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Globodera Alliance Newsletter

The Fascinating Biology of Potato Cyst Nematodes

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Inside this issue:

Introduction	1
Effects of nematodes on potato crop	1
How does PCN infects plants?	2
About GLOBAL Project	3
PCN Field Tour	4
Upcoming Event	5

Introduction

Potato cyst nematodes (PCN) may appear to be unremarkable – if damaging – animals. They are microscopically small and are only visible to the naked eye as small brown cysts when extracted from soil, or as white or golden spheres on the roots of infested plants (Figure 1). However, potato cyst nematodes are complex pathogens that show incredible adaptations that allow them to feed on potato. Since they are only able to feed on a small number of related plants they have to remain dormant in the soil until a suitable food source is detected; there is no value in starting your life cycle when there is nothing growing nearby that can be used as a food source. This article provides some background information on the basic biology of PCN and how this impacts the damage it causes and control options.

Figure 1: PCN is only visible to the naked eye as cysts, pictured above attached to potato root. (Photo: NemaPix)

Figure 2: Visible symptoms of a PCN infected field— stunted, unhealthy potato plant growth — can be confused with nutritional stress. (Photo: M. Phillips)

Effects of nematodes on potato crop

Potato cyst nematodes are a quarantine pathogen and where they are newly detected in a potato region, huge efforts are made to eradicate the infestation and thus prevent further spread. In parts of the world where PCN has become established, it has a serious impact on potato production. In some areas populations of PCN are so high, and control options so limited, that the future of the crop is threatened.

Unlike many other pathogens, there are few specific visible symptoms with potato that are associated with PCN infestation. Infested areas of the field appear to be generally unhealthy (Figure 2) and these symptoms are frequently confused with nutrient stresses. Death of the plant as a result of PCN infection is extremely rare, although infection with PCN may make a plant more susceptible to other pathogens such as fungi.

The most important effect of PCN infestation from the grower's perspective is a reduction in crop yield. The extent of this yield reduction varies depending on soil type and potato cultivar but is also related to the population level of PCN at planting (the initial population – Pi); generally the higher the nematode population the greater the yield loss (Figure 3). At a certain Pi the economic threshold is passed – the point at which the yield loss is so great as to make growing potato economically unviable. One of the key implications of this relationship between yield loss and population level is that it is critical for growers to know the level of PCN infestation in the soil. Effective sampling for PCN is therefore of key importance.

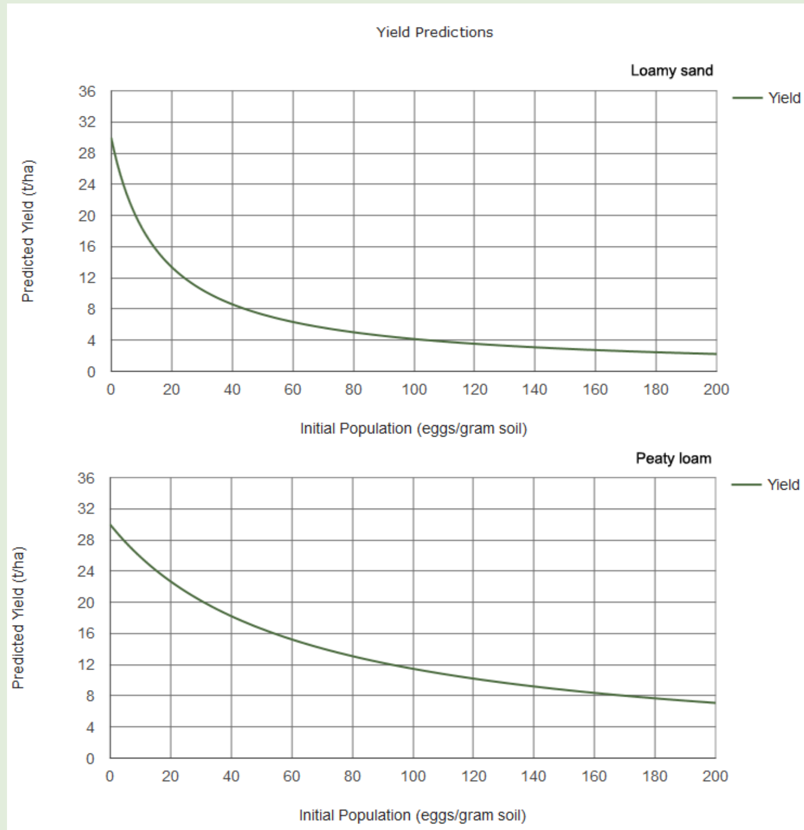

Figure 3: A comparison of PCN related yield loss in potato crops planted in loamy sand verses peaty loam. Regardless of soil type, the higher the nematode population in the field, the greater the yield loss. (Chart: AHDB PCN calculator)

Once introduced into a field, PCN are extremely persistent. PCN is a specialist and relies on potato and a small number of other Solanaceous plants to complete their life cycle. They have evolved an extremely effective survival stage – the eggs within the cysts – which remain dormant in the soil until a suitable host is detected growing nearby. Although a proportion of the dormant nematodes in a field will die each year, there is evidence that PCN can survive for periods of over 20 years in the absence of a host, meaning that once a field is infested removing all viable nematodes is extremely difficult. Given the tiny size of the cysts, it is also very difficult to detect their presence until they reach a threshold level. Demonstrating that they have been eradicated is therefore very difficult.

How do potato cyst nematodes infect plants?

Although many animals that feed on plants are simple grazers, or herbivores, which destroy plants as they feed, potato cyst nematodes, like many of the most damaging plant pathogens, are biotrophic and need to keep their host alive while they feed.

The life cycle of the potato cyst nematode starts with cysts – the survival stage of the nematode. Each cyst contains several hundred eggs and each egg contains a dormant juvenile nematode (Figure 4). The eggshell is an extremely tough, resilient structure that protects the dormant nematode from environmental extremes such as cold temperatures and from fungi and bacteria in the soil. It is this structure that allows the nematode to persist in the field. The nematode is activated by the presence of chemicals produced by the growing roots of plants that the nematode can infest. This response is specific – chemicals from plants that the nematode cannot infest do not activate the nematode. Following detection of these root exudates a series of changes in the eggshell are induced that make it permeable to wa-

Figure 4: A nematode egg, as viewed under the microscope. Each egg — one of hundreds found inside a single nematode cyst — contains a dormant juvenile nematode. The egg hatches in the presence of chemical (exudates) produced by the roots of the potato plant. (Photo: NemaPix)

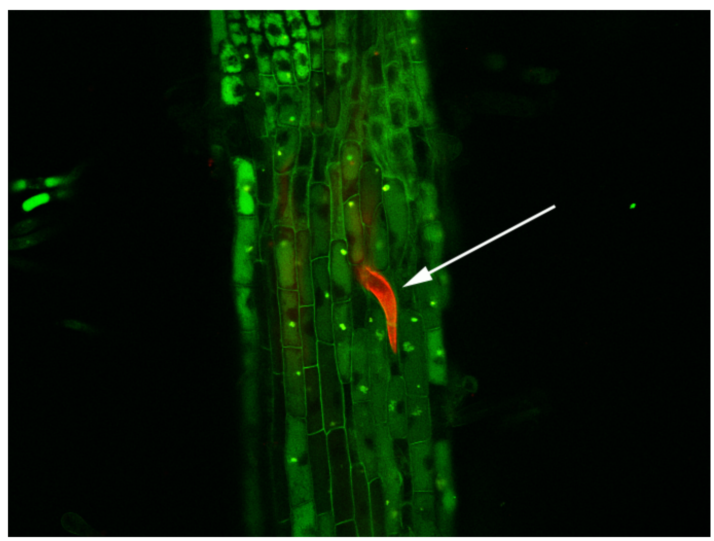

Figure 5: A juvenile nematode—stained red for better viewing under the microscope — enters the potato root. (Photo: V. Blok)

About the GLOBAL Project

GLOBAL
Globodera Alliance

GLOBAL stands for "Globodera Alliance", an international group of research, extension, and education professionals working to eradicate *Globodera spp.* in U.S. potato production.

GLOBAL Project members include scientists from the University of Idaho, Oregon State University, Cornell University, U.S. Department of Agriculture (USDA), Agriculture and Agri-Food Canada, The James Hutton Institute, and the French National Institute of Agricultural Research.

For periodic updates on this ongoing work:

Visit **www.globodera.org**

Or contact Louise-Marie Dandurand: lmd@uidaho.edu

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ter and subsequently lead to the nematode becoming active and it hatches from the egg. The nematode then moves through the soil and locates host roots, following chemical gradients to the growing root tips where it invades the root (Figure 5).

Perhaps the most remarkable aspect of PCN biology is its feeding behaviour. Once inside the root the nematode migrates destructively through the plant tissues until it finds a specific cell type. Here the nematode induces the formation of a large, metabolically active and multinucleate feeding site – the syncytium (Figure 6). This syncytium is formed by controlled breakdown of the plant cell walls between the initially selected cell and its neighbours, followed by fusion of the protoplasts. This process is repeated until up to 300 cells are gradually incorporated into the syncytium. The nematode can only induce one syncytium and relies on this structure for all the food required for the rest of its development to the adult stage. The details of how the nematode is able to induce this feeding structure are still sketchy, although it is known that the nematode is able to produce mimics of key plant peptide hormones which play important roles in controlling cell fate. Once the feeding site is established the nematode remains here and feeds, developing through a series of moults to the adult female or adult male. Females remain attached to the feeding site and grow until they burst through the root surface (Figure 7). Males retain the worm-like body structure, leave the root and find females that they mate with. After fertilization the female dies and her body wall forms the cyst which encloses the next generation of eggs in the soil.

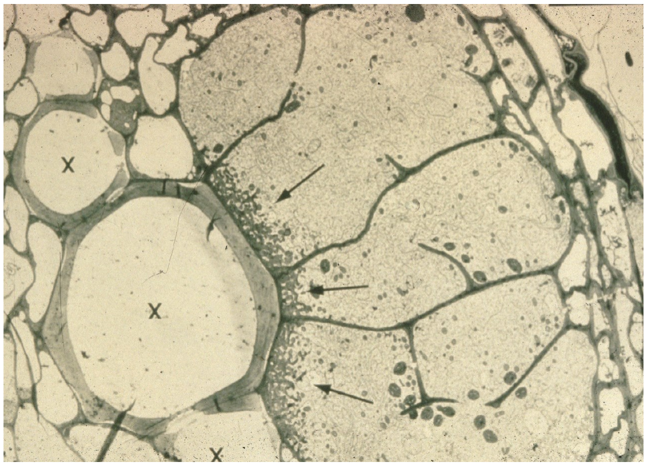


Figure 6: Cross section through the syncytium—feeding site—of PCN in potato root. The syncytium cell wall becomes folded (marked by arrows) where in contact with plant tissue vessels (X) to allow more effective transfer of nutrients into the syncytium. (Photo: The James Hutton Institute)

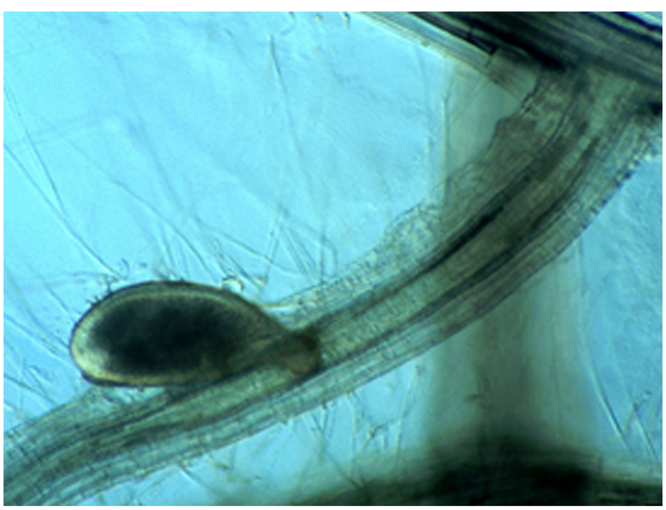
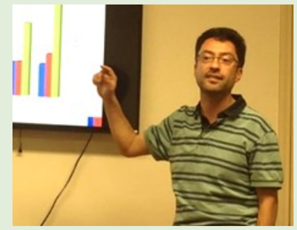


Figure 7: A female nematode attached to its potato root feeding site, where it has grown and burst through the root surface. (Photo: NemaPix)

Although the ability to induce these feeding sites is a remarkable adaptation, the fact that the nematode can only induce a single feeding structure is a vulnerability that plant breeders seek to exploit. In a resistant plant, the presence of the feeding structure is detected and a localised cell death response which either kills or isolates the feeding structure is triggered. Knowledge of how this process is induced and controlled provides information that can be used to develop more durable resistance. Resistant potatoes will provide an effective solution to producing potato on infested land and ultimately over time will restore land to be PCN free.

Chilean Nematologists Tour Pacific Northwest



Nematologists from Chili visited the Pacific Northwest this fall to exchange information about the identification of potato cyst nematodes and to learn more about control methods for the pale cyst nematode in southern Idaho, as well as the USDA-APHIS PCN containment and eradication program.

The visitors: Ingrid Moreno, Hugo Pacheco, and Oriana Acevedo, were representatives from Servicio Agrícola y Grandero/ SAG (the Department of Agriculture and Livestock Services).

Traveling with Louise-Marie Dandurand (University of Idaho, Moscow) and Inga Zasada (USDA-ARS, Corvallis, OR), the group met with researchers and toured potato cyst nematode laboratories run by the University and USDA. Meeting with Pat Kole, Idaho Potato Commission and Brian Marschman, USDA-APHIS provided an opportunity to exchange information about the potato industries in Chili and Idaho.

In southern Idaho, potato harvesting was in full swing. Tina Gresham, Director, USDA-APHIS Pale Cyst Nematode Program, provided a tour of the soil testing lab serving to monitor PCN in Bingham and Bonneville counties. The group also observed the equipment power washing and steam cleaning process used to prevent the spread of PCN.

Upcoming Event:

2018 Idaho Potato Conference & Ag Expo

January 17-18, 2018

Pocatello, Idaho

GLOBAL Project Investigators will be presenting several workshops at the Idaho Potato Conference, including an update on work underway to control PCN and develop PCN resistant potatoes. A workshop about PCN will also be conducted in Spanish. For more information and links to registration, see:

https://www.uidaho.edu/cals/potatoes/conferences/idaho-potato-conference

GLOBAL Investigators

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- Inga Zasada, PhD, USDA ARS, GLOBAL Co-Director
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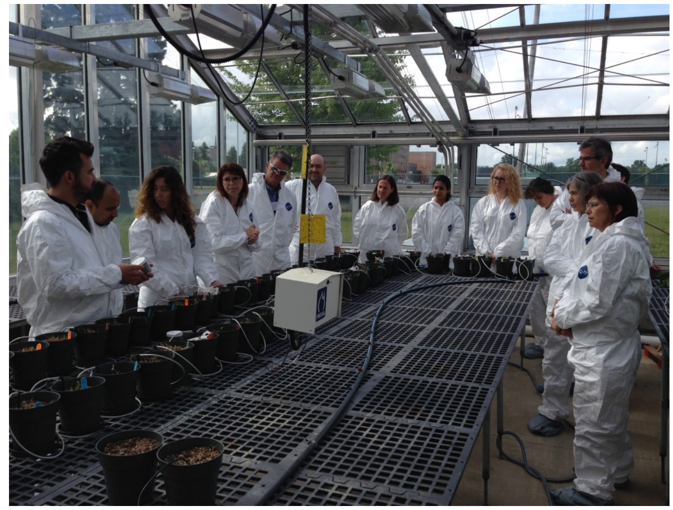
- Glenn Bryan, PhD, James Hutton Institute, Scotland
- Walter De Jong, PhD, Cornell University
- Dee Denver, PhD, Oregon State University
- Eric Grenier, PhD, Nat. Inst. of Agr. Research (INRA), France
- Pam Hutchinson, PhD, University of Idaho
- John Jones, PhD, James Hutton Institute, Scotland
- Joe Kuhl, PhD, University of Idaho
- Chris McIntosh, PhD, University of Idaho
- Benjamin Mimee, PhD, Agriculture and Agri-Food Canada
- Rich Novy, PhD, USDA ARS
- Mike Thornton, PhD, University of Idaho
- Xiaohong Wang, PhD, USDA ARS and Cornell University
- Jonathan Whitworth, PhD, USDA



GLOBAL Project scientists tour the potato cyst nematode greenhouse research facility at Agriculture and Agri-Food Canada, a GLOBAL partner agency (I. Zasada)

GLOBAL Advisory Committee

- Bill Brewer, Oregon Potato Commission
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- Tina Gresham, PhD, USDA APHIS PPQ
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- Brian Marschman, USDA APHIS PPQ
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- Andrea Skantar, PhD, USDA ARS
- Alan Westra, Idaho Crop Improvement Association
- Melanie Wickham, Empire State Potato Growers, Inc.
- Ryan Krabill, United States Potato Board

GLOBAL Advisory Committee consists of potato industry, state and federal regulatory and academic individuals who have volunteered their time and efforts. We thank them!

Contact us:

For more information, comments, or suggestions, please contact Louise-Marie Dandurand, **lmd@uidaho.edu**, or Inga Zasada, **inga.zasada@usda.ars.gov**