Preparation for Crops Diagnostic Workshop

Soils were collected in 35 fields; from Dusty to Colfax to Uniontown
10 sub-samples/sample; ¾ - 1½ acres/sample

Nematodes detected:

<table>
<thead>
<tr>
<th></th>
<th>Root-lesion</th>
<th>Cereal cyst</th>
<th>Stunt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive detections</td>
<td>33</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>% of samples</td>
<td>94%</td>
<td>57%</td>
<td>46%</td>
</tr>
<tr>
<td>Present in high numbers</td>
<td>12</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>% of samples</td>
<td>34%</td>
<td>31%</td>
<td>9%</td>
</tr>
</tbody>
</table>
Root-lesion Nematodes (RLN)

*Pratylenchus neglectus* and *Pratylenchus thornei*

Nematodes were stained to reveal presence in root tissue.

Simple life cycle: egg → juvenile → adult female → egg
Effect of Root-lesion Nematodes on Wheat Health

- Reduced extraction of soil water & nutrients
- Reduced tillering & plant vigor
- Reduced grain yield & grain quality (lower test weight)
- Reduced economic efficiency in infested fields

Field test at OSU (+/- nematicide)

Greenhouse test at WSU

- Alpowa (susceptible)
- AUS 28451 (resistant)
- Louise (susceptible)

roots turn black
Root-lesion nematodes are widely distributed in PNW surveys revealed counties (●) with potentially damaging densities.

1999-2000
- *P. neglectus* in 94% fields
- *P. thornei* in 36% fields
- 30% of fields had mixtures

2002-2003
- *P. neglectus* in 96% fields
- *P. thornei* in 11% of fields
- Some species mixtures

2005-2006
- *P. neglectus* in 40% fields

OR & WA: Smiley et al. (2004) *Plant Disease* 36:54-68
WA: Kandel et al. (2013) *Plant Disease* 97:1448-1456
Horizontal Variability of Root-lesion Nematodes near Pendleton
(nematodes/ lb of soil in 5 ½ x 20 ft plots)

<table>
<thead>
<tr>
<th></th>
<th>168</th>
<th>1,936</th>
<th>73</th>
<th>1,755</th>
<th>2,764</th>
<th>532</th>
<th>205</th>
<th>77</th>
<th>1,677</th>
<th>82</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,318</td>
<td>1,564</td>
<td>50</td>
<td>223</td>
<td>18</td>
<td>4,873</td>
<td>132</td>
<td>577</td>
<td>9,418</td>
<td>318</td>
<td></td>
</tr>
<tr>
<td>1,232</td>
<td>336</td>
<td>0</td>
<td>41</td>
<td>173</td>
<td>23</td>
<td>5,800</td>
<td>4,882</td>
<td>732</td>
<td>150</td>
<td></td>
</tr>
</tbody>
</table>

sampled to 12” depth
12 cores/ 110 ft² plot
total area = 0.1 acre
range = 0 - 9,418 nematodes/ lb of soil
average = 1,404 nematodes/ lb of soil
Vertical Distribution of Root-lesion Nematodes at 6” Depth Intervals

Pratylenchus spp. / lb of soil

Soil depth (inches)

In deep soils, collect RLN samples to a depth of 18”

900/lb of soil is an approximate threshold above which economic damage could become substantial
Root-lesion Nematodes vs Yield of SW in Oregon

\[ y = 87.2 - 0.01x \]

\[ R^2 = 0.57 \quad P < 0.01 \]

50 1,000 2,000 3,000

Pratylenchus / lb of soil

Yield (bu / acre)

34% of Whitman Co. fields exceeded this threshold
# Concepts of Resistance and Tolerance

**Resistance:** is the nematode’s ability to multiply in roots

*After harvest, how many nematodes will be left in soil to attack the next crop?*

**Tolerance:** is the effect of nematode invasion & reproduction on grain yield

*How will the yield of the current crop be affected?*

Resistance and tolerance are genetically independent!

<table>
<thead>
<tr>
<th></th>
<th>high reproduction</th>
<th>low reproduction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>susceptible</strong></td>
<td>high reproduction</td>
<td>low reproduction</td>
</tr>
<tr>
<td>minor yield loss</td>
<td>major yield loss</td>
<td>minor yield loss</td>
</tr>
<tr>
<td><strong>resistant</strong></td>
<td>low reproduction</td>
<td>low reproduction</td>
</tr>
<tr>
<td>minor yield loss</td>
<td>major yield loss</td>
<td>major yield loss</td>
</tr>
</tbody>
</table>
Spring Wheat Tolerance to *P. neglectus* at Heppner

data were averaged over 3 years; 2006–2008

Grain yield (bu / ac)

Temik-treated plots

Untreated control plots
Multiplication of Root-lesion Nematode in Winter Wheat

Multiplication rate (MR) = final ÷ initial population over the 16-wk test period
Resistance is defined as <5% of maximum MR in the test (the ‘red line’)

Pratylenchus neglectus

2 resistant land-race wheats were detected
Multiplication of *P. neglectus* in Roots of Spring Wheat and Barley

Multiplication rate (MR) = final ÷ initial population

- all PNW wheat varieties tested were susceptible
- resistant land-race wheat lines were identified
- barley was less susceptible than wheat
RLN Density after Harvest & Yield Increase from Nematicide Application
(average of 4 site-yrs; 2 yrs at each of 2 locations; mixtures of *P. neglectus* and *P. thornei*)

** RLN reduced profitability of wheat by >$8/acre in this experiment **

- **red** = untreated control: “What the farmer would experience”
- **blue** = application of a non-registered nematicide for this research

Economic threshold
Density of Root-lesion Nematodes after Growing Alpowa and AUS28451 in Field Trials
(5 experiments at 2 locations over 3 years)

- Crosses of AUS28451 with PNW-adapted varieties are being developed by WSU/USDA-ARS
- Genetic markers are being developed to allow breeders to identify resistant lines

### RLN/lb of soil following Alpowa & AUS28451

<table>
<thead>
<tr>
<th>Year</th>
<th>Mission</th>
<th>Pendleton</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>1,754</td>
<td>253</td>
</tr>
<tr>
<td>2012</td>
<td>16,143</td>
<td>1,397</td>
</tr>
<tr>
<td>2013</td>
<td>19,253</td>
<td>2,428</td>
</tr>
</tbody>
</table>

### % reduction: AUS28451 vs Alpowa

<table>
<thead>
<tr>
<th>Year</th>
<th>Mission</th>
<th>Pendleton</th>
<th>Ave.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>-81%</td>
<td>nd</td>
<td>-81%</td>
</tr>
<tr>
<td>2012</td>
<td>-92%</td>
<td>-82%</td>
<td>-87%</td>
</tr>
<tr>
<td>2013</td>
<td>-87%</td>
<td>-73%</td>
<td>-80%</td>
</tr>
<tr>
<td>Ave.</td>
<td>-87%</td>
<td>-78%</td>
<td>-83%</td>
</tr>
</tbody>
</table>

Greenhouse test at WSU

- roots turned black
- roots turned black

- Alpowa
- AUS 28451
- Louise
Crops as Hosts for Root-lesion Nematodes (2013)
(relative multiplication rate)

**P. neglectus**
- safflower, sunflower, gamagrass, switchgrass
- canola, mustard, camelina
- wheat, oat, flax, sudangrass

**P. thornei**
- safflower, sunflower, gamagrass, switchgrass
- canola, mustard, camelina
- wheat, oat, flax, sudangrass

**Pea, lentil, chickpea**
# Crops as Hosts for *Pratylenchus* Species

Nematode species identification is essential to understand the potential impact of rotations and of individual crops and varieties on each species!

<table>
<thead>
<tr>
<th>Hosting:</th>
<th><em>P. neglectus</em></th>
<th><em>P. thornei</em></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Very good &amp; good hosts</strong></td>
<td>wheat, canola, camelina, yellow mustard, chickpea, oats</td>
<td>wheat, field pea, lentil, oats</td>
</tr>
<tr>
<td><strong>Minor hosts</strong></td>
<td>barley, brown mustard, lentil, yellow pea, field pea, alfalfa, vetch</td>
<td>barley, chickpea, yellow pea</td>
</tr>
<tr>
<td><strong>Poor hosts &amp; non-hosts</strong></td>
<td>safflower, sunflower, switchgrass, flax</td>
<td>canola, camelina, flax, brown mustard, vetch, yellow mustard, alfalfa</td>
</tr>
<tr>
<td></td>
<td></td>
<td>safflower, sunflower, switchgrass, sudangrass</td>
</tr>
</tbody>
</table>
Weeds as Hosts for Root-lesion Nematodes (2013) (relative multiplication rate)

- P. neglectus
  - broadleafs
  - monocots

- P. thornei
  - broadleafs
  - monocots
CRP (rangeland) Plants as Hosts for Root-lesion Nematodes (2013)
(relative multiplication rate)

- *P. neglectus*
  - Grasses
  - Legumes

- *P. thornei*
  - Grasses
  - Legumes
Range Plants & Weeds as Hosts for *Pratylenchus* Species

<table>
<thead>
<tr>
<th>Hosting:</th>
<th><em>P. neglectus</em></th>
<th><em>P. thornei</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Very good &amp; good</td>
<td>most range grasses, kochia, pigweed, palmer amaranth, jointed goatgrass, crabgrass, foxtail, wild oat</td>
<td>most range grasses, jointed goatgrass, rattail fescue</td>
</tr>
<tr>
<td>good hosts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor hosts</td>
<td>alfalfa, hairy vetch, lambsquarters</td>
<td>downy brome</td>
</tr>
<tr>
<td>Poor hosts &amp; non-</td>
<td>russian thistle, rattail fescue, prostrate spurge, dandelion, horseweed, downy brome</td>
<td>alfalfa, hairy vetch, kochia, pigweed, russian thistle, dandelion, palmer amaranth, crabgrass, lambsquarters, foxtail, wild oat, prostrate spurge, horseweed</td>
</tr>
<tr>
<td>hosts</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Nematode species identification is essential for understanding the potential impact of rotations and of individual varieties on each species!
Long-Term Cropping Systems Experiment at Moro, OR
14 treatments, 3 reps, 4 years, 48 x 350 ft plots

- Annual winter wheat NT
- Annual spring wheat NT
- Annual spring barley NT
- WW / cultivated fallow tilled
- WW / chemical fallow NT
- WW / winter pea NT
- WW / SB / chem fallow NT
- Flex-crop sequences NT

Effect of RLN density on yield of winter wheat

\[ y = 60.9 - 0.02x \]
\[ R^2 = 0.77 \quad P < 0.01 \]
Root-lesion Nematode Density in a Long-term Experiment at Moro  
(averaged over 8 years; sampling was after the crop or management shown in bold)

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>Nematodes/lb of soil</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual no-till crops:</strong></td>
<td></td>
</tr>
<tr>
<td>winter wheat</td>
<td>1,259</td>
</tr>
<tr>
<td>spring wheat</td>
<td>1,146</td>
</tr>
<tr>
<td>spring barley</td>
<td>171</td>
</tr>
<tr>
<td><strong>Comparison of fallow systems:</strong></td>
<td></td>
</tr>
<tr>
<td>winter wheat/cultivated fallow</td>
<td>2,084</td>
</tr>
<tr>
<td>winter wheat/<em>cultivated fallow</em></td>
<td>892</td>
</tr>
<tr>
<td>winter wheat/chemical fallow</td>
<td>1,440</td>
</tr>
<tr>
<td>winter wheat/<em>chemical fallow</em></td>
<td>702</td>
</tr>
<tr>
<td><strong>Winter wheat-winter pea no-till rotation:</strong></td>
<td></td>
</tr>
<tr>
<td>winter wheat/winter pea</td>
<td>893</td>
</tr>
<tr>
<td>winter wheat/<em>winter pea</em></td>
<td>1,031</td>
</tr>
<tr>
<td><strong>3-year no-till rotation:</strong></td>
<td></td>
</tr>
<tr>
<td>winter wheat/spring barley/chemical fallow</td>
<td>567</td>
</tr>
<tr>
<td>winter wheat/<em>spring barley</em>/chemical fallow</td>
<td>355</td>
</tr>
<tr>
<td>winter wheat/spring barley/*chemical fallow</td>
<td>30</td>
</tr>
</tbody>
</table>
Cereal Cyst Nematodes (CCN)

*Heterodera avenae*

and

*Heterodera filipjevi*
Known distribution of cereal cyst nematode in the western USA

it is almost certain that many other regions are also infested but have not yet been discovered
1. In spring, 2nd stage juveniles emerge from brown cysts & migrate through soil; some are released each year, over several years.

2. Stylet thrusts outward; injuring root cells & injecting toxins.

3. Inflated 3rd stage female becomes embedded in roots of small seedlings.

4. Roots become knotted & shallow, restricting uptake of water & nutrients.

5. Swollen 4th stage females embedded in roots.

6. Egg-filled swollen white female (≈1/32” diam.) at time of crop anthesis.

7. At crop maturity, brown cysts are released into the soil.

8. Hundreds of eggs & juveniles are released when a brown cyst is ruptured.

Cereal cyst nematode

*Heterodera avenae*

(1-year life cycle)
Peak populations of *H. avenae* invasive juveniles present in soil at two Oregon locations with diverse climates. The timing of the peak population of invasive juveniles in soil coincides with the dominant production practice and spring-time temperature in each area. 

- **near Portland**: mild winters
- **near La Grande**: long-cold winters
Cereal Cyst Nematode vs Yield of Irrigated WW in Oregon

Yield = 106 - 0.0027x
\( R^2 = 0.70 \)

31% of Whitman Co. fields exceeded threshold.
Resistance of wheat to *Heterodera avenae* in Greenhouse Trials
Smiley et al. (2011) Nematology 13:539-552

- Results from testing Idaho, Oregon & Washington soils
- Ouyen is an improved variety in Australia
- AUS10894 is an un-adapted landrace wheat

![Graph showing new cysts per plant](image)

Resistance is <3 cysts/plant
Resistance and Tolerance to *Heterodera avenae* in Spring Wheat at Cashup - 2012

- paired drill passes ± Temik
- change varieties every 30 feet
- count white females on roots (R)
- rate severity of damage to roots (R)
- count eggs/lb of soil after harvest (R)
- compare yield and test weight (T)
Spring Wheat Resistance to CCN
averaged over 2 locations in 2012: St. Anthony, ID & Cashup, WA

- WB-Rockland
- Ouyen
- Klasic
- JD
- Cabernet
- Alturas
- Louise
- Bullseye
- Jedd
- UI Pettit
- Alpowa
- Buck Pronto
- Otis
- WB 1035C1+
- Westbred 936
- Kelse
- Babe
- Glee
- UI Stone
- Jefferson

R = resistant (<3 females)
S = susceptible (>3 females)
Reproduction of *H. avenae* on Susc. & Res. Wheat in the Field averaged over 2 sites in 2012: St. Anthony, ID & Cashup, WA
Density of *H. avenae* after Harvesting Susceptible or Resistant Wheat
2012 - St. Anthony, ID

<table>
<thead>
<tr>
<th>Variety</th>
<th>No. of <em>H. avenae</em> / lb of soil</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpowa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Louise</td>
<td></td>
<td>-16%</td>
</tr>
<tr>
<td>Ouyen</td>
<td></td>
<td>-72%</td>
</tr>
<tr>
<td>WB Rockland</td>
<td></td>
<td>-66%</td>
</tr>
</tbody>
</table>
Resistance & Tolerance of 39 Wheats to *H. avenae* at St. Anthony, ID in 2013
Resistance of 46 Malting & Feed Barleys to *H. avenae* at St. Anthony, ID in 2013

(6 = 6-row; all others are 2-row)

**Malting barley**

- Odyssey
- Legacy (6)
- 01Ab9663 (6)
- Tradition (6)
- Celebration (6)
- Quest (6)
- Morex (6)
- LCS1820
- Conrad
- 2B05-0811 (B0811)
- 02Ab17271
- 2Ab07-X031098-31
- Merit
- Meredith
- Metcalf
- Overture
- Copeland
- Pinnacle
- Harrington
- 2Ab04-X001084-27
- B1202
- Hockett
- Merit 57
- Genie
- ABI Voyager

**Feed barley**

- Millennium (6)
- Steptoe (6)
- Herald (6)
- Goldeneye (6)
- Lenetah
- Idagold II
- Transit
- Xena
- CDC Fibar
- RWA 1758
- Baronesse
- Champion
- 08ID1549
- Julie
- 08ID2661
- Clearwater
- CDC McGwire
- Vespa
- Tetonia
- Spaulding

new cysts/untreated plant
Nematode Management

1. Field sanitation
   • avoid spreading the nematodes (in soil or on plant roots)
   • control weeds & volunteers (don’t let nematodes keep multiplying)

2. Crop rotation
   • fallow reduces nematode density (tillage intensity isn’t important)
   • 2-yr rotation is not adequate if wheat is planted in alternate years

   • **Root-lesion nematode:**
     • broad host range (good rotation crops are barley, flax, safflower, triticale or spring pea)
     • 3-yr rotations greatly reduce nematode density (WW-SB-fallow)

   • **Cereal cyst nematode:**
     • only multiplies on wheat, barley & oat (good rotation crops include any broadleaf species)
     • controlled by 3-yr rotations if host crop occurs only once
Nematode Management

3. Crop nutrition
   • in addition to the normal fertilizer application, place a starter fertilizer below or near the seed to enhance seedling vigor

4. Water supply
   • if available, apply supplemental irrigation to reduce plant stress

5. Genetic resistance
   • resistance has been identified and is available in some instances

6. Genetic tolerance
   • Root-lesion nematode: variety guidelines are available
   • Cereal cyst nematode: guidelines are being determined

7. Chemical & biological control
   • none have been shown to be effective in dryland situations
   • fumigant nematicides and bio-fumigant crops are effective when applied before planting high-value irrigated crops
Would You Like More Information?

Contact me:

richard.smiley@oregonstate.edu
http://cbarc.aes.oregonstate.edu/plant-pathology
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• Syngenta Crop Protection

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• CIMMYT Soilborne Pathogen Program
• Mid-Columbia Producers (Wasco, OR)
• USDA-ARS Nat’l. Small Grains Collection
• Western Laboratories
• Whitgro (St. John, WA)
• Nordic Gene Bank

University & USDA-ARS Staff:
• Dr. Juliet Marshall (ID)
• Dr. Carl Strausbaugh (ID)
• Dr. Guiping Yan (OR)
• Dr. Dan Ball (OR)
• Dr. Stephen Machado (OR)
• Dr. Steve Petrie (OR)
• Dr. Mike Flowers (OR)
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Wheat Producers:
• Dale Daw (ID)
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