Managing PVY in Potato

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2013 Western Washington Potato Workshop
Potato Virus Y (PVY)

- Reduces yield and quality
  - Dependent on variety
  - Time of infection
  - Virus strain
- Symptom expression can vary by strain or cultivar
- Tuber borne
- Mechanical transmission
  - Seed cutting/cultivation
- Aphid transmission
  - Non-persistant, stylet- borne
- Multiple strain types
  - PVYO, PVYN, PVYN:O, PVYN:T
    - PVYN:T:O, PVYN:Wi
  - High Recombination Frequency to allow for new strain formation
PVY yield reduction

- Yield reductions can be as high as 30-80%
  - PVY$^N$, NTN strains cause internal necrosis and external blemishes that may preclude certain fresh and processing markets

- Losses depends on:
  - Variety
  - Strain of PVY
  - Time of infection
  - Early infection greatest yields loss, late small yield loss
PVY
Currently most important virus in Potato certification programs

In some states 50%+ of lots fail certification

Stylet-borne by both potato colonizing and non-colonizing aphids

New strains
Mechanical Transmission

- Seed cutter - particularly sprouted seed
- Disinfest with quaternary ammonium compound

- Mechanical transmission in field by workers/equipment not considered to be of major importance
Aphid Transmission

- 40-50 species of aphids shown to transmit PVY in non persistent manner.
- Aphid can carry PVY on stylet for 1-17 hours-transmission efficiency drops rapidly with time. At 5 min ~30-40% transmission, at >2 hrs generally less than 1%.

- Potato colonizing aphids- feed and reside on potato
- Non- colonizing aphids moving from other crops (corn, cereal grains, etc) will probe (taste) potato but will move on quickly
Stylet-borne/Non Persistent Viruses

Â Transmission in instantaneous as soon as stylet enters cell. This is why insecticides are generally ineffective in reducing transmission of PVY

Â Virus carried on stylet tip for 1-2 hours until feeding on another plant then virus is lost. In rare instances virus may be retained for up to ten probes.

Â Virus released from stylet tip is associated with salivation
PVY

Non-persistent stylet-borne viruses in epidermis

PLRV

Circulating (Persistent) viruses in phloem

Styllet in phloem

Styllet in epidermis

Circulating virus multiply in the body of the aphid and reaches the salivary glands

Accessory salivary gland

Cibarial Pump

Procibarial gustatory organ

Food duct

Common Duct

Precibarial valve

Salivary duct

Salivary gland-borne

(Luteovirus, Potexvirus, Enarvovirus, Begomovirus, Curtovirus)

Foregut-borne (Nakamura)

Cuticular-borne

Stylet-borne

(Polyivirus, Cusamovirus, Caulimovirus)
Integrated Management of PVY

No single tool will provide complete control
PVY Management Tools

- PVY free seed – don’t plant a problem
- Plant early so infection by non-colonizing aphids from ripening grain or other crops happens with greatest plant maturity possible
- Varieties – Resistance depends on strain

<table>
<thead>
<tr>
<th>Variety</th>
<th>PVY-O</th>
<th>PVY N-Wi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yukon Gem</td>
<td>resistant</td>
<td>Very susceptible</td>
</tr>
<tr>
<td>Yukon Gold</td>
<td>susceptible</td>
<td>Very susceptible</td>
</tr>
<tr>
<td>Ranger Russet</td>
<td>resistant</td>
<td>Moderately susceptible</td>
</tr>
</tbody>
</table>
PVY Management Tools

Â Use neonicotinoid insecticide seed treatment or at planting-this will control potato colonizing aphids for ~60 days. Remember this will also control Potato Leaf roll virus , (PLRV)

ï Admire Pro, Gaucho, Cruiser, Platinum, Belay

Â Eliminate overwintering sources before crop emerges or rouge volunteers as seen

ï volunteers/cull piles
Clearfield-Beyond herbicide
Imidazolinone
Volunteer wheat, potato, etc
PVY Management Tools

- Control weeds that are PVY and aphid hosts
  - Hairy nightshade
  - Lambsquarter
  - Other Solaneaceous weeds
  - ~120 host plants
PVY Management Tools

- Avoid bare soil on borders. Aphids will look for edges to initially alight.
- Use non-host crop borders - eg. Corn, soybean, pea, winter wheat. This will avoid the breaks that aphids look for - remember roads, etc. This technique has provided 25-65% control
Virus sticks to mouthparts and is wiped off during next probing event.

Transmission is instantaneous—too fast for insecticide to kill.

Border/Barrier plant works like aphid cleaning station.
Management Tools

Â Mineral Crop Oils

- Use at 1-3% with emulsifier (0.75-1.25%)
- Many products-JMS Stylet oil, Aphoil, Glacial spray fluid, Sunco 7E, Ultra-Fine, Organic leaf oil, etc

- Chemical characteristics
  - SUS (Saybolt Universal Seconds) 60-150
  - VGC (Viscosity Gravity Constant) 0.79-0.819
  - Boiling range 370-420 C
  - Molecular weight 340-380 daltons
  - Unsulfonated residues (USR) 95-100
  - Paraffin-pour point<-0 C

Â Have provided 25-70% control

- Reduce virus acquisition, persistence on stylet (<2 minutes compared to 2 hrs), transmission
P-FB Fallow border
PO-FB potato sprayed with oil, Fallow border
P-PB potato border
PO-PB potato sprayed with oil potato border
P-LB low height border
P-POB potato border sprayed with oil
PO-POB potato sprayed with oil + potato sprayed with oil

Crop border and mineral oil sprays used in combination as physical control methods of the aphid-transmitted potato virus Y in potato – Boiteau et al, 2009
Mineral Oils

- Must have excellent plant coverage
  - Aphids prefer young plant growth - when plant growing rapidly need to apply every 4 days when growth slows every 7 days is sufficient
  - Coverage - higher volume, higher pressures - want coverage of upper and lower leaves
- Phytotoxicity associated with rates >3% most use at 1-2%
- Phytotoxicity with some fungicides (Bravo, Super-Tin, Polyram) apply day before or day after
- Do not apply to wet plants - poor coverage
- Phytotoxicity at high temperatures has been reported - yield drag?
Integrating Rogueing, Stylet oils and Induced Resistance for PVY Management
What is Induced Systemic Resistance?

- Inducible broad-spectrum, systemic host response against a wide-array of potential pathogens. Equivocal to an “immune response”, but without specific antigen-antibody interactions.
- Rapid accumulation of host produced defense compounds (PR proteins and other factors) that act systemically- initial rxn in minutes –usually 3-5 days for max effect.
- Plant is Primed to defend itself for prolonged period (7-20+ days)
- Effective against diseases caused by fungi, bacteria, viruses, nematodes, some insects
- Probably the most common disease control
PGPR, etc

- Wounding
- Priming
- Pathogen attack
- Expression of induced resistance (reduced disease symptoms)

Natural and synthetic compounds
Beneficial microorganisms

Naïve plant with normal defense capacity
Dramatically diseased plant
Induced Resistance: A tool in Managing Virus Diseases
Historical Background

Å 1961-Ross-TMV/TMV-coined term Systemic Acquired Resistance-SAR
Å 1960s-present- Kuc‘ and others- SAR- necrotizing pathogen or chemical, salicylic acid signaling pathway, may involve activation of npr 1 gene, initial reactive oxygen burst and induction of pathogensis-related (PR) proteins
Å 1982-Bergstrom- prior inoculation with *Colletotrichum obiculare, Pseudomonas lachrymans* or tobacco necrosis virus induce systemic resistance against CMV
PGPR- Viruses

Â 1996- Raupach et al. Two strains of PGPR induce ISR in cucumber and tomato against CMV

Â Some strains of *Pseudomonas fluorescens*, *Bacillus pumilis*, *B. amyloliquefaciens*, *B subtilis*, *Kluyvera cryocrescens* rhizobacteria reduced CMV and Tomato Mottle geminivirus infection (50-70%), reduced symptoms and lengthened period from infection to symptom development-Zehender et al, 1999

Â *Bacillus globisporus*, *Pseudomonas fluorescens*, *Streptomyces* gibsonii-30-60% reduction of tobacco necrosis virus local lesions in bean. Shoman, et al 2003

Â *Pseudomonas fluorescens*- Barley Yellow Dwarf Mosaic- Mysus avenae-Wheat and Barley~50% reduced disease severity. Al Ani et al.2011
SAR/SIR/ISR

Â Induce by necrotizing pathogen, heavy metals, dichloroisonicotinic acid (INA), agents-BABA-Beta DL-3-aminobutyric acid, G(amma)ABA, dipotassium phosphate, phosphorus acid

Â Non-necrotizing -Acibenzolar-s-methyl-(Actigard,Bion), salicylic acid, PGPR-Pseudomonas, Bacillus, etc, Bacillus mycoides (BmJ Microbial Fungicide-CERTIS USA), cell wall components of *Pythium nunn* or *P. oligandrum, Trichoderma harzianum, T. viridae*
Bacillus mycoides-BmJ

Å Isolated from phyllosphere of sugarbeet with lower incidence of Cercospora leaf spot
Å Epiphyte-log 3-4 –Collins, 1999
Å Demonstrated 38-91% control of Cercospora leaf spot statistically equal to best fungicide in 5/9 years-Jacobsen
Å Study of spatial and temporal population dynamics showed no correlation for either Bac J or B. subtilis (Bac B) and Cercospora leaf spot severity-no antibiosis or parasitism-Collins, 2001, Collins, et al., 2002
Å Equal control at log 2 to log 9/ ml- Collins, 1999
Å No control with dead BmJ-Bargabus, et al. 2003, 2004
   ï Dead BmJ reduces aphid feeding
SAR/ISR-Foliar Induction

- Protective effects of SAR extend to all plant parts
- Resistance is detectable 2-3 days post induction
- Peaks 5-7 days post induction
- Effective for ~14-20 days or longer
- Suppresses many pathogens: fungi, bacteria, viruses
## Virus Disease Control

### mechanical transmission

<table>
<thead>
<tr>
<th>Virus</th>
<th>Latent period - days</th>
<th>% symptomatic plants</th>
<th>Virus titer Symptomatic plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMV-cucumber</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>water</td>
<td>6.7</td>
<td>75</td>
<td>2.37</td>
</tr>
<tr>
<td>BmJ</td>
<td>9.0</td>
<td>25</td>
<td>0.49</td>
</tr>
<tr>
<td>TMV-tomato</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>water</td>
<td>4.8</td>
<td>82</td>
<td>2.35</td>
</tr>
<tr>
<td>BmJ</td>
<td>8.3</td>
<td>24</td>
<td>1.1</td>
</tr>
</tbody>
</table>
Greenhouse-mechanical transmission

<table>
<thead>
<tr>
<th>Treatment</th>
<th>% PVY Trial 1</th>
<th>% PVY Trial 2</th>
<th>% PVY Trial 3</th>
<th>% PVY Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead BmJ +PVY</td>
<td>25</td>
<td>50</td>
<td>100</td>
<td>58.3 a</td>
</tr>
<tr>
<td>Dead BmJ</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0 c</td>
</tr>
<tr>
<td>BmJ induction 5 days before inoculation with PVY + BmJ @ 14, 28, and 42 days post inoculation</td>
<td>5</td>
<td>0</td>
<td>75</td>
<td>26.6 b</td>
</tr>
</tbody>
</table>

Note variability in results but consistent reduction
Greenhouse PVY Aphid Transmission March-May

Aphid Transmission of PVY

Transferred 10 green peach Aphid/plant from PVY infected potato- 20 replications summary of 3 experiments
Figure 1. Percent infection of Russet Norkotah potatoes at different times planted at Hermiston, OR. either induced with BmJ at emergence then every 14 days compared to non-induced potatoes. Data are statistically different at day 71 and day 84 @P<0.05.
Diseases controlled by BmJ

Viruses

- Cucumber Mosaic-cucumber
- Tobacco Mosaic-tomato
- Squash vein yellowing virus-watermelon
- Potato virus Y-both aphid and mechanical transmission
- Wheat Streak Mosaic mechanical and mite transmission
- Both reduced infection and reduced virus titer
Integrated PVY Management Plots
Red flags - Russet-Norkotah-Mazzama Borders
2010 Hermiston PVY Trial
4 replications- 50 plants each

<table>
<thead>
<tr>
<th>Treatment</th>
<th>% PVY total including winter test</th>
</tr>
</thead>
<tbody>
<tr>
<td>BmJ WP 2.0 oz/A 14 days emergence to harvest</td>
<td>3.5</td>
</tr>
<tr>
<td>BmJ WP 2.0 oz/A 14 days emergence to harvest- rogue out infected plants</td>
<td>1.5</td>
</tr>
<tr>
<td>Admire Pro 8.7 oz @ plant + BmJ WP 2.0 oz/A 14 days emergence to harvest @ 60 days post emergence Assail 1.7 oz, 67 days Fulfill 5.5 oz, 75 days Beleaf 2.8 oz, 87 days Leverage 3.8 oz- rogue out infected plants</td>
<td>3.0</td>
</tr>
<tr>
<td>Admire Pro 8.7 oz @ plant @ 60 days post emergence Assail 1.7 oz, 67 days Fulfill 5.5 oz, 75 days Beleaf 2.8 oz, 87 days Leverage 3.8 oz- rogue out infected plants</td>
<td>4.5</td>
</tr>
<tr>
<td>Untreated</td>
<td>10.0</td>
</tr>
<tr>
<td>Flsd 0.05</td>
<td>5.86</td>
</tr>
</tbody>
</table>
## 2011 Hermiston PVY Trial

<table>
<thead>
<tr>
<th>Treatment</th>
<th>% PVY total Field</th>
<th>% PVY Total Field + winter test</th>
<th>Yield CWT/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>BmJ WP 2.0 oz/A 14 days emergence to harvest</td>
<td>4.0</td>
<td>10.4</td>
<td>278 a</td>
</tr>
<tr>
<td>BmJ WP 2.0 oz/A 14 days emergence to harvest-rogue out infected plants</td>
<td>2.0</td>
<td>4.7</td>
<td>250 a</td>
</tr>
<tr>
<td>Admire Pro 8.7 oz @ plant +BmJ WP 2.0 oz/A 14 days emergence to harvest</td>
<td>5.0</td>
<td>6.3</td>
<td>241 ab</td>
</tr>
<tr>
<td>@ 60 days post emergence Assail 1.7 oz, 67 days Fulfill 5.5 oz, 75 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beleaf 2.8 oz, 87 days Leverage 3.8 oz-rogue out infected plants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Admire Pro 8.7 oz @ plant @ 60 days post emergence Assail 1.7 oz, 67 days</td>
<td>7.0</td>
<td>7.6</td>
<td>215 b</td>
</tr>
<tr>
<td>Fulfill 5.5 oz, 75 days Beleaf 2.8 oz, 87 days Leverage 3.8 oz-rogue out infected plants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Untreated</td>
<td>8.0</td>
<td>10.0</td>
<td>238 ab</td>
</tr>
<tr>
<td>Flsd 0.05</td>
<td>2.5</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>#</td>
<td>Hermiston 2012 Treatments</td>
<td>BmJ</td>
<td>Aph Oil</td>
</tr>
<tr>
<td>----</td>
<td>------------------------------------------------------------------------------------------------------------</td>
<td>-----</td>
<td>---------</td>
</tr>
<tr>
<td>1</td>
<td>UTC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>BmJ Microbial Fungicide @ 2 oz /A applied @ a 12 day interval from emergence till vine kill (~9/1/12-13)</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>3</td>
<td>JMS Stylet Oil at 1.5% applied every 4 days from emergence till vine-kill</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>4</td>
<td>BmJ, JMS Stylet Oil- rates and timing as above</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>5</td>
<td>No- gap insecticide ( Movento 5 oz/A@60 days, Fulfill 5.5oz/A @ 72 days, Movento 5 oz/A @84 days and Beleaf 2.8 oz /A@96 days post planting)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>BmJ, No-gap insecticide and timing as above</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>JMS Stylet Oil, No-gap insecticide- rates and timing as above</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>8</td>
<td>BmJ, JMS Stylet Oil, No-gap insecticide- rates and timing as above</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>
2012 Hermiston, OR- PVY Plots
<table>
<thead>
<tr>
<th></th>
<th>Treatment</th>
<th>% PVY infection August 1, 2012</th>
<th>8 rep % PVY Winter test</th>
<th>4 rep % PVY Winter test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UTC</td>
<td>17.5</td>
<td>57.8 abc</td>
<td>51.5 a</td>
</tr>
<tr>
<td>2</td>
<td>BmJ Microbial Fungicide @ 2 oz /A applied @ a 12 day interval from emergence till vine kill (~9/1/12-13)</td>
<td>11.5</td>
<td>66.4 a</td>
<td>53.5 a</td>
</tr>
<tr>
<td>3</td>
<td>Stylet oil at 4% applied every 4 days from emergence till vine-kill</td>
<td>4.5</td>
<td>35.4 d</td>
<td>18.7 b</td>
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<tr>
<td>4</td>
<td>BmJ, Stylet oil- rates and timing as above</td>
<td>7</td>
<td>45.0 dc</td>
<td>27.2 ab</td>
</tr>
<tr>
<td>5</td>
<td>No- gap insecticide ( Movento 5 oz/A@60 days, Fulfill 5.5oz/A @ 72 days, Movento 5 oz/A @84 days and Beleaf 2.8 oz /A@96 days post planting)</td>
<td>22</td>
<td>65.4 a</td>
<td>49.7 a</td>
</tr>
<tr>
<td>6</td>
<td>BmJ, No-gap insecticide</td>
<td>15</td>
<td>65.3 a</td>
<td>36.3 ab</td>
</tr>
<tr>
<td>7</td>
<td>Stylet oil, No-gap insecticide</td>
<td>7.5</td>
<td>48.9 abcd</td>
<td>40.2 ab</td>
</tr>
<tr>
<td>8</td>
<td>BmJ, Stylet oil, No-gap insecticide</td>
<td>8.0</td>
<td>45.7bcd</td>
<td>27.3 ab</td>
</tr>
<tr>
<td></td>
<td>Flsd 0.05</td>
<td>3.8</td>
<td>19.9</td>
<td>26.5</td>
</tr>
</tbody>
</table>
2012 Hermiston, OR- PVY Plots

Problems
2 row border-bare soil-wheat
Yellow flags-attracted aphids?
Each plot bordered by row with 1% PVY
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Under 4 oz</th>
<th>4-8 oz</th>
<th>8-12 oz</th>
<th>Over 12 oz</th>
<th>Combined Weight for 4-12 oz Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>19.7 a</td>
<td>.57 a</td>
<td>74.94 a</td>
<td>22.99 a-b</td>
<td>3.72 a-b</td>
</tr>
<tr>
<td>2.</td>
<td>19.87 a</td>
<td>.51 a</td>
<td>62.44 b-c</td>
<td>22.39 a-b</td>
<td>3.91 a-b</td>
</tr>
<tr>
<td>3.</td>
<td>21.85 a</td>
<td>.68 a</td>
<td>65.74 a-c</td>
<td>20.28 a-b</td>
<td>3.49 a-b</td>
</tr>
<tr>
<td>4.</td>
<td>21.88 a</td>
<td>.48 a</td>
<td>56.39 c</td>
<td>14.96 b</td>
<td>1.46 b</td>
</tr>
<tr>
<td>5.</td>
<td>19.39 a</td>
<td>.61 a</td>
<td>69.03 a-b</td>
<td>31.15 a</td>
<td>5.13 a</td>
</tr>
<tr>
<td>6.</td>
<td>19.44 a</td>
<td>.70 a</td>
<td>65.14 a-c</td>
<td>27.46 a</td>
<td>4.74 a-b</td>
</tr>
<tr>
<td>7.</td>
<td>19.79 a</td>
<td>.46 a</td>
<td>68.4 a-b</td>
<td>20.75 a-b</td>
<td>4.08 a-b</td>
</tr>
<tr>
<td>8.</td>
<td>22.33 a</td>
<td>.93 a</td>
<td>70.60 a-b</td>
<td>21.01 a-b</td>
<td>3.03 a-b</td>
</tr>
</tbody>
</table>
2013 Hermiston Small Roguing Plot % PVY infection 8/8/13

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Not Rogued</th>
<th>Rogued</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>6.84</td>
<td>4.03</td>
</tr>
<tr>
<td>BmJ 12 day interval from emergence</td>
<td>6.51</td>
<td>2.85 *</td>
</tr>
<tr>
<td>BmJ + JMS Stylet oil + no gap insecticide from emergence</td>
<td>1.82 **</td>
<td>1.29 **</td>
</tr>
</tbody>
</table>

* Differ from untreated unrogued @ P=0.1
** Differ from untreated unrogued @ P=0.05

Data including winter test results from large scale non rogued plot (very low infection in August) will be available in February 2014.
induced resistance reduce virus?

- No data from biological systems yet
- In Arabiopsis mutant / cauliflower mosaic virus studies with mutants Love, et al., 2007 showed salicylic acid pathway involved in delayed symptoms and severity and alternative oxidase. Ethylene/Jasmonic acid deficient mutants show reduce long distance spread. Lewsey et al., 2009 showed RNA silencing and salicylic acid mediated defense to restrict virus replication and movement. Jasmonic acid may have direct effect on aphid vector.
- Data using salicylic acid, Acibenzolar-s-methyl-(Actigard,Bion)/ CMV TMV in tobacco, squash, Arabidopsis show reduced virus movement-cell to cell (delay symptom development) and systemic movement. IR involves mitochondrial enzyme alternate oxidase and RNA dependent RNA polymerase.
  
Conclusion

IR shown to delay symptom onset and reduce infection, disease severity, virus titer, virus movement or symptom severity for a wide range of viruses. Viruses where some level of control has been noted include; cucumber mosaic virus (CMV), tobacco mosaic virus (TMV), potato virus Y (PVY), tomato mottle virus, cauliflower mosaic virus, barley yellow dwarf mosaic virus and tobacco necrosis virus.

Control levels are generally in the range of 30-80% and that the mode of action or efficacy differs remarkably by biological control agent and plant species.

May have direct effect on aphid vectors.
PVY/PVA

- Consider crop/oil borders-”aphid stylet cleaning stations”
- Control volunteers and Hairy nightshade (a good host for virus and green peach aphid)
- Use oils -start just before cereal crops begin to turn
- When registered use induce resistance from emergence till harvest
- Start foliar applied aphid insecticide program 60-70 days after planting treatments with group 4A materials (Admire, Cruiser, etc)
  - Non colonizing aphids like Bird Cherry- Oat aphids move from grain as crop ripens-late June-July
  - Mineral crop oils- oil reduces aphid acquisition and transmission of virus- need coverage, 5-7 day intervals, can use with insecticides
- Use “soft materials” Fullfill, Beleaf, Movento, neonicotinoid-4A materials – use till vine kill (no green vine tissue)- follow insecticide resistance management suggestions
Reducing PVY Risk

- Disease-free seed
  - Seed growers-100% testing nuclear and G1 (tuber unit)
  - Rogueing
- Crop Borders
- Systemic insecticides at planting
- Roguing symptomatic plants
- Stylet oils, Induced systemic resistance
- No gap insecticide program- feeding deterrents, “soft insecticides” thru vine kill
- Early Vine-kill
- Volunteer potato control
THANK YOU TO LAB GROUP

Dr. Nina Zidack
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Dr. Andrea Braun-Kiewnick
Doug Collins
Dr. Rebecca Bargabus-Larson
Dr. Oliver Neher
Hope Talbert
Dr. Alice Pilgeram
Tyler Samuelson