier
Agriculture and Agri-Food Canada Research Centre, Saskatoon.

Agronomy update, Lethbridge
January 14th, 2012.
Phytoplasma

- How to grow them?
- How do they reproduce?
- Identification and characteristics?
- Transmission?
Phytoplasmas are specialised wall-less bacteria that are obligate parasites of plant phloem tissue and of insect vectors.

**Characteristics**
- Pleomorphic, small genome (580-1350 kb).
- Classification based on molecular & ecological characteristics.
- 28 groups worldwide (Wei et al, 2007) & 7 groups in Canada (Olivier et al., 2009)
- AY the most common and widespread (Weintraub & Beanland, 2006)
AY phytoplasma

Transmission
- By insects, mostly leafhoppers (a few planthoppers, psyllids)
  From plant to plant.

Acquisition

Multiplication

Infection

2-4 weeks
AY phytoplasma

Transmission
- By insects, mostly leafhoppers (a few planthoppers, psyllids)
  From plant to plant
  Via eggs (=transovarially)
  - 4 species (3 exotic, *Scaphoideus titanus* in Canada)

- Overwinter in roots and dormant tissues of perennial plants
  (dandelion, quackgrass, shrubs, ..)

Disease reservoir
AY phytoplasma

Transmission
- By insects, mostly leafhoppers (a few planthoppers, psyllids)
  From plant to plant
  Via eggs (=transovarially)
  - 4 species (3 exotic, *Scaphoideus titanus* in Canada)

- Overwinter in roots and dormant tissues of perennial plants
  (dandelion, quackgrass, shrubs, ..)

- By seeds?
- Detection in embryos of mulberry, coconut and alfalfa (Jiang et al., 2004; Necas et al., 2008; Nipah et al., 2007).

- Detection in flowers, seeds & seedlings of *Brassica napus*,
  *B. rapa*, tomatoes and corn (Olivier et al., 2008; 2010; Bertaccini et al., 2012)
In Vivo:

- How to grow them?
- How do they reproduce?
- Identification and characteristics?
- Transmission?
- How do they manipulate plants & insects?
Symptom expression

After a latent period: 2-6 weeks, depending on the weather/strain, varieties, stresses, … (parameters?)

Cause of symptoms: Poorly understood!

Phytoplasmas lack genes for a lot of metabolites

Pump all the metabolites directly from the plant phloem

Multiplication of phytoplasmas

Clogging of sieve elements

Chlorosis, stunting, poor growth

Flowers become leaf-like structures

Poor seed production
AY phytoplasma

Consequences of AY on vectors
- Beneficial: Increased lifespan and fecundity, better survival, host range expansion & higher flight activity.
- Neutral: No consequences
- Detrimental: Decreased lifespan, fecundity, ...

Beneficial effects usually on primary vectors
Neutral / detrimental effects usually on secondary vectors

Co-evolution between phytoplasma / vector?
AY symptoms on canola

- Sterile bladder like pods
- Small witches’-broom
- Yellowing, purpling
- Other causes for purpling:
  • Varieties
  • Deficiency in minerals
  • Herbicide injuries
AY symptoms in 2012
Re-growth of symptomatic branches at the base?

- AY: induce the plant to keep growing…. to attract leafhoppers.
- High temperatures slow down phytoplasmas in above-ground tissues, but in roots may induce symptoms later in the season.
AY symptoms on Camelina sativa & Sinapis alba
AY symptoms on other plants

- Garlic
- Periwinkle
- Tame Buckwheat
- Raspberry
- Echinacea

Images by: A. Diederichsen, PGRC, Saskatoon, J. Whetter, copied from Twitter.
AY symptoms on other plants

Photos: CABI
Yield losses: AY symptoms on seeds

- Sterile bladder-like pods.
- Normal looking pods with germinated seeds.
- Normal looking pods with normal-looking & misshapen seeds.

~30-60% misshapen seeds in AY infected canola (2002-05).

Same in 2012?
8-10% plants with no seeds
AY incidence in canola

About normal-looking seeds in infected plants?
- Phytoplasma DNA detected in seed coats and embryos (PCRs).
  2002-2005: <1%        2012: ~ 8% (AAFC small plot nursery)
- EMs show intact phytoplasma (?) in seed coats.
- 30-45% progeny plants malformed (high number of trichomes, no growing point, condensed flowers, strong growth delay).
Phytoplasma infection

- Malformed progeny
- Strong growth delay on progeny, meaning no survival of malformed plants.

AY incidence in canola
AY symptoms on cereals

- Yellowing, red & purple pigmentation
- Leaf rolling, erect habit and necrosis
- Head small, sterile, distorted, twisted.
- Very similar to BYDV....only way to differentiate: PCR
AY symptoms on cereals

AY or BYDV?

PCR on cereal samples:
- Wheat: <5%
- Barley: ~25%
- Oats: 17%
- More PCRs to do...
In Vivogen

Phytoplasma

How to grow them?

How do they reproduce?

Identification and characteristics?

Transmission?

How do they manipulate plants & induce symptoms?

AY epidemiology

In the prairies?
Aster Yellows phytoplasma (16SrI)
In oilseeds in Canada
- 3 strains (16SrI-A, B, C), +200 plant species.
- Vectors
Main vector: Aster leafhopper (*Macrosteles quadrilineatus*)
Aster Yellows phytoplasma (16SrI)
In oilseeds in Canada
- 3 strains (16SrI-A, B, C), +200 plant species.
- Vectors
  Main vector: Aster leafhopper (*Macrosteles quadrilineatus*, formerly *M. fascifrons*)
  - Migratory: South winds in spring
    - High number of leafhoppers
    - Infection in South USA
    - Several South winds
  Local pop.: abundance?
**Aster Yellows phytoplasma (16SrI)**

In oilseeds in Canada
- 3 strains (16SrI-A, B, C), +200 plant species.
- Vectors
  Main vector: Aster leafhopper (*Macrosteles quadrilineatus*, formerly *M. fascifrons*)
  7 other potential leafhopper vectors (role in outbreak, maintain reservoir?, abundance?)

**Potential vectors in oilseeds**

<table>
<thead>
<tr>
<th>Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Endria inimica</em></td>
</tr>
<tr>
<td><em>Colladonus montanus</em></td>
</tr>
<tr>
<td><em>Colladonus geminatus</em></td>
</tr>
<tr>
<td><em>Euscelis maculipennis</em></td>
</tr>
<tr>
<td><em>Scaphytopius acutus</em></td>
</tr>
<tr>
<td><em>Exitianus exitiosius</em></td>
</tr>
<tr>
<td><em>Paraphlesius irroratus</em></td>
</tr>
</tbody>
</table>

*Photo: R. Panzer*

*Endria inimica*

*Photo: Stephen Crosswell*
- *M. quadrilineatus* is the most abundant leafhopper in canola and camelina.
- *M. quadrilineatus* is the most abundant leafhopper in cereal.
- 2012: analysis of samples in process.
Leafhopper infection and number

Range: 3-45%
Average: 12-17%

M. quadrilineatus

Potential vectors

% of AY infection in *Macrosteles quadrilineatus*

Range: 3-45%
Average: 12-17%
AY epidemiology

High % of asymptomatic infected plants

Canola
AY epidemiology

Camelina sativa

High % of asymptomatic infected plants
### AY epidemiology

<table>
<thead>
<tr>
<th>SK</th>
<th>Barley</th>
<th>Wheat</th>
<th>Oat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Visual</td>
<td>PCR</td>
<td>Visual</td>
</tr>
<tr>
<td>2005</td>
<td>(-)</td>
<td>9.4</td>
<td>(-)</td>
</tr>
<tr>
<td>2006</td>
<td>(-)</td>
<td>9.3</td>
<td>(-)</td>
</tr>
<tr>
<td>2007</td>
<td>(-)</td>
<td>66.6</td>
<td>(-)</td>
</tr>
<tr>
<td>2008</td>
<td>(-)</td>
<td>14.3</td>
<td>(-)</td>
</tr>
<tr>
<td>2012</td>
<td>(?)</td>
<td>25</td>
<td>(?)</td>
</tr>
</tbody>
</table>

Very high % of asymptomatic infected plants

From samples collected in 2004, AYP was detected from 48% (present in 12 of 25), 36% (present in 9 of 25), and 40% (present in 10 of 25) of plant collections made at transect location points 1, 3, and 5, respectively. Samples of DNA originat-

Hollingsworth et al., 2008
AY epidemiology

Next outbreaks????
  Cannot forecast the date...
  need to monitor winds, and leafhopper arrival and infection.

Are we at risk of more outbreaks? YES!
  - Local population of vectors on the increase, AY in weeds
  - Warmer winters: higher survival of phytoplasmas and overwintered leafhopper adults and eggs.
  - Southerly winds coming earlier?

<table>
<thead>
<tr>
<th>Date</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>April 29</td>
</tr>
<tr>
<td>2002</td>
<td>May 22</td>
</tr>
<tr>
<td>2003</td>
<td>June 20</td>
</tr>
<tr>
<td>2004</td>
<td>May 9</td>
</tr>
<tr>
<td>2005</td>
<td>May 7</td>
</tr>
<tr>
<td>2006</td>
<td>April 1</td>
</tr>
<tr>
<td><strong>2007</strong></td>
<td><strong>April 1</strong></td>
</tr>
<tr>
<td>2008</td>
<td>April 10</td>
</tr>
<tr>
<td>2009</td>
<td>April 11</td>
</tr>
<tr>
<td>2010</td>
<td>April 13</td>
</tr>
<tr>
<td>2011</td>
<td>April 10</td>
</tr>
<tr>
<td><strong>2012</strong></td>
<td><strong>April 1</strong></td>
</tr>
</tbody>
</table>

Inoculum coming earlier, with higher probability of survival
Phytoplasma

- How to grow them?
- How do they reproduce?
- Identification and characteristics?
- Transmission?
- Control measures?
- AY epidemiology in the prairies?
- How do they manipulate plants & induce symptoms?
**AY phytoplasma control**

**Phytoplasma weaknesses**

- Antibiotics (tetracycline, erythromycin, streptomycin, chloramphenicol)…delay symptom expression
- Heat: > 32ºC for several days slows down phytoplasmas
  40ºC-50ºC for several hours kills phytoplasmas
- No commercially available chemicals to control phytoplasmas

---

**Chiesa et al., 2007**

---

**Kunkel, 1953. Exp.at + 40ºC**

---

**Commercially non viable to control phytoplasma in annual plants**
Insecticides to control the vector population.
- Need several sprayings (waves of southerly winds).
- Negative impact on beneficial insects and environment.
- Leafhoppers are mobile, can transmit the disease before being killed.
- Latent period of 2-6 weeks for symptom development on canola (& most annual plants) after inoculation by leafhoppers.

**When symptoms are observed, it is too late to spray**

Talk to your agronomist
Other control measures:
- Resistance or disease avoidance (?): small plots (no field scale trials yet)

Canola – 2012 (0-80%)
Camelina – 2012 (15-100%)
Other control measures:
- Resistance or disease avoidance
- Early warning system...feasible but lots of unknowns.
  - Ratio local / migratory population of *M. quadrilineatus*
  - Role of other vectors & of reservoir plants
  - Leafhopper movement crop-to-crop.
  - ..... 
- Weed management: weed abundance and diversity favors leafhopper population.
- Mulching (aluminium mulching on carrot)
- Insect-exclusion screens (vineyard in Australia)
- Predators / parasitoids...not well known for AY vectors in the prairies
- .....
Conclusion

- Phytoplasma diseases: difficult to study & to control.
  - Many unknowns…strains ID, role of vectors, symptom expression

- Risks of increased AY incidence in the future
  - Due to (?) climate change, increased number of leafhoppers, …

- Solutions?...few!
  - Insecticides: controversial
  - Early warning system and resistance / avoidance: need further study
  - Other options (symbionts, seed treatment…?)
Conclusion

- Phytoplasma diseases: difficult to study & to control.
  - Many unknowns
    - Accurate ID of phytoplasma strains
    - Why and how some leafhoppers are vectors?
    - Extent of the disease reservoir
    - Ratio local / migratory pop. & role of local population in AY outbreak
    - Correlation (symptom severity, incidence) with yield losses.
    - Seed transmission.
    - Parameters involved in symptom expression.

- Risks of increased AY incidence in the future: early warning systems

- Solutions?...few!
  - Insecticides: controversial
  - Other options
    - cultivar resistance
    - seed treatments
    - Symbiont
Acknowledgements

Producers
Many growers, in particular:
   Ed Seidle (Medstead)
   Al Mereschuck (Saskatoon)
   Francois Messier (Alvena)
   Brock Shear (Osler)
   Many more, especially in 2012
   …

Funding Agencies
Agriculture Development Fund
Canola Council,
Genome Research Development Initiative
Agriculture and Agri-Food Canada

Colleagues
Dr. O. Olfert
Dr. J. Soroka
Dr. C. Xiangsheng
Dr. C. Heyinck
Dr. R. Andrahenndi
B. Galka
Murray Braun
Ross Weiss
Larry Grenkow
Jennifer Otani
Xiaomeng Peng
Andrew Pearce
A. Lukash
S. and H. Ghani
………..
A lot of summer students…..