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Novel Eradication Strategies for Pale Cyst Nematode

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The Pale Cyst Nematode

Cyst nematodes are obligate pathogens of numerous plant species, and are major production constraints for a number of crops worldwide. Most economically important species of the cyst-forming nematodes are in the genera *Heterodera* and *Globodera*. Potato cyst nematodes are internationally recognized quarantine pests, are among the most damaging pests of potato, and can cause up to 100% yield loss (Brodie 1984). Cyst nematodes are also extremely damaging to soybean (Riggs 1977), sugarbeet (Steel 1984), tobacco (LaMondia 1995), and other important crops.

Two species of potato cyst nematode are found in the United States: *Globodera pallida*, the pale cyst nematode (PCN), was first found in Idaho in 2006, whereas the golden nematode, *G. rostochiensis* (GN), was first found in New York in 1941. Both species are regulated under a Federal Domestic Quarantine Order (USDA-APHIS) and parallel State Rules (Idaho State Dept. of Agriculture, New York State Dept. of Agriculture), and eradication efforts are underway.

In New York State, 922,395 acres are currently regulated because of the presence of golden nematode; of the regulated area, 5,985 acres are infested with GN. In Idaho, surveys after the initial detection in 2006 confirmed seven infested fields, totaling 911 acres in eastern Idaho. Since 2007, another fourteen PCN-infested fields have been found. Currently, 13,053 acres are regulated, of which 2,300 acres are PCN-infested. The infested fields all fall within a 5-mile radius. More than 416,000 additional samples have been collected and tested in Idaho outside the infested area to confirm freedom from PCN.

Cyst nematodes survive away from the plant host as eggs inside of cysts. A cyst is actually the dead body of an adult female nematode, with her eggs inside. There may be hundreds of eggs inside a single cyst. The narrow host range of *Globodera* species suggests that crop rotation could be effective for their control. However, due to their obligate nature, *Globodera* species, and particularly *G. pallida*, hatch only in the presence of a suitable host (or closely related non-host) that produces an appropriate chemical hatching factor, so that cysts with viable eggs inside can remain in the soil for years when a host is not present. Consequently, PCN population decline to non-detectable levels in the absence of a host can take upwards of 30 years for *G. pallida*. This makes crop rotation a relatively ineffective control strategy.

Control of PCN is also complicated by the slow hatch rate of the nematode over the growing season (i.e., not all eggs hatch at the same time), which results in lower susceptibility of nematode populations to nematicides. While some resistance to PCN is present in potato varieties grown in Europe and elsewhere in the U.S., there is no resistance in most of Idaho's signature russet varieties. Innovator has partial resistance to some pathotypes of *G. pallida*. Resistant or immune varieties are anticipated to be at least several years away. Because of regulatory considerations, potatoes cannot be grown in infested fields, and as discussed above, other crops have little effect on population decline.

The presence of *G. pallida* in Idaho has been viewed with alarm by other states and countries that import Idaho potatoes and other farm products. After the initial Idaho PCN detection in 2006, markets for Idaho fresh potato products and nursery stock were lost for Canada, Mexico, and Korea. Japan temporarily closed the market for all U.S. potatoes, and continues to disallow Idaho shipments. Consequently, eradication of PCN is a top priority for the Idaho potato industry, including the Idaho Potato Commission, the Idaho State Department of Agriculture, and USDA-APHIS. Millions of dollars have been spent in Idaho in eradication efforts. A critical component of this work has been treatment of infested fields with the fumigant methyl bromide (MeBr), which has been ongoing since the spring of 2007. Lab tests conducted after each treatment indicate a 95% viability reduction after one year's fumigation, and over 99% viability reduction after successive treatments. However, there are a number of economic considerations and MeBr label changes may negatively impact its prolonged use against PCN. Therefore, there is an urgent need for alternative, economically effective eradication approaches for PCN.

<u>Alternative PCN Eradication Strategies</u>

The University of Idaho PCN Project, with its collaborators, addresses many facets of the PCN problem, including bioassay of cysts from infested fields for USDA-APHIS, collaborative research with other USDA and university researchers, studies of PCN biology, molecular detection methods for PCN, and molecular genetic approaches to nematode resistance in potato. One important goal of the UI PCN Project is to develop and deploy biologically-based alternative eradication measures for PCN, in a comprehensive strategy to supplement and/or replace the current fumigation with MeBr. These measures include trap crops that stimulate hatching without allowing nematode development, fungal biological control agents that attack nematode cysts and eggs, and which may also protect potato roots, biofumigants, combinations of these methods, and outreach activities including demonstration plots, workshops, meetings, and internet materials, to transfer these new technological approaches into use by stakeholders.

Alternative eradication measures are aimed at all life stages of the nematode. Trap crops, which are non-host crops that stimulate egg hatching but do not support nematode reproduction, provide one mechanism to control PCN, since hatched juveniles have limited food reserves and will die if they do not successfully parasitize plant roots within days. With our colleague Dr. Chuck Brown, we have identified trap crop species, including *Solanum sisymbriifolium,* that stimulate this "suicide hatch." *Solanum sisymbriifolium* is an annual herb native to South America that can reach up to 3 feet in height. The stems and branches are armed with spines that can be up to ½ inch in length. The flowers are white to pale blue. *S. sisymbriifolium,* commonly known as litchi tomato, is preferred as a trap crop because it combines strong hatch stimulus with immunity to *G. pallida* and *G. rostochiensis.* One advantage of a trap crop such as *S. sisymbriifolium*, is that roots can access greater depths of the soil than fumigants without the environmental consequences. In preliminary experiments (Dandurand et al. 2013b), we observed a complete elimination of PCN reproduction in *S. sisymbriifolium* versus potato (**Table 1**).

Table 1. Mean number of cysts in *S. sisymbriifolium* vs. potato, after 16 weeks

Potato	**412**	***S. sisymbriifolium***	**0**

In contrast, cyst nematode population decline in the absence of a host is typically low and under fallow conditions may take 30 years or more.

A study of the life history of *G. pallida* on *S. sisymbriifolium* conducted at University of Idaho has already found several landmark changes in the appearance of either the nematode or its infected host (Dandurand et al. 2013b). We know that hatching of eggs is about equal whether we use potato or *S. sisymbriifolium* root diffusate. Thus, the two plants are physiologically equivalent, with regard to hatch stimulation, up to that point. However, by week 4 post-infection, many fewer J2s are found in *S. sisymbriifolium* roots compared to potato, and their development is arrested (**Fig. 1**).

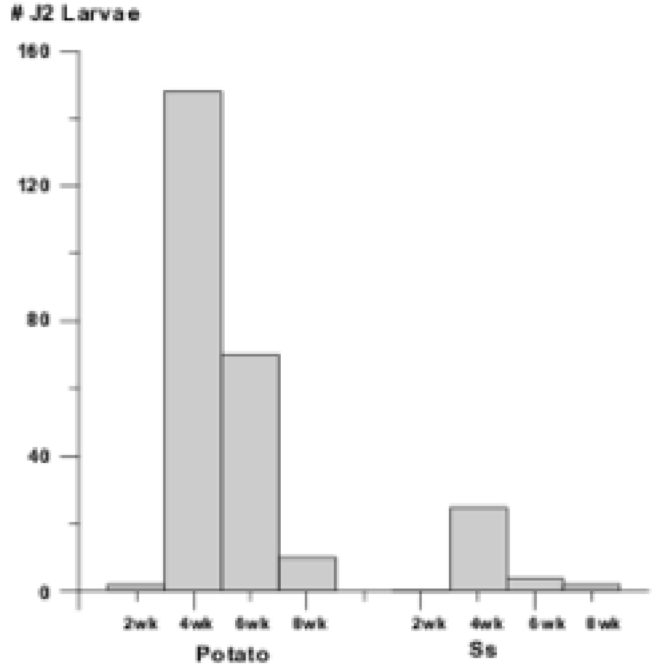

Fig. 1. Numbers of J2 larvae in roots of potato vs. *S. sisymbriifolium* (Ss) after 2, 4, 6, and 8 wk.

Current research to examine the potential of *S. sisymbriifolium* as a trap crop for infested fields in Idaho includes selection for decreased spines, investigation into aspects of early germination of seeds and rapid growth of the plant, and use of herbicides for its control. We are also assessing the length of time that the trap crop needs to be grown to maximize its effectiveness, and determining whether another crop could be grown in the same season.

Several nematode-killing fungi are known to be natural enemies of cyst nematodes, and have potential to be suitable agents for biological control. We have isolated and identified at least three strains of cyst- and/or juvenile-parasitising fungi (*Paecilomyces lilacinus*, *Plectosphaerella cucumerina*, and *Trichoderma harzianum*). If non-host trap plants arrest cyst nematode development, it may increase exposure of infective juveniles to biological control agents over longer periods of time. Thus, the combination of trap crops with biocontrol organisms may increase the efficacy of cyst nematode death. Mustard seed meal, which produces nematode-killing compounds, is still another possible approach.

Laboratory, greenhouse, and field trials are currently underway with all of these potential eradication technologies. Trap crops look especially promising: in greenhouse studies, while *S. sisymbriifolium* caused hatch of PCN eggs, the numbers of juveniles entering roots was significantly reduced, compared to potato (Dandurand et al. 2013a). Development of the nematode was arrested in the trap crop within several weeks, so that PCN reproduction did not occur. Trap crops were evaluated in the field for the first time in 2011. Biological control fungi continue to look promising: greenhouse evaluation showed all three species to be effective in reducing cyst numbers and viability of PCN, and two species applied in the field were able to persist in soil and on the roots of a non-host crop (barley)

(Dandurand et al. 2013b). In preliminary laboratory and greenhouse studies, the biofumigant crops *Brassica juncea* and *B. napis* significantly reduced hatching of PCN.

Each of these strategies, as well as combinations of them, shows promise for eradication of PCN in Idaho. Unlike in Europe, where the nematode is widespread, PCN populations in Idaho remain localized. In this scenario, eradication of PCN remains the goal, which is why the exploration of every possible eradication tool is a top priority.

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Jim Crosslin Retires in October

James M. Crosslin, Research Plant Pathologist, USDA-ARS, Prosser, WA, will retire October 1st, 2013. We wish him happy retirement. His expertise in virus and phytoplasma related disorders in potatoes will be missed. Furthermore, his leadership will be missed in the potato psyllid/ZC research team.

Photo: Jim on the summit of Zumsteinspitze (14,970 ft) in the Alps this July.